MITSUBISHI HEAVY INDUSTRIES, LTD.

General Purpose Robot
PA10 SERIES

PROGRAMMING MANUAL

MITSUBISHI
HEAVY INDUSTRIES, LTD.

INDEX

PA10 Series

Programing Manual

SKC-GC20002

Rev. 0

Chapter 1.　Foreword

This is the programming manual of the new concept robot "Mitsubishi heavy Industries, Ltd. – General Purpose Robot: PA" to be employed in various ways for a wide range of customers.

The "PA" has two controllers: at the operation and motion control section. At the operation control section, the C– language library (PA library) is provided to access the motion control section.

This manual explains how to use this "PA library" in C and BASIC language.

Remark

In this manual both 6–axis and 7–axis arm are explained as the same.　If there is a different function either in 6 or 7 axis, it is respectively shown as follows.

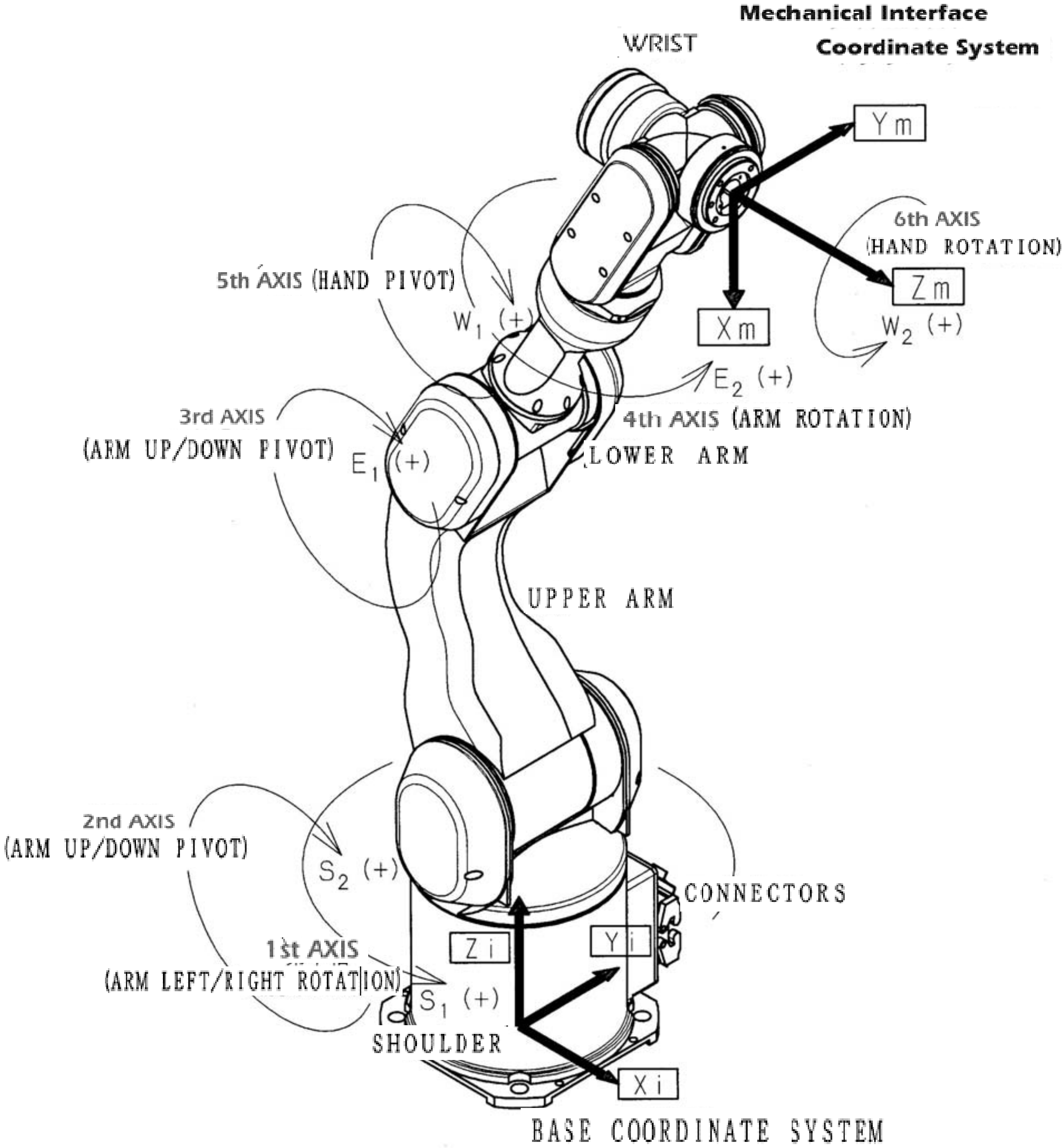
- The only function obtained by 6–axis arm　*6 axis arm function*
- The only function obtained by 7–axis arm　*7 axis arm function*

Chapter 2. Arm Designation and Motion

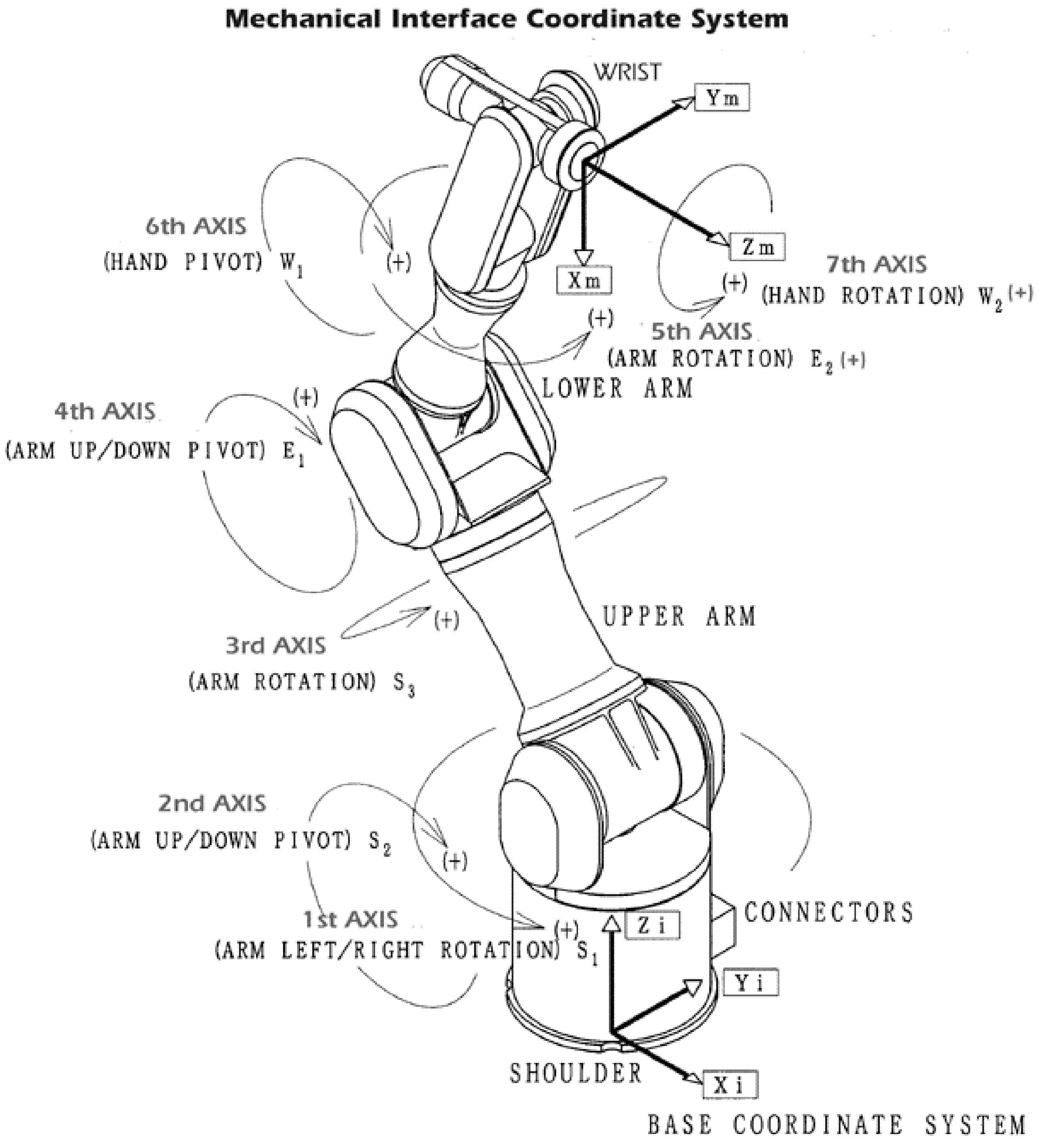
2. 1 AXIS DESIGNATION

Joint structure, axis designation and motion of "Mitsubishi heavy Industries, Ltd. – General Purpose Intelligent Robot PA" are shown in the drawing below. It might have a difference between configuration of the actual machines and this illustration. However, the coordinate system is the same to both.

6 -AXIS ARM



7 -AXIS ARM

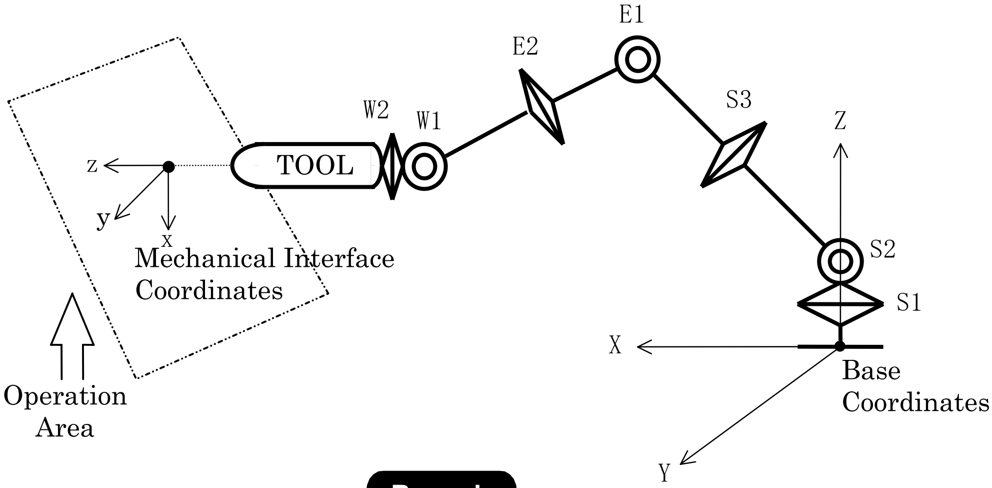

Mechanical Interface Coordinate System
WRIST
Ym
Zm
Xm
6th AXIS
(HAND PIVOT) W1
(+)
7th AXIS
(HAND ROTATION) W2 (+)
(+)
(+)
5th AXIS
(ARM ROTATION) E2 (+)
LOWER ARM
(+)
4th AXIS
(ARM UP/DOWN PIVOT) E1
UPPER ARM
(+)
3rd AXIS
(ARM ROTATION) S3
2nd AXIS
(ARM UP/DOWN PIVOT) S2
(+)
1st AXIS
(ARM LEFT/RIGHT ROTATION) S1
(+)
Zi
CONNECTORS
Yi
SHOULDER
Xi
BASE COORDINATE SYSTEM

2. 2 COORDINATE SYSTEMS

In manipulator control, to indicate the current position/orientation and the target position/orientation, the standard coordinate system is needed. Inputting the deviation of position and orientation (rotation angle on the standard axis) for coordinates they can be controlled.

The coordinate systems used in the motion controller are as follows:

- **Base Coordinates** ‥The manipulator origin is the basic standard.
  <u>Its standard is for all coordinate systems and will never change.</u>
- **Mechanical Interface Coordinates** ‥The coordinate system is altered by changes of each axis angle in the manipulator tip coordinate (included tool + offset.)
  (Tip coordinate system)

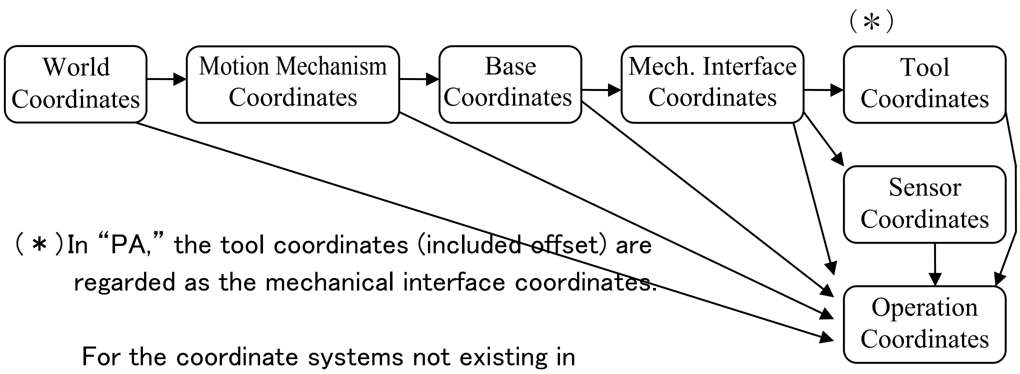


Remark

This illustration is the 7-axis arm composition. For the 6-axis arm, there is no S3-axis.

Memo

Later on, this kind of coordinate system will be needed if combining with motion mechanism or attaching sensors.



(∗)In "PA," the tool coordinates (included offset) are regarded as the mechanical interface coordinates.

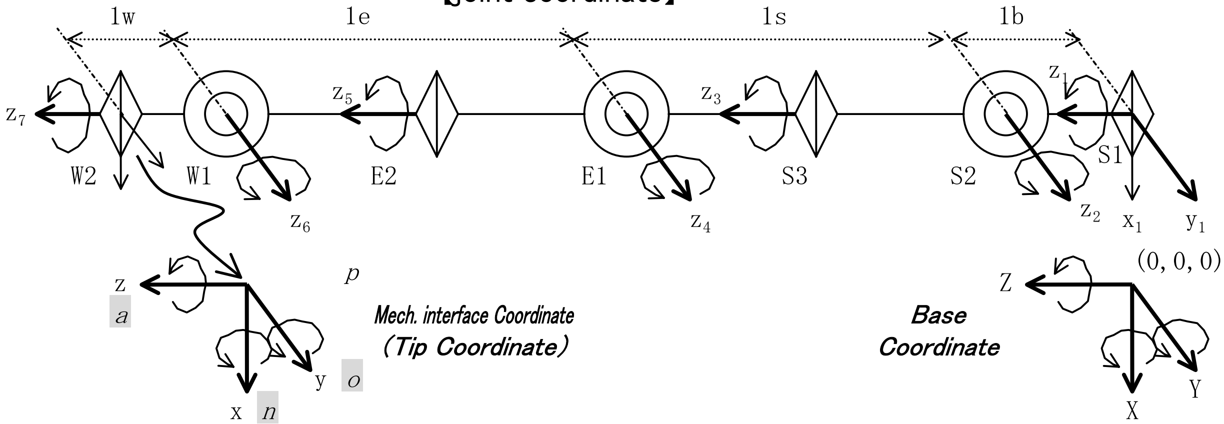
For the coordinate systems not existing in the motion control section, following the application, make coordinate-calculations inside the operation control section.

2. 3 COORDINATE SYSTEM CREATION

How should the coordinate system shown in the section 2.2 be created:

Here it is explained how to assign coordinate to each link which constructs a manipulator.

【joint coordinate】



【Link parameters】

	Axis	Axis Des.	Twisting Angle	Rotation Angle	X	Y	Z
Link 1	1st	S1	Roll	ϕ_{S1}	0	0	1b
Link 2	2nd	S2	Pitch	ϕ_{S2}	0	−1s	0
Link 3	3rd	S3	Roll	ϕ_{S3}	0	0	0
Link 4	4th	E1	Pitch	ϕ_{E1}	0	−1e	0
Link 5	5th	E2	Roll	ϕ_{E2}	0	0	0
Link 6	6th	W1	Pitch	ϕ_{W1}	0	−1w	0
Link 7	7th	W2	Roll	ϕ_{W2}	0	0	0

Remark

This chart shows only the 7−axis arm composition. For the 6−axis arm, there is no Link 3.

Twisting Angles

Roll : Rotation around Z−axis of the base coordinate.

Pitch : Rotation around Y−axis of the base coordinate.

Yaw : Rotation around X−axis of the base coordinate.

Joint Coordinates

Roll coordinate : the same as the base coordinate.

Pitch coordinate : 90 degrees diverted around X−axis of the base coordinate.

Yaw coordinate : 90 degrees rotated around Y axis of the pitch coordinates.

＜A−Matrix＞

Any manipulator is constructed with a series of links connected by joints. At each link (each axis) the coordinate is fixed one by one. At this point, the conversion matrix showing the relation between a link and another one is called A−matrix. To summarize: the A−matrix indicates a relative translation and rotation between link coordinates.

＜T−Matrix＞

It can be indicated by the A−matrix product if seeing each link from the base coordinate (the origin. of the manipulator coordinate.) This A−matrix product is called T−matrix. T−matrix of each link seeing from the base coordinate is indicated with $T_i(={}^{0}T_i)$.

(1)Base Coordinate Systems

The base coordinate is the origin of a manipulator. This coordinate itself becomes the standard coordinate system (the absolute coordinate system) as follows:

$$T_0 = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

(2) Mechanical Interface Coordinates

Mechanical interface coordinates (tool tip coordinate) will be created as follows:

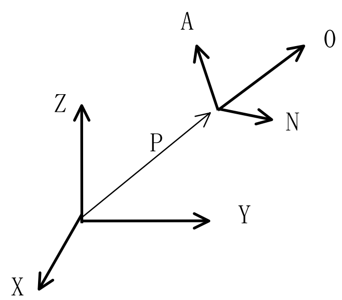
- First of all, create the conversion matrix A1 from the manipulator origin, indicating the S1 origin.
  →The coordinate of S1 origin located at base coordinate:
  $T_1 = T_0 A_1$
- Then, create conversion matrix: A2 indicating the S2 origin for the S1 origin (T1 coordinate.)
  →The coordinate of S2 origin located at the base coordinate:
  $T_2 = T_1 A_2 = A_1 A_2$
- Then, create conversion matrix: A3 indicating the S3 origin for the S2 origin (T2 coordinate.)
  →The coordinate of S3 origin located at the base coordinate:
  $T_3 = T_2 A_3 = A_1 A_2 A_3$
- Then, create conversion matrix: A4 indicating the E1 origin for the S3 origin (T3 coordinate.)
  →The coordinate of E1 origin located at the base coordinate:
  $T_4 = T_3 A_4 = A_1 A_2 A_3 A_4$
- Then, create conversion matrix: A5 indicating the E2 origin for the E1 origin (T4 coordinate.)
  →The coordinate of E2 origin located at the base coordinate:
  $T_5 = T_4 A_5 = A_1 A_2 A_3 A_4 A_5$
- Then, create conversion matrix: A6 indicating the W1 origin for the E2 origin (T5 coordinate.)
  →The coordinate of W1 origin located at the base coordinate:
  $T_6 = T_5 A_6 = A_1 A_2 A_3 A_4 A_5 A_6$
- Then, create conversion matrix: A7 indicating the W2 origin for the W1 origin (T6 coordinate.)
  →The coordinate of W2 origin located at the base coordinate:
  $T_7 = T_6 A_7 = A_1 A_2 A_3 A_4 A_5 A_6 A_7$
- Then, create conversion matrix: A tool indicating tool tip for the W2 origin (T7 coordinate.)
  →The tool tip coordinate located at the base coordinate:
  $T_{tool} = T_7 A_{tool} = A_1 A_2 A_3 A_4 A_5 A_6 A_7 A_{tool}$

Thus, if it is successively indicated with a conversion for new coordinates, multiply the conversion matrix of each joint on the right.

To summarize: the finally created <u>T_{tool} ($^{0}T_{t}$) matrix indicates the position / direction of the mechanical interface coordinate (included the tool) seen from the base coordinate. Using this matrix, it also makes the conversion from the mechanical interface coordinate to the base coordinate.</u>

$$T_{TOOL} = \begin{pmatrix} N\ O\ A\ P \\ \\ \\ \end{pmatrix} = \begin{pmatrix} n_x & o_x & a_x & p_x \\ n_y & o_y & a_y & p_y \\ n_z & n_z & a_z & p_z \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Tip Orientation　Tip position



Remark

This is the 7-axis arm composition.　For 6-axis arm, there is no A3.

2. 4 ROTATION DIRECTION FOR COORDINATE SYSTEMS

Input values for each coordinate as follows.

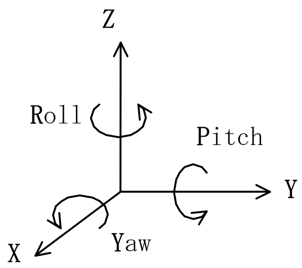
(1)Input values in the base coordinate

<Position>

- ・Deviation toward X(△X)
- ・Deviation toward Y(△Y)
- ・Deviation toward Z(△Z)
- ・Velocity toward X(VX)
- ・Velocity toward Y(VY)
- ・Velocity toward the V-axis(VZ)

<Orientation>

- ・Rotation deviation on X(△Yaw)
- ・Rotation deviation on Y(△Pitch)
- ・Rotation deviation on Z(△Roll)
- ・Rotation velocity on X(VYaw)
- ・Rotation velocity on Y(VPitch)
- ・Rotation velocity on Z(VRoll)



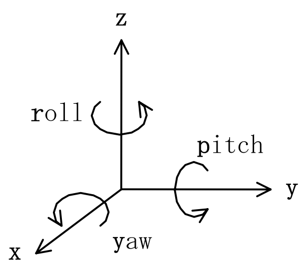
(2)Input value in the mechanical interface coordinate

<Position>

- ・Deviation toward X(△x)
- ・Deviation toward Y(△y)
- ・Deviation toward Z(△z)
- ・Velocity toward X(Vx)
- ・Velocity toward Y(Vy)
- ・Velocity toward Z(Vz)

<Orientation>

- ・Rotation deviation on X(△yaw)
- ・Rotation deviation on Y(△pitch)
- ・Rotation deviation on Z(△roll)
- ・Velocity toward X(Vyaw)
- ・Velocity toward Y(Vpitch)
- ・Velocity toward Z(Vroll)



2. 5 CONVERSION

Space conversion with a 4x4 Matrix can indicate the conversion of translation and rotation. Using these conversions and coordinates, they designate the position and orientation of a manipulator.

(1) Position designation

Position designation (conversion) is to translate X, Y and Z directions of the basic coordinate T.

$$\mathrm{Trans}(x,\ y,\ z) = \begin{pmatrix} 1 & 0 & 0 & x \\ 0 & 1 & 0 & y \\ 0 & 0 & 1 & z \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

(2) Orientation designation (Roll, Pitch, Yaw)

Roll, pitch and yaw is generally used for the orientation designation (conversion).

In a standard coordinate T, Yaw is the rotation around X-axis. Pitch is the rotation around Y-axis. Roll is the rotation around Z-axis.

Memo

As these three conversions are based on the original coordinate, pay attention to the conversion formula, the multiplication order is reversed.

R P Y (roll, pitch, yaw)

← Processing order

$$= \mathrm{Rot}(z,\ roll)\ \mathrm{Rot}(y,\ pitch)\ \mathrm{Rot}(x,\ yaw)$$

$$= \begin{pmatrix} C_r & -S_r & 0 & 0 \\ S_r & C_r & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} C_p & 0 & S_p & 0 \\ 0 & 1 & 0 & 0 \\ -S_p & 0 & C_p & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & C_y & -S_y & 0 \\ 0 & S_y & C_y & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$$= \begin{pmatrix} C_r C_p & C_r S_p S_y - S_r C_y & C_r S_p C_y + S_r S_y & 0 \\ S_r C_p & S_r S_p S_y + C_r C_y & S_r S_p C_y - C_r S_y & 0 \\ -S_p & C_p S_y & C_p C_y & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

However、S_y = sin (yaw), C_y = cos (yaw)
S_p = sin (pitch), C_p = cos (pitch)
S_r = sin (roll), C_r = cos (roll)

Memo

Conversions responding to the rotation angle θ around X, Y and Z-axis are:

$$\mathrm{Rot}(x, \theta) = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta & 0 \\ 0 & \sin\theta & \cos\theta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\mathrm{Rot}(y, \theta) = \begin{bmatrix} \cos\theta & 0 & \sin\theta & 0 \\ 0 & 1 & 0 & 0 \\ -\sin\theta & 0 & \cos\theta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\mathrm{Rot}(z, \theta) = \begin{bmatrix} \cos\theta & -\sin\theta & 0 & 0 \\ \sin\theta & \cos\theta & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Chapter 3. CONTROL MODE

Looking at the nearest point to H/W in the manipulator control, command values are given to each axis. As the actual operation method, not only makes each axis move, but also needs complex movements controlling orientation or the tip position to be straight.

3. 1 ACTUATING CONTROL MODE

Actuating control methods for PA, are provided as follows:
Also data interpolation will be performed when it operates for all modes.

- ・Axis angle control
- ・Axis speed control
- ・6 direction deviation control for the RMRC base coordinate system
- ・6 direction velocity control for the RMRC base coordinate system
- ・Tip coordinate matrix control for the RMRC base coordinate system
- ・6 direction deviation control for the RMRC mechanical interface coordinate system
- ・6 direction velocity control for the RMRC mechanical interface coordinate system
- ・Redundant axis control for RMRC control
- ・Teach data acquisition control
- ・Playback (axis / linear / circle / arc interpolation) control
- ・Coordinate conversion control for playback
- ・redundant axis control for playback *7-axis arm function*
- ・Direct control *.. optional function*
- ・Axis angle real-time control
- ・RMRC real-time control
- ・Absolute target position / orientation designation control
- ・others

Direct teaching is optional.

(1)Axis angle Control

Operation method ordering each axis target angle or previously defined each axis value, through the operation controller.

Reference

Programming is explained in Section 6-3.

(2)Tip Position /Tip Orientation Control

Method to shift the tip straight or rotate the tip direction by inputting the tip position/orientation deviation for the defined coordinate axis by the operation controller.

The Motion controller calculates the linear interpolation for each tip position/orientation and control position/orientation feedback.

In PA10, tip position/orientation control is called RMRC control.

Reference

Programming for the 6 axis arm is explained in section 6-4 and for the axis arm, in section 6-5.

(3)Velocity Control

Operation method to select the axis for velocity control and input command value. Input to each axis or to the coordinate system axis is accessible.

Reference

Programming is explained in section 6-6.

(4)Redundant Axis Control

7-axis arm function

For the 7-axis arm, the same as PA, there are several axis values at the same tip position/orientation. The arm, with these characteristics, is called "Redundant axis arm".

By controlling this redundant axis, complex movements can be achieved.

For instance, even if the elbow encounters obstacles, this elbow position can be shifted, without changing the tip position/orientation.

The redundant axis control is the mode restricting each axis of the 7-arm axis to any direction.

There are two types of redundant axis control, as follows:

・The control restricts the redundant axis altering the tip position/ orientation.

・The control shifts, only, the redundant axis (elbow) position not altering the tip position/orientation.

Reference

Programming is explained in section 6-5.

(7) Real-Time Control

This mode controls the arm in position/orientation or each axis angle, at actual time, inputting tip position/ orientation or each axis angle every control cyclic time.

The command (tip position/orientation Matrix or each axis angle every control cyclic time) has to be issued every time-out.

Reference

Programming is explained in the section 6.8.

(5) **Direct Control** (Optional function)

After switching on the torque control and releasing the brake, this direct control is for the manually arm operation mode.

This control mode memorizes each axis data as the teach (PTP) data when an arm is operated manually. It revives the movements through the playback control.

- Simple weight compensation control

Reference

Programming is explained in section 6-7.

(6) **Playback Control**

This playback control is managed by continuous teach data (each axis value or NOAP) Between a non continuous teach data the playback control will be interpolated adjusting the data types.

Teach data 1 (θ_{S11}, θ_{S21}, ･･･ θ_{W21})
Teach data 2 (θ_{S12}, θ_{S22}, ･･･ θ_{W22})
:
Teach data n (θ_{S1n}, θ_{S2n}, ･･･ θ_{W2n})

The teach data is as follows:

- PTP for axis interpolation each axis ($\theta_{S1} \sim \theta_{W2}$) data
- PTP for linear interpolation each axis ($\theta_{S1} \sim \theta_{W2}$) data
- PTP for arc interpolation each axis ($\theta_{S1} \sim \theta_{W2}$) data
- PTP for circle interpolation each axis ($\theta_{S1} \sim \theta_{W2}$) data

- PTP for linear interpolation tip (NOAP) data
- PTP for arc interpolation tip (NOAP) data
- PTP for circle interpolation tip (NOAP) data

Interpolation methods are as follows:

- Axis angle interpolation
- Tip linear interpolation
- Tip arc interpolation
- Tip circle interpolation

Reference

Interpolation methods are explained in the section 3.2 – 3.5.
Programming is explained in the section 6.10 and 6.7.

Memo

The teaching data is the PTP data. The PTP data is the abbreviation for "Point to Point". The trajectory between different data is haphazard. But when the playback control is operated, the interpolation has to be surely performed between different PTP data.

3. 2 Trajectory Control Mode

How to operate each axis or tip position/orientation of a manipulator:
In PA10, the interpolation is as follows:

a. Trajectory Interpolations

- ・Axis angle interpolation
- ・Tip linear interpolation
- ・Tip arc interpolation
- ・Tip circle interpolation
- ・Tip orientation interpolation

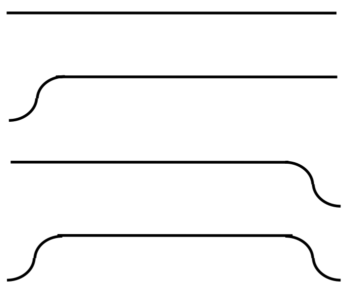
b. Velocity Control

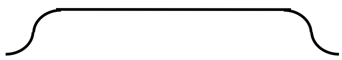
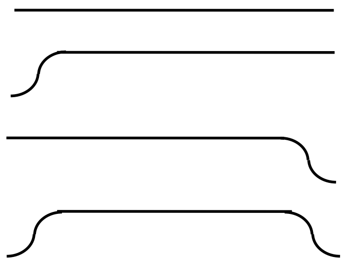
・Constant velocity interpolation

・(Acceleration + Constant velocity) Interpolation

・(Constant velocity + deceleration) Interpolation

・(Acceleration + Constant velocity + deceleration) Interpolation



Control Mode	a. Trajectory interpolation	b. Velocity Control
Each Axis Control	Each Axis Interpolation	
Tip Position Control	Tip Linear Interpolation	
Tip Orientation Control	Tip Orientation Interpolation	
Playback Control	Each Axis Interpolation	
	Tip Linear Interpolation	
	Tip Orientation Interpolation	
	Tip Arc Interpolation	
	Tip Orientation Interpolation	
	Tip Circle Interpolation	

3. 3 Axis Angle Interpolation

Here is the explanation for each axis angle control in the trajectory control mode.

Each axis angle control

<Input value>

target angle(θr_{S1}, θr_{S2}, $\cdot\cdot \theta r_{W2}$)

<Calculation>

① Calculate deviation angle and subtract the current value from the target one, at each axis.

$$\begin{pmatrix} \Delta\theta_{S1} \\ \Delta\theta_{S2} \\ \vdots \\ \Delta\theta_{W2} \end{pmatrix} = \begin{pmatrix} \theta r_{S1} - \theta c_{S1} \\ \theta r_{S2} - \theta c_{S2} \\ \vdots \\ \theta r_{W2} - \theta c_{W2} \end{pmatrix}$$

② From the calculation, dividing each axis deviation by each axis default velocity, the axis, obtaining the biggest shifting time, is defined as the basic axis of interpolation.

$$\begin{pmatrix} \Delta T_{S1} \\ \Delta T_{S2} \\ \vdots \\ \Delta T_{W2} \end{pmatrix} = \begin{pmatrix} \Delta\theta_{S1} / V_{S1} \\ \Delta\theta_{S2} / V_{S2} \\ \vdots \\ \Delta\theta_{W2} / V_{W2} \end{pmatrix}$$

The axis obtained the biggest ΔT_{io} is defined as the standard of interpolation.

③ Calculate each axis command angle on the basis of the interpolation basic axis deviation($\Delta\theta_i$). In the interpolation method, calculate the target trajectory (command angle) to control the velocity to form the letter "S" shape.

Reference

For the velocity control, refer to the section 3.5.

3. 4 RMRC Tip Interpolation

The method to shift a manipulator tip position/orientation to the next target position/orientation in the trajectory control mode is explained here.

Tip position/orientation interpolation methods currently provided in PA10 are three as follows:

- **Linear Interpolation** ･･･The tip trajectory is straight. The tip orientation is concurrently interpolated, too.
- **Arc Interpolation** ･･･The tip trajectory is an arc. The tip orientation is concurrently interpolated, too.
- **Circle Interpolation** ･･･The tip trajectory is a circle.

The target tip position/orientation "Tr_n" is calculated from interpolation every sampling period to shift on the trajectory to the target position/orientation from the current position/orientation.

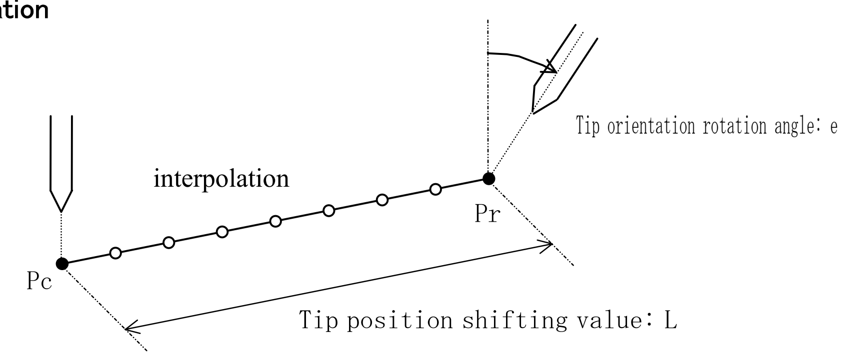
7–axis arm function

For the 7–axis arm, when the redundant axis control modes – "S3–axis restriction" and "S3–axis interpolation" – are selected and the interpolation above is operated, the S3–axis angle deviation (difference between the current angle and the target angle) is simultaneously interpolated and target "S3–axis" angles are calculated every sampling period.
For trajectory interpolation methods, the target tip position/orientation trajectory (command angle) is calculated for velocity to form the letter "S" shape.

Reference

Refer to the section 3.5 for velocity control.

(1) Linear interpolation



<When the redundant axis control mode is NOT "S3-axis restriction" and "S3-axis interpolation mode in 6-axis and 7-axis arm>

OUTLINE PROCEDURE FOR LINEAR INTERPOLATION

1. Calculate the current tip position and the tip orientation (Tc).
2. Calculate the target tip position and the tip orientation (Tr).
3. Calculate the tip moving distance (L) from the current tip position and the target position.
4. Calculate the tip orientation/rotation angle (θ) from the current orientation and the target tip orientation.
5. To simultaneously operate the position and the orientation, the standard must be chosen.
6. Following the selected velocity control method, interpolate and calculate the target tip position/target orientation (Tr_1, ･･･ , Tr_{n-1}, Tr_n, ･･･ Tr) of each sampling.
7. If the work coordinate conversion Matrix is designated, multiply "Tr_n" by the coordinate conversion Matrix.

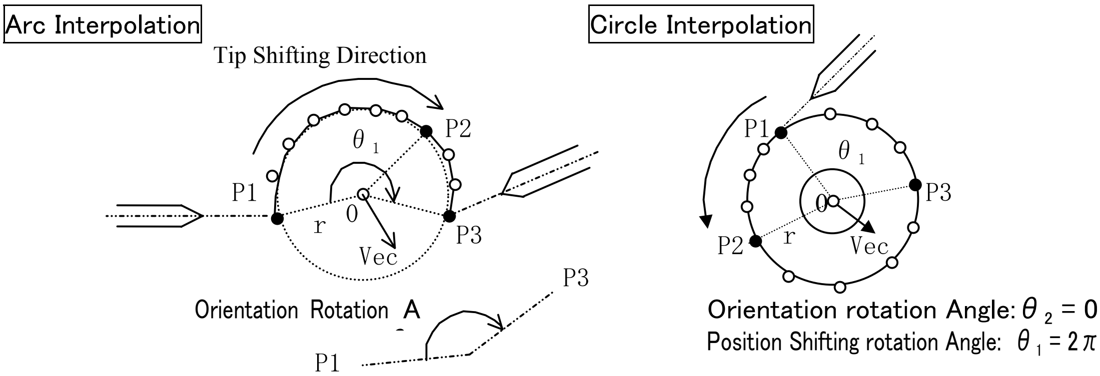
<When the redundant axis control mode is "S3-axis restriction" and "S3-axis interpolation mode>

7-axis arm function

OUTLINE PROCEDURE FOR LINEAR INTERPOLATION

1. Calculate the current tip position and the tip orientation (Tc).
2. Calculate the target tip position and the tip orientation (Tr).
3. Calculate the tip moving distance (L) from the current tip position and the target position.
4. Calculate the tip orientation/rotation angle (θ) from the current orientation and the target tip orientation.
5. Calculate the S3-axis angle/rotation angle(θ_{S3}) from the current S3-axis angle and the target S3-axis angle.
6. To operate the position and the orientation, the standard for interpolation must be chosen from the position, the orientation or the S3-axis.
7. Following the selected velocity control method, interpolate and calculate the target tip position, the target orientation and the S3-axis of each sampling.
8. If the work coordinate conversion Matrix is designated, multiply "Tr_n" by the coordinate conversion Matrix.

(2) Arc & Circle Interpolation



<When the redundant axis control mode is NOT "S3-axis restriction" and "S3-axis interpolation mode in 6-axis and 7-axis arm>

OUTLINE PROCEDURE FOR ARK & CIRCL INTERPOLATION

1. Calculate the current tip position (P1) and the tip orientation (T1).
2. Calculate the tip position and the tip orientation (T2) of the passing point (P2).
3. Calculate the tip position and the tip orientation (T3) of the target value (P3). In the case of the circle, P3-point is also the passing point.
4. Calculate the center point (O), the semi-diameter (r) and the normal vector (Vec) of the circle trajectory from three points.
5. Calculate the angle of the tip accurate motion (θ_1) from the tip position of the current value P1 and P3. For the circle, $\theta_1 = 2\pi$.
6. Calculate the rotation angle of the tip orientation (θ_2) from the tip position of the current value P1 and P3. For the circle, $\theta_2 = 0$ (current orientation maintained.)
7. To simultaneously operate the position and the orientation, the standard must be chosen.
8. Following the selected velocity control method, interpolate and calculate the target tip position/target orientation (Tr_1, ･･･ , Tr_{n-1}, Tr_n, ･･･ Tr) of each sampling.
9. If the work coordinate conversion Matrix is designated, multiply "Tr_n" by the coordinate conversion Matrix.

<When the redundant axis control mode is "S3-axis restriction" and "S3-axis interpolation mode>

7-axis arm function

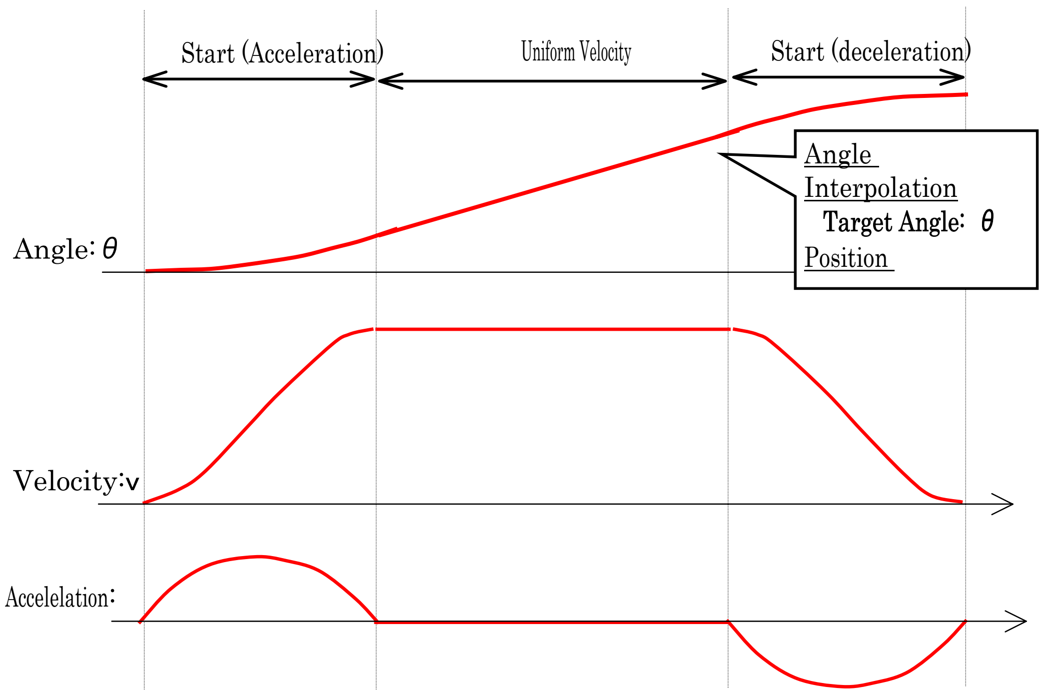
OUTLINE PROCEDURE FOR LINEAR INTERPOLATION

1. Calculate the current tip position (P1) and the tip orientation (T1).
2. Calculate the tip position and the tip orientation (T2) of the passing point (P2).
3. Calculate the tip position and the tip orientation (T3) of the target value (P3). In the case of the circle, P3-point is also the passing point.
4. Calculate the center point (O), the semi-diameter (r) and the normal vector (Vec) of the circle trajectory from three points.
5. Calculate the angle of the tip accurate motion (θ_1) from the tip position of the current value P1 and P3. For the circle, $\theta_1 = 2\pi$.
6. Calculate the rotation angle of the tip orientation (θ_2) from the tip position of the current value P1 and P3. For the circle, $\theta_2 = 0$ (current orientation maintained.)

7. Calculate rotation angle (θ_{S3}) if S3-axis orientation from the S3-axis angle, of the current value (P1) and the S3-axis angle of the target value (P3). In the case of the circle, it is (θ_{S3}) = 0.0 [rad] (in the case of circle interpolation, S3-axis DOES NOT move and make the same motion as "S3-axis fixed".
8. To operate the position and the orientation, the standard for interpolation must be chosen from the position, the orientation or the S3-axis.
9. Following the selected velocity control method, interpolate and calculate the target tip position/target orientation/target S3-axis angle of each sampling.
10. If the work coordinate conversion Matrix is designated, multiply "Tr_n" by the coordinate conversion Matrix.

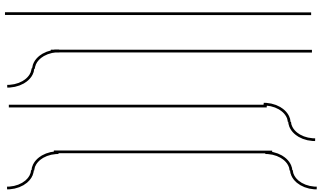
3. 5 Velocity Control

When a manipulator plus a machine operator perform, if, command value is given intermittently, it causes undesirable mechanical oscillation. For this reason, the command speed at the start has to be controlled, to gradually accelerate and at stop to gradually decelerate.
On manipulator trajectory, velocity is generally controlled to make a trapezoid wave.
With this trapezoid wave, the acceleration wave becomes non continuous. It causes acceleration shock and mechanical oscillation. In PA10, to create a target trajectory to reduce acceleration shock, interpolation methods are employed to create the letter “S” shaped target trajectory for velocity.
This satisfies conditions to keep each curve continuity and hold the maximum velocity, lower. The most reliable curve, even if used in a situation when the load characteristic is unpredictable, the maximum velocity is lowered



These options below are available for a velocity control type.

0 : Uniform velocity
1 : with Acceleration
2 : with Deceleration
3 : with Acceleration and Deceleration



Memo

For position change, the trapezoid control is available. Not available for velocity change. When in a continuous movement as:(ex)p1→p2 is v1[mm/s], p2→p3 is v2[mm/s], velocity command is intermittently changed at p2 point. In this case, velocity command intermittent change has to be lowered and controlled at the servo driver side.

Chapter 4.　Motion & Operation Control Section

The PA controller consists of two sections shown below:

- ・Motion Control Section
- ・Operation Control Section (man-machine controller)

4. 1 Motion Control Section

The motion control section – the controller handles the basic control for PA – operates following each control mode explained in chapter 3.　The limitation cycle is 2ms.

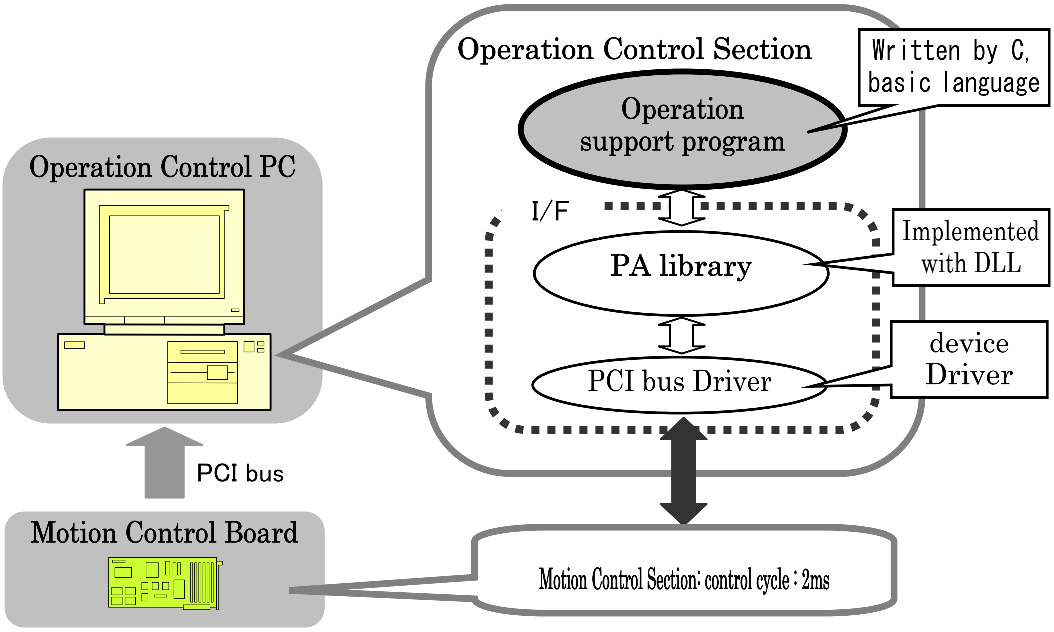
Regarding the program for this section, as long as PA is employed, even if the operation contents are changed, the program remains the same.

4. 2 Operation Control Section

The operation control section – the controller handles the operation procedures. The program for this section changes depending on the operation: (on each application: weddings, painting, etc)

The standard software for PA: the operation support program (man– machine) and PA Library (the motion and control section and interface section) are provided.

The motion control board is compatible with PCI bus. Employ a PC with PCI bus sold in the market.



Application development

To develop and implement an application a device driver is needed besides PA library. With PCI bus sold in the market, using "WinnRT" (created by bSQUARE Co.).

The PA Library is created through the DLL form. The program will be kinetically linked when it is employed. The standard Windows version "PA library is created by Compiler Visual C ++ Ver. 6.0. Some application samples, created by Visual C++ and Visual BASIC, are attached.

4. 3 Operation & Motion Control Section Interface

The Operation section and the Motion Control section are connected by PCI bus.
The memory area is shared at the PCI space.
The operation control section sets the target command (event) to this memory area. The motion control section operates following a event. The arm movement can be observed at actual time.
Using this memory area, the one provided to ease the motion control section from the operation one, is: the “PA library.”

Chapter5　Program Development & Processing Conditions

5. 1　Development & Processing Conditions

For processing conditions, if you intend to provide your own operation control section (Personal Computer), you must need the following:

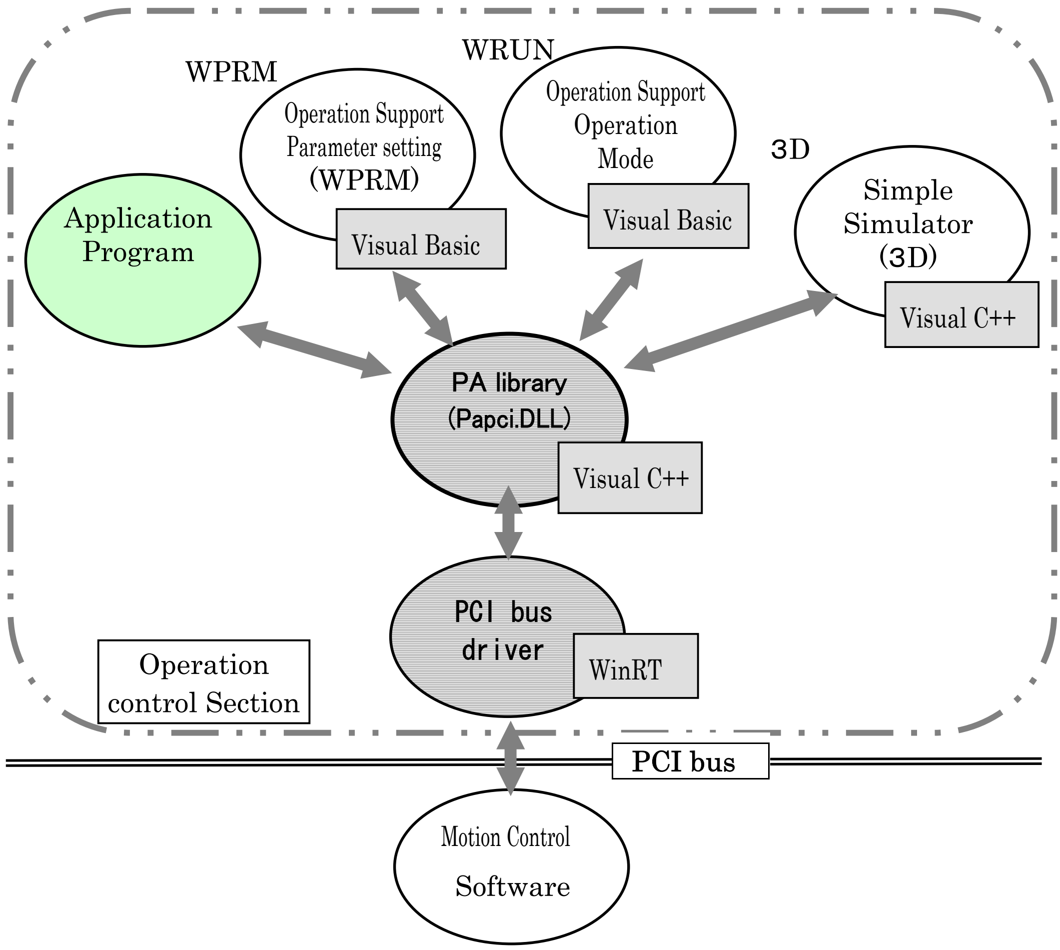
- ・OS　　　　:Windows NT/2000/XP
- ・Memory　　:More than 128 MB

Further more, for development, the following are needed.
・Compiler:Visual C++ Compiler Ver.6.0 or
　　　　　Visual BASIC Compiler Ver.6.0

5. 2　PA Library Status

The PA library stands for:

- ・A library to develop an application program for the operation control section.
- ・The interface library to ease the operation of all actuating functions for the motion control section. To access the motion control CPU, besides the PA library, a driver for PCI bus created by the device driver – WinRT – sold in the market, is needed.
- ・The PA library is the DLL (Dynamic-link library) model created employing Visual C++ ver.6.0.



5. 3 PA library Directory Composition

The PA library is provided by the CD-ROM.

When the CD-ROM is set, installation starts automatically. (For further information, refer to the installation manual.)

Reference

The PA library compositions provided in PA are as follows:

```
¥WinPApci  (Default name of installation destination)
 ├── BIN        … Execution file
 │              Passage.exe
 │              Wprm.exe
 ├── INCLUDE  ･･･ Header file of PA library
 │              PA.H     PA library prototype declaration (for development employing Visual C++)
 │              PAERR.H PA library error information declaration (for development employing Visual C++)
 │              PACMD.H
 │              PACTL.H      File needed for PA library construction
 │              PAMMC.H
 │              PA.BAS
 │              PAERR.BAS  for development with Visual BACIS
 ├── HELP             ･･･ Online help file
 │              PAHELP.HLP
 └── SRC ──── LIB   ･･･ PA library source file
       │        │  PA_CUB.C        CUBE information
       │        │  PA_DIO.C        Digital I/O
       │        │  PA_DIR.C        Direct control mode
       │        │  PA_DPD.C        Real-time T-matrix control
       │        │  PA_EGT.C        Relatedto additional functions (information acquisition)
       │        │  PA_ETC.C        VMEinterface connected to the motion control section
       │        │  PA_EXT.C        Related to additional functions (control)
       │        │  PA_GET.C        Arm information acquisition
       │        │  PA_JMP.C        JUMP data
       │        │  PA_JOU.C        Redundant axis/velocity control
       │        │  PA_MOD.C        Related to teach mode
       │        │  PA_MOV.C        initial setting/each axis control/RMRC
       │        │  PA_MTX.C        Coordinate conversion matrix setting
       │        │  PA_PNT.C        Teach/playback control
       │        │  PA_PRM.C        Parameter alteration
       │        │  PA_PRV.C        Related to parameter loading/saving
       │        │  PA_SET.C        Basic orientation registration
       │        │  PA_VEL.C        Velocity mode selection
       │        │
       │        └──────── PCI   ･･･ PA library (for PCI) project file
       │                    PA_PCI.C      related to PCI-bus access
       │                    PCI.DEF       Default definition file
       │                    PCI.DSW       Project work space
       │                    PCI.DSP       project file
       │
```

```
│
└── SAMPLE ─┬─ MFC ── EX1  … Sample program employing MFC
            │              EX1.CPP        EX1.ICO
            │              EX1.H          EX1.RC2
            │              EX1.RCEX1DLG.CPP
            │              EX1DLG.H       RESOURCE.H
            │              STDAFX.CPP     STDAFX.H
            │              EX1.DSW        EX1.DSP
            │
            ├─ VC ─┬─ EX1…Sample program employing VisualC++
            │      │       DLGPROC.CPP    MAIN.CPP
            │      │       RESOURCE.H     EX1.RC
            │      │       EX1.DSW        EX1.DSP
            │      │       EX1.EXE
            │      └─ EX2…Sample program employing VisualC++
            │              DLGPROC.CPP    MAIN.CPP
            │              RESOURCE.H     EX2.RC
            │              EX2.DSW        EX2.DSP
            │              EX2.EXE
            │
            └─ VB ─┬─ EX1…Sample program−1 employing VisualBasic
                   │       MAIN.BAS       DEFINE.BAS
                   │       FUNC.BAS       AXISOPE.FRM
                   │       EX1MAIN.FRM    EX1.VBP
                   │       EX1.EXE
                   │
                   ├─ EX2…Sample program−2 employing VisualBasic
                   │       MAIN.BAS       DEFINE.BAS
                   │       FUNC.BAS       EX2MAIN.FRM
                   │       EX2.EXE        EX2.VBP
                   │
                   └─ EX3 …Sample program−3 employing VisualBasic
                       │   EX3.VBP        EX3.FRM
                       │   JS.BMP                 EX3.EXE
                       ├─ DLLJS
                       │      PAJS.DEF     PAJS.DSP
                       │      PAJS.DSW     PAPAJS.C
                       └─ OCXJS
                              PAJS.VBP     MODULE1.BAS
                              PAJS.LIB     PAJS.CTL

WINDOWS ──── SYSTEM
               PAPCI.LIB       PA library (for PCI-bus) − Import library
               PAPCI.DLL       PA library (for PCI-bus) − DLL

               Asycfilt.DLL    CMDLGJP.DLL     COMCAT.DLL
               FLGDJP.DLL      Msvbvm60.DLL    oleaut32.DLL
               olepro32.DLL    VB6JP.DLL       mfc42.DLL
               SPR32X30.ocx    Comdlg32.ocx    MSFLXGRD.ocx
               Stdole2.tlb
```

Additionally, if the operation support software is purchased together, the following files are installed into the system directory.

CMCTLJP.DLL	MSSTDFMT.DLL	msvcrt.DLL	scrrnjp.DLL
Scrrun.DLL	STDFTJP.DLL	MSCMCJP.DLL	MSCOMJP.DLL
MSCOMM32.ocx	MSCOMCTL.ocx		

Remark

・Files needed to develop an application program for the operation control section employing Visual C++ (Ver.6.0) are the following, indicated on gray background:

PA.H
PAERR.H
PAPCI.LIB
PAPCI.DLL（needed for implementation）

・Files needed to develop an application program for the operation control section employing Visual BASIC (Ver.6.0) are the following, indicated on gray background:

PA.BAS
PAERR.BAS
PAPCI.DLL（needed for implementation）

5. 4 Notes for application development employing Visual C++

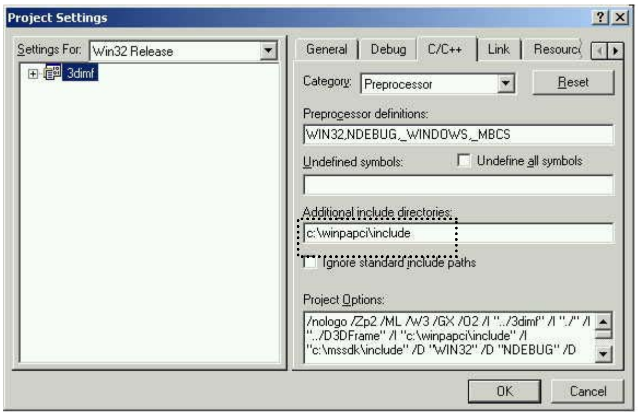
(1)Header files are needed to be included.

Using the PA library, if an application program is developed employing Visual C++ ver.6.0, the following header files have to be included. (using MFC, likewise.)

PA.H　　････ PA library prototype declaration is described.

PAERR.H ････ PA library error code declaration is described.

<Setting method> Choose "Setting…" inside "Project" of the menu bar, then, choose "the preprocessor" in the category of C/C++, then, set the path (c:¥winpapc¥include) to the header file of the PA library.

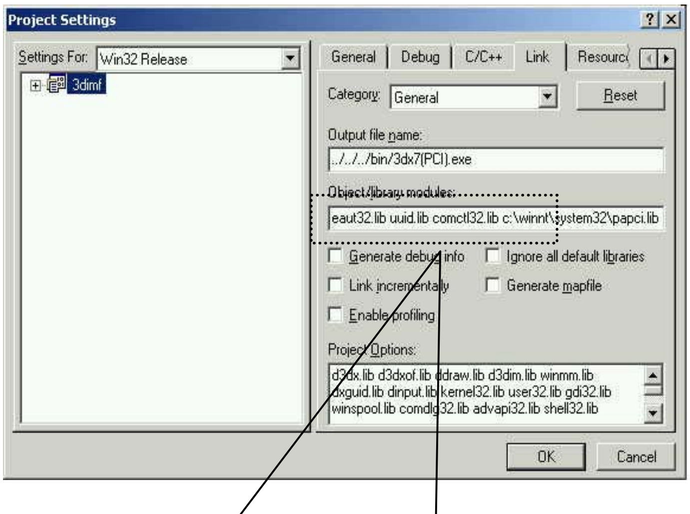


(2)Needed library files to be linked.

As far as developing an application employing Visual C++ Ver.6.0, using the PA library, the following import library files have to be linked.

PAPCI.LIB ････ The import library file including the PA library.

<Setting Method> Choose "Setting…" inside "Project" of the menu bar, then, choose "general" in the link category, then, set the PA library intended to be linked.

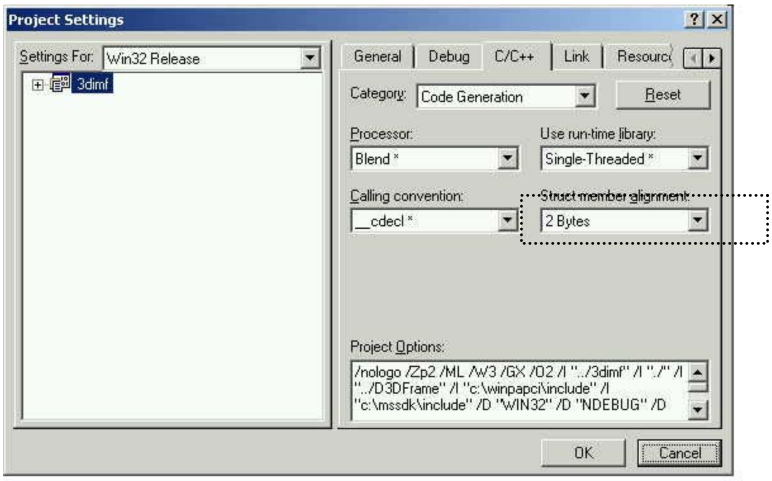


Windows2000 or NT	c:¥winnt¥system32¥papci.lib
Windows XP	c:¥windows¥system32¥papci.lib

(3) Structural Member Alignment Alteration

Structural member alignment has to be set for 2 bytes. (default is 8 bytes)

<Setting Method> Choose "Setting…" inside "Project" of the menu bar, then choose "code creation" in the C/C++ category, then, change the structural member alignment for 2 bytes.



(4) Needed DLL file for processing

To process the application program the following DLL is needed to be located in the designated place:

Windows2000/NT: ¥WINNT¥SYSTEM32,
Windows XP: ¥WINDOWS¥SYSTEM32.
(There is no need to operate any linking or such.)

PAPCI.DLL ････ The file keeping the PA library processing module.

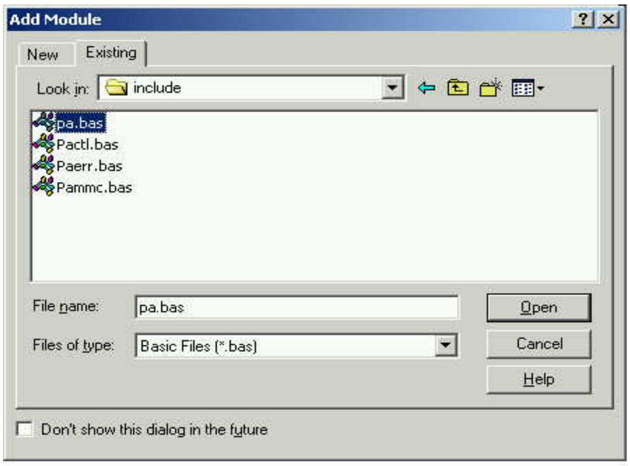
5. 5 Notes for application development employing Visual BASIC

(1)Necessary header files to include

Using the PA library, if develop an application program employing BASIC ver.6.0, add the following header files. (the standard module file) to the "project."

PA.BAS ‥‥ The prototype declaration is described when load the PA library created with C-programming language employing BASIC.

<Setting method> Choose "Add the standard module" inside "Project" of the menu bar, then, add "ps.bas."



(2)Necessary DLL file for implementation

To process the application program the following DLL is needed to be located in the designated place:

Windows2000/NT: ¥WINNT¥SYSTEM32
Windows XP: ¥WINDOWS¥SYSTEM32.
(There is no need to operate any linking or such.)

PAPCI.DLL ‥‥ The file keeping the PA library processing module.

Chapter 6　Programming

How to create an application using the PA library.

6. 1 Control Arm

(1)6-axis and 7-axis arm

The PA library for 6-axis and 7-axis is described as the same.
Some libraries can only be used for the 7-axis arm, not for the 6-axis one. A processable library inter-lock is checked at the motion control side.

For the 6-axis arm, on command values to each axis, the S3-axis (configuration [2]) value becomes invalid.

(example)	Type Declaration	6-axis arm	7-axis arm
Axis value	ANGLE axis		
	axs.S1	1st axis : S1	1st axis : S1
	axs.S2	2nd axis : S2	2nd axis : S2
	axs.S3	(not used)	3rd axis : S3
	axs.E1	3rd axis : E1	4th axis : E1
	axs.E2	4th axis : E2	5th axis : E2
	axs.W1	5th axis : W1	6th axis : W1
	axs.W2	6th axis : W2	7th axis : W2
Velocity command Value	float speed[7]		
	speed[0]	1st axis : S1	1st axis : S1
	speed[1]	2nd axis : S2	2nd axis : S2
	speed[2]	(not used)	3rd axis : S3
	speed[3]	3rd axis : E1	4th axis : E1
	speed[4]	4th axis : E2	5th axis : E2
	speed[5]	5h axis : W1	6th axis : W1
	speed[6]	6th axis : W2	7th axis : W2

(2)Plural Arm Control

For one operation control PC (Personal Computer), plural motion control boards can be inserted. Besides, two arms can be controlled with one motion control board. In the case of plural arms, the controlled arm is classified with its own number.

For the PA library, all arm numbers are needed.

```
pa_opn_arm(ARM armno,……..)

ARM    =ARM0
       =ARM1
       =ARM2
          :
       =ARM16
```

Reference

For arm number settings, refer to "the PROGRAMING MANUAL (ADDITIONAL EDITION)."

6. 2 Common Items

On the control programming using the PA library, there are some that must be known and followed through.

(1) Synchronization between controllers

One command is issued for one PA library from the operation control section to the motion control section. The motion control section performs the motion/processing, responding to this command.

Synchronization between controllers is operated by the control counter. When the motion/processing is completed, the count value of the control counter will be increased one counter value.

During processing, if any error occurs, it stops processing, adds one counter value, then, returns an error code.

If the return value (error code) of the library shows "ERROR-OK." It means the control is normally terminated.

(2) Minimum required programming procedures

If controlling the motion control section using the PA library, the following descriptions are needed:

①PA Library Initialization　:pa_ini_sys

Declaration to use the PA library.

②Open Arm (Control Arm Selection)　:pa_opn_arm

Plural motion control sections (arm) can be controlled by one operation control section.　The control arm and the number of the arm (ARMO ˜ ARM15) have to be designated by the motion control section.

Reference

For the arm number setting, refer to the section 4.3 – the operation & motion control interface.

③Control Start (Motion Control Section)　:　pa_sta_arm or pa_sta_sim

If issuing the "pa_sta_arm" library, the communication with the servo driver will be started. If issuing the "pa_sim_arm" library, the simulation mode starts.　In this mode, regarding all commands issued from hereafter, the motion and the program can be confirmed without operating any actual machine.

④Control Stop (Motion Control Section)　:　pa_ext_arm or pa_ext_sim

If issuing the "pa_ext_arm" library, the communication with the servo driver will be terminated. If issuing the "pa_ext_arm" library, the simulation mode will be terminated.

⑤Close the arm　:　pa_cls_arm

Separates the selected arm from the motion control section.

⑥PA library Exit　:　pa_ter_sys

Explanation on the programming employing samples.

- Example: for Visual C++ – the one written with the visual C++6.0 programming language is indicated.
- It is the same as other C-programming language (either Windows or not)

- Example: for Visual BASIC – the one written with the visual BASIC programming language is indicated.

Remark

In the sample, making easier to understand the description method, function return values ARE NOT checked. When you actually make programming, check any error shown by a return value.

Depending on the error type, the motion control section terminates the control automatically.

Reference

Regarding errors, refer to the error table.

Program Description:

Example: for Visual C++

```
pa_ini_sys();                        … PA library initialization
pa_opn_arm( ARM0 );                  … 1st arm open
pa_sta_arm( ARM0 );                  … Control Start
        :
    Motion Description Section
        :
pa_ext_arm( ARM0 );                  … Control Stop
pa_cls_arm( ARM0 );                  … 1st arm close
pa_ter_sys();                        … PA library termination
```

Example: for Visual BASIC

```
Dim ret As Long
        :
ret = pa_ini_sys()                   … PA library initialization
ret = pa_opn_arm( ARM0 )             … 1st arm open
ret = pa_sta_arm( ARM0 )             … Control Start
        :
    Motion Description Section
        :
ret = pa_ext_arm( ARM0 )             … Control Exit
ret = pa_cls_arm( ARM0 )             …   1st arm close
ret = pa_ter_sys()                   … PA library termination
```

This is the minimum necessary description library.

(3) Processing during a library performance

Explaining processing methods while a library describing motion is performing.

func = WM_WAIT　　:Wait until the arm motion is terminated.
　　= WM_NOWAIT:No wait until the arm motion is terminated.

func = WM_WAIT　:　Wait until the arm motion is terminated

<Library Processing Contents>

- Issues command to the motion control section.
- Observes the motion termination.
- If any error occurs, terminates processing.　An error number is shown as a return value.

Example: for Visual C++

```
if( pa_exe_hom(ARM0, WM_NOWAIT) != ERR_OK )
                Error termination
else
                Normal termination
```

Example: for Visual BASIC

```
Dim ret As Long

ret = pa_exe_hom(ARM0, WM_NOWAIT)
If ret <> ERR_OK Then
                Error termination
Else
                Normal termination
End If
```

<u>func = WM_NOWAIT</u> : No wait until the arm motion is terminated

<Library Processing Contents>

- Issues commands to the motion control section.
- If any error occurs, terminates processing. An error number is shown as a return value.
- Confirmation and error observation are not performed at the motion termination.

Example: for Visual C++

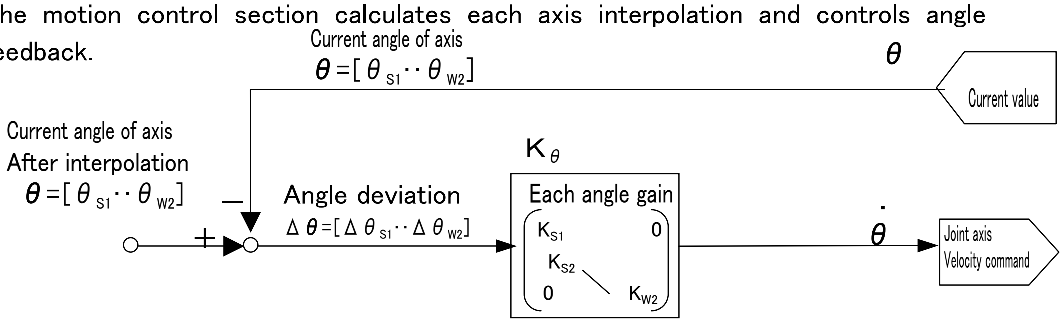
```
long   new, old;
long   err;
          :
pa_get_cnt(ARM0, &old); …Control counter setting before the command issue
pa_exe_hom(ARM0, WM_NOWAIT);
while(1){
    if(( err=pa_get_cnt(ARM0,&new))!=ERR_OK){
          An error occurrence processing
          break;
    }else if( new != old ){
          Motion termination processing
          break;
    }else{
        Processing during performance (Example; axis indication)
    }
}
```

Example: for Visual BASIC

```
 Dim new As Long
 Dim old As Long
 Dim err As Long
          :
err = pa_get_cnt(ARM0, old) …Control counter setting before the command issue
err = pa_exe_hom(ARM0, WM_NOWAIT)
Do While 1
    err = pa_get_cnt(ARM0, new)
     If err <> ERR_OK Then
        An error occurrence processing
        Exit Do
    Else
        If new <> old Then
           Motion termination processing
           Exit Do
        Else
           Processing during performance (Example; axis indication)
        End If
     End If
Loop
```

6. 3 Axis Angle Control

Method to control from the operation control section providing axis target angle. The motion control section calculates each axis interpolation and controls angle feedback.



The method to provide target values is as follows:

＜Method to input angles＞

Axis angle control(θ_{S1}, θ_{S2}, ··· θ_{W2})

＜Axis Angle Control＞ The method to use a orientation previously registered.

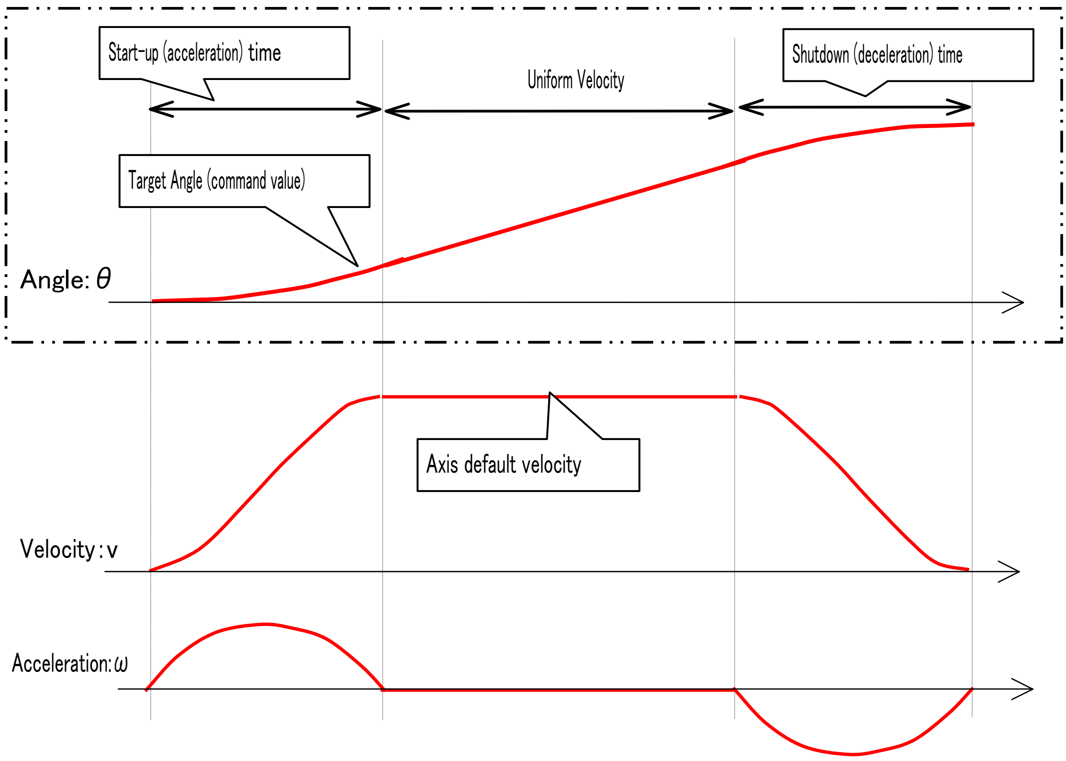
- ･Basic Orientation Control
- ･Escape orientation control
- ･Safety Orientation Control

<u>Axis Angle Interpolation Method</u>

This method to control the selected axis to the target angle, calculating axis interpolation.

This method interpolates the velocity command to form a letter "S" shape.

The motion velocity is interpolated adjusting to the default velocity.



6. 3. 1 Axis Angle Control

Designates axes to be controlled and provides target angles.

Program Description::

Example: for Visual C++ To control only S1,S2 and E1 at 90 [deg]

```
        :
  ANGLE angle;
          :
  angle.s1 = 1.57; (= 90.0 * M_PI / (double)180.0)
  angle.s2 = 1.57;
  angle.e1 = 1.57;
  pa_exe_axs( ARM0, S1|S2|E1, & angle, WM_NOWAIT );
```

Example: for Visual BASIC

```
          :
  Dim ret As Long
  Dim axs As Long
  Dim agl As ANGLE
          :
  agl.s1 = 1.57
  agl.s2 = 1.57
  agl.e1 = 1.57
  axs = S1 Or S2 Or E1
  ret = pa_exe_axs( ARM0, axs, agl, WM_NOWAIT )
```

The motion speed is adjusted to the default one and interpolated forming a letter “S” shape.

6. 3. 2 Axis Orientation Control

This control method is the same as the axis control.

・Basic Orientation

All Axes : 0 [deg]

・Escape Orientation

S2 : 30[deg]
E1 : 90[deg]
W1 : 60[deg]
Others : 0[deg]

・safety Orientation

S2 : 45[deg]
E1 : 90[deg]
W1 : -45[deg]
Others : 0[deg]

Alteration methods for each orientation angle are:

・Method to input the angle. (ex) pa_set_hom
・Method to replace with a current angle. (ex) pa_def_hom

These values are erased when the power is off. To change the arm parameter default value, use the parameter setting program.

Program Description:

Example: for Visual C++

```
ANGLE   angle;
          :
pa_exe_esc( ARM0, WM_NOWAIT );                    to default escape orientation.
          :
angle.s1 = 1.57;                         [rad]( = 90.0[deg]*M_PI/(double)180.0)
angle.s2 = 1.57;
angle.e1 = 1.57;
          :
angle.w2 = 1.57;
pa_set_esc( ARM0, & angle );                      escape orientation alteration
pa_exe_esc( ARM0, WM_NOWAIT );                    all axes to 90[deg]
          :
angle.s1 = 0.785;
angle.s2 = 0.785;
pa_exe_axs( ARM0, S1|S2, & angle ,WM_NOWAIT);            to S1,S2 = 45[deg]
          :
pa_def_esc( ARM0 );                          loading as escape orientation
```

Example: for Visual BASIC

```
Dim agl As ANGLE
Dim ret As Long
Dim axs As Long

ret = pa_exe_esc( ARM0, WM_NOWAIT )     to the default escape orientation.

agl.s1 = 1.57
agl.s2 = 1.57
agl.e1 = 1.57
        :
agl.w2 = 1.57
ret = pa_set_esc( ARM0, agl )           escape orientation alteration
ret = pa_exe_esc( ARM0, WM_NOWAIT )           all axes to 90[deg]
        :
agl.s1 = 0.785
agl.s2 = 0.785
axs = S1 Or S2
ret = pa_exe_axs( ARM0, axs, agl ,WM_NOWAIT)
        :
ret = pa_def_esc( ARM0 )                      loading as escape orientation
```

It would be useful to register angles often used following operation purposes.

(*1) The arm parameter is the file setting data needed for a control, located in the motion control section.

Reference

For further information, refer to "parameter setting" in the section 6.13.

The contents can be seen with the command – pa_get_prm – from the operation control section. They cannot be directly changed in the program.

But, the operation support program (parameter setting) for alteration is provided.

Reference

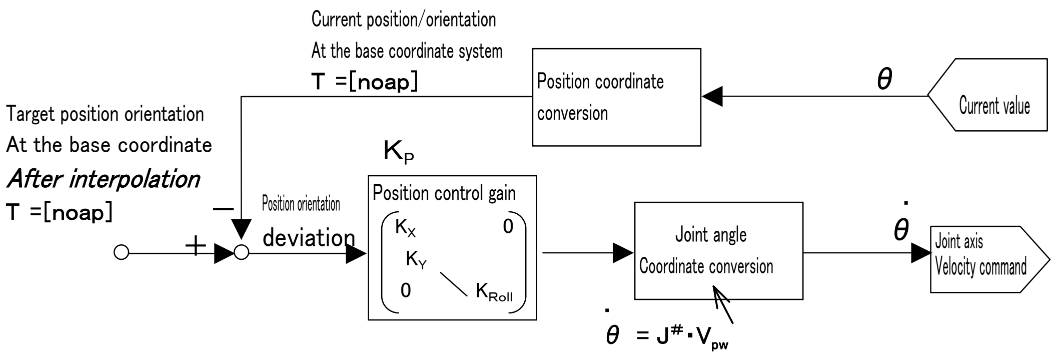
For the alteration method, refer to the operation support program (parameter setting) instruction.

6. 4　Tip Position/Orientation (RMRC) Control: 6-axis arm

The following explanation about the tip position/orientation control for the 6-axis arm is the summarized one.　For the 7-axis arm, it is explained in the section 6.5.

6. 4. 1　Tip Position/Orientation (RMRC) Control

PA10 tip position/orientation (RMRC) control is the method to control arm providing its tip position/orientation as the target value from the operation control section.　The motion control section calculates interpolation of each tip position/orientation and controls the position feedback.



Memo

In PA10, the tip position/orientation control is called RMRC control.

As target value, there are input values below:

- Tip Position Deviation（ ΔX, ΔY, ΔZ ）
- Tip Orientation Deviation（ ΔYaw, ΔPitch, ΔRoll ）
- Tip Position/Orientation $\begin{pmatrix} nx & ox & ax & px \\ ny & oy & ay & py \\ nz & oz & az & pz \end{pmatrix}$

Tip position/orientation (RMRC) control are as follows:

- Tip position deviation control
- Tip position orientation control
- Absolute position/orientation designation control

- Tip position/orientation/velocity control
- Current point motion control (Tip linear motion)
- Playback control (Except data for PTP axis interpolation)

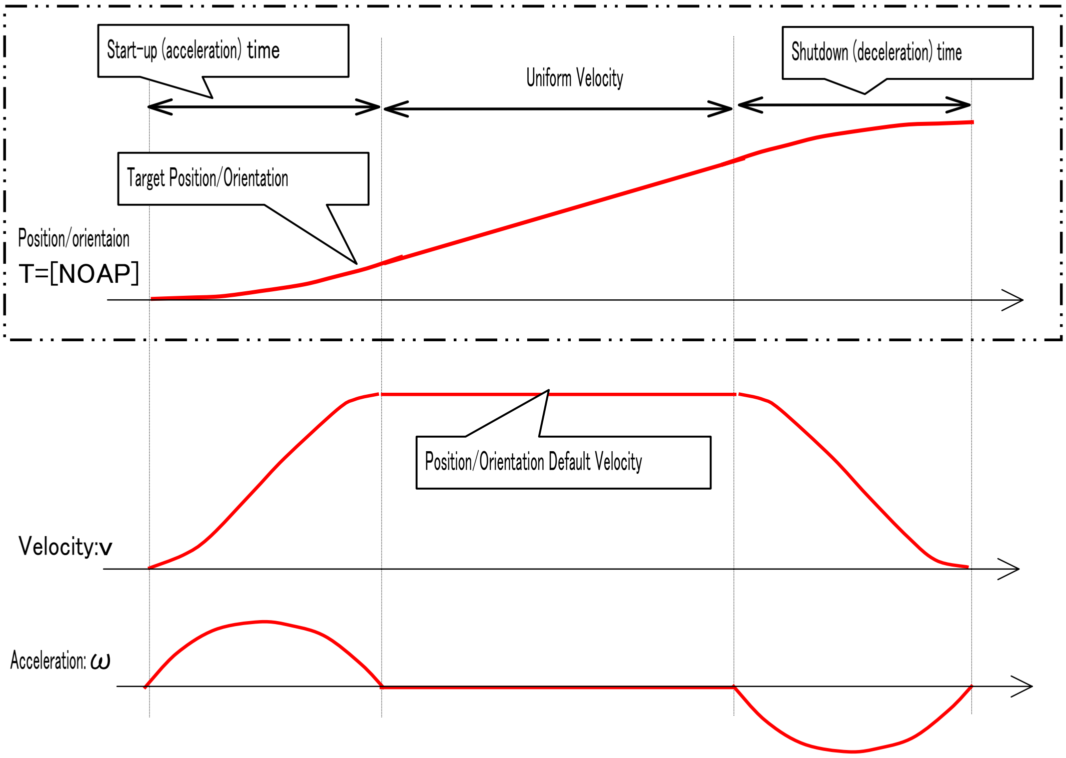
- RMRC real-time control mode

Tip Position/Orientation Interpolation Method

This method calculates the tip position/orientation interpolation and controls the tip to the input target position/orientation.

This method interpolates the velocity command to form a letter “S” shape.

The motion velocity, adjusting to the position/orientation default velocity, is interpolated to form a letter “S” shape.



(1) Tip Position Deviation Control

Position deviations (ΔX, ΔY, ΔZ) from the current tip position are provided to each axis in the selected coordinate system.

・Base coordinate tip position control：pa_mov_XYZ(ARM0, dX, dY, dZ, WM_WAIT)

・Mechanical interface coordinate tip position control：pa_mov_xyz(ARM0, dx, dy, dz, WM_WAIT)

(Visual BASIC: pa_mov_XYZ0(ARM0,dx,dy, dz, WM_WAIT))

In Visual BASIC, there is no distinction between capital and small letters.

Control Method:

- The target position is defined by adding the current tip position to the input position deviation.
- The tip position is interpolated linearly.
- The arm parameter default tip linear velocity is interpolated to form the letter "S" shape
- The tip orientation does not change.

Program Description:

① Adjusts the axis value to the RMRC controllable one.: pa_exe_esc

The possible start range for RMRC control is limited.

The entry to the RMRC control is not allowed when E1＝0[deg].

The entry to the RMRC control from the basic orientation is not allowed. One of the ways to enter the RMRC control is to shift to the escape orientation.

② Chooses the coordinate system and provides deviation. : pa_mov_XYZ

It moves 100 (mm) toward X (axis) in the base coordinate.

A coordinate system selection depends on the intended direction to shift. The one to be applied should be chosen.

Example: for Visual C++

```
                    :
    pa_exe_esc( ARM0, WM_WAIT );        ･･･to RMRC controllable orientation
    pa_mov_XYZ( ARM0, 100.0, 0.0, 0.0,WM_WAIT );
         :                    ･･･Proceed X=100.0 in the base coordinate.
```

Example: for Visual BASIC

```
    Dim ret As Long
            :
    ret = pa_exe_esc( ARM0, WM_WAIT )
    ret = pa_mov_XYZ( ARM0, 100.0, 0.0, 0.0,WM_WAIT )
```

(2) Tip Orientation Deviation Control

Orientation deviations (ΔYaw, ΔPitch, ΔRoll) from the current tip orientation are provided to each axis in the selected coordinate system.

・Base coordinate tip orientation control:

pa_mov_YPR(ARM0, dYaw,dPitch,dRoll,WM_WAIT)

・Mechanical interface coordinate tip orientation control:

pa_mov_ypr(ARM0,dyaw,dpitch,droll, WM_WAIT)

(In the case of Visual BASIC: pa_mov_YPR0(ARM0,dyaw,dpitch, droll, WM_WAIT))

Control Method:

・The tip position does not change.
・The target orientation is defined by adding the current tip orientation to the input orientation deviation.
・The rotation angle deviation of the tip orientation is interpolated.
・The arm parameter default tip rotational velocity – the rotational velocity – is i nterpolated to form the letter “S” shape

・

Program Description:

① Adjusts the axis value to the RMRC controllable one.: pa_exe_esc

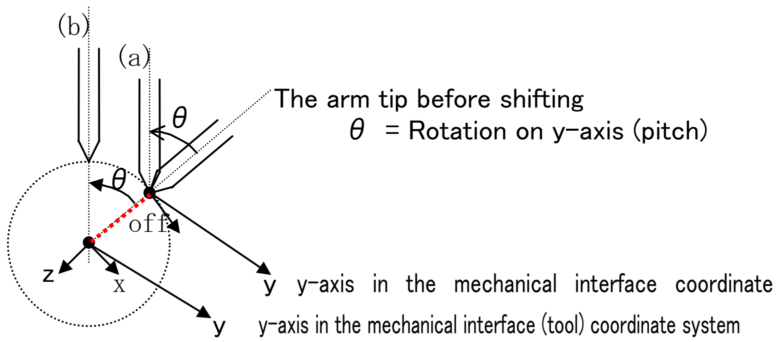
The possible start range for RMRC control is limited.
The entry to the RMRC control is not allowed when E1=0[deg].
The entry to the RMRC control from the basic orientation is not allowed. One of the ways to enter the RMRC control is to shift to the escape orientation.

② Chooses the coordinate system and provides deviation.: pa_mov_ypr

It moves around an axis in a mechanical interface coordinate. The tip position does not change. If tool information/offset values are set, it rotates around the tip.
A coordinate system selection depends on the intended direction to shift. The one to be applied should be chosen.

Example: for Visual C++

```
                    :
pa_exe_esc(ARM0,WM_WAIT);
pa_mov_ypr(ARM0,0.0,20.0*PI/180.0,0.0,WM_WAIT);  ･･･ (a)
   : A 20[deg] rotation on Y-axis in the mechanical interface coordinate system
              :
pa_set_tol(ARM0,0.0,0.0,0.0,0.0);     ･･･ Set tool offset (float type)
pa_mov_ypr(ARM0,0.0,20.0*PI/180.0,0.0,WM_WAIT);  ･･･ (b)
 : A 20[deg] rotation on y-axis in the mechanical interface (tool) coordinate
                                                                    system
```



Setting tool information/offset values, the position will be changed even with the tip orientation conversion function. If to shift the tip to the work face is to be applied, use "pa_set_tol."

Example: for Visual C++

```
Dim ret As Long

ret = pa_exe_esc(ARM0,WM_WAIT)
ret = pa_mov_YPRO(ARM0,0.0,20.0*PAI/180.0,0.0,WM_WAIT)
                    :
                    :
ret = pa_set_tol(ARM0,0.0,0.0,0.0,0.0)
ret = pa_mov_YPR0(ARM0,0.0,20.0*PAI/180.0,0.0,WM_WAIT)
```

(3) Designated Absolute Position/Orientation Control

The tip matrix (T-matrix) on the base coordinate system and each axis value for restriction data are provided.

$$\text{T-matrix}: \begin{pmatrix} nx & ox & ax & px \\ ny & oy & ay & py \\ nz & oz & az & pz \end{pmatrix}$$

Target matrixes are as follows:

・Absolute position target matrix: controls only positions and orientation does not change.

・Absolute orientation target matrix: controls only orientation and positions do not change.

・Absolute position/orientation matrix: controls positions and orientations.

Control methods:

・The input tip position/orientation becomes the target position/orientation.

・The tip position is interpolated linearly.

・The rotation angle of the tip orientation is interpolated.

・Calculates the motion and the rotational velocity from a default tip motion and rotational velocity of the arm parameter.

Vxyz : Default tip linear velocity
Vypr : Default tip rotational velocity
△xyz : Tip position motion value
△ypr : Tip orientation rotation angle

Txyz = △xyz／Vxyz : Time taken for tip motion.
Typr = △ypr／Vypr : Time taken for rotation.

If Txyz ≧ Typr, "Vxyz" becomes the standard.
If Txyz ＜ Typr. "Vypr" becomes the standard.

Program Description:

① Adjusts the axis value to the RMRC controllable one.: pa_exe_saf

The possible start range for RMRC control is limited.

The entry to the RMRC control is not allowed when E1＝0[deg].

The entry to the RMRC control from the basic orientation is not allowed. One of the ways to enter the RMRC control is to shift to the safety orientation.

② The tip position/orientation matrix described in the base coordinate system is provided.: pa_mov_mat

It moves toward the tip matrix (T-matrix) indicated in the base coordinate. A coordinate system selection depends on the intended direction to shift. The one to be applied should be chosen.

MOVEMODE types are:

- MM_XYZ : Absolute position target matrix
- MM_NOA : Absolute orientation target matrix
- MM_XYZNOA : Absolute position/orientation matrix

Example: for Visual C++

```
MATRIX mat;
ANGLE  an;
        :
pa_exe_saf(ARM0, WM_WAIT);
        :
    Tip T-matrix :mat set
    Set 0.0 for "an" which is not used for 6-axis arm.
        :
pa_mov_mat(ARM0,MM_XYZNOA,mat,&an,WM_WAIT);
```

From the current position, perform the RMRC interpolation and shift to the tip position/orientation indicated by "mat."

Example: for Visual BASIC

```
Dim mat As MATRIX
Dim an As ANGLE
Dim ret As Long
        :
ret = pa_exe_saf(ARM0)
        :
ret = pa_mov_mat(ARM0,MM_XYZNOA,mat,an,WM_WAIT)
```

(4) Tip Position/Orientation/velocity Control

Method to control providing linear motion velocity (Vx, Vy, Vz) and rotational velocity (Vyaw, Vpitch, Vroll.) on each coordinate axis in the selected coordinate system

Reference

For further information, refer to "Velocity Control" in the section 6.6

(5) Current Point Motion Control (Tip Linear motion)

Shifts, interpolating the tip position/orientation linearly with the RMRC control to the current point.

Reference

For further information, refer to "shift to the current point" in the section 6.10.3

(6) Playback Control

The playback control is performed using teach data acquired in various control situations.

Reference

For further information, refer to "Playback Control" in the section 6.10 ~ 6.11

(7) RMRC Real-Time Control Mode

The control method providing target axis angles and T-matrix indicating the target tip linear motion and rotation in the maximum 1000msec cycle.

Reference

For further information, refer to "Real-Time Control" in the section 6.8

6. 4. 2 Motion at the singular posture (singularity)

Awareness on RMRC control operation.

In RMRC control, arm is usually actuated by providing commands to the tip position and orientation of the manipulator, calculating joint angle velocity to actualize.

⚠ CAUTION

When the tip takes a position/orientation called a singularity, to maintain a consistent tip trajectory and motion velocity, it is needed to instantly increase some joint velocity.

THIS OPERATION, IF ACTUALIZED, CAUSES ENORMOUS DANGER, CREATING UNCONTROLABLE POSITION/ORIENTATION.

---

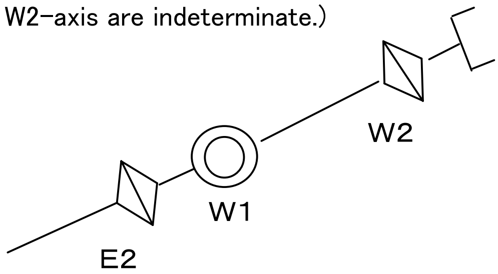
6. 4. 2. 1 Singularity types

On singularity, there are three inner singularities (wrist, elbow and shoulder singularity) and the outer singularity located out of the arm movable range.

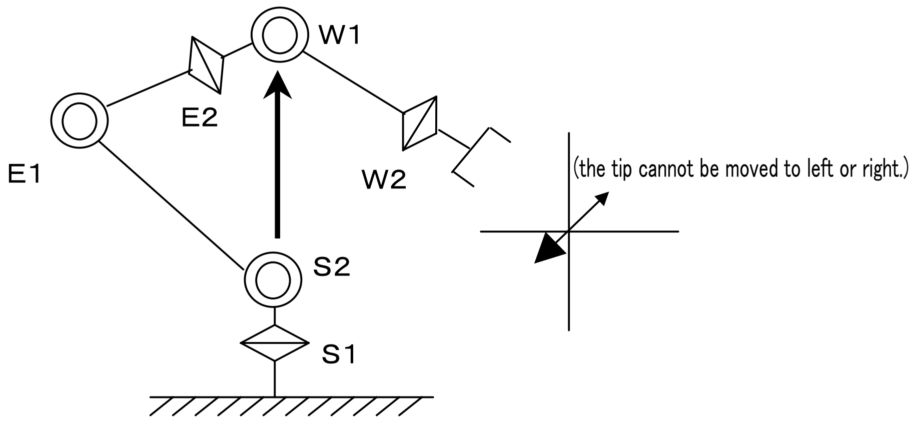
＜Inner Singularity＞

Inside the arm movable range, the position/orientation cannot be controlled when a joint angle is exceeded, or lowers the control accuracy.

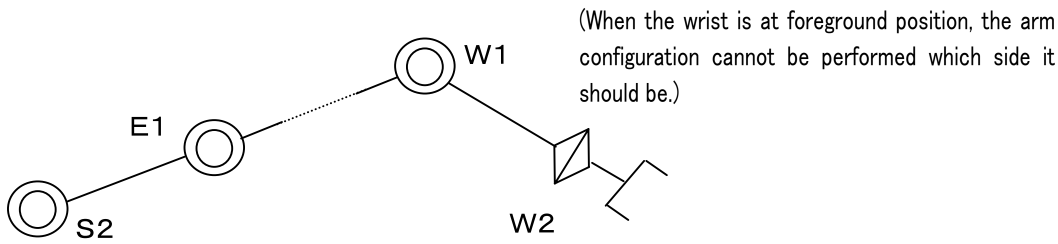
Wrist Singularity…Rotational axes of E2 and W2-axis are linear. = W1-axis is 0
(E2 and W2-axis are indeterminate.)



Shoulder Singularity…the intersecting point of E2,W1 and W2 rotational axis is on the S1 rotational axis. (the tip cannot be moved to left or right.)

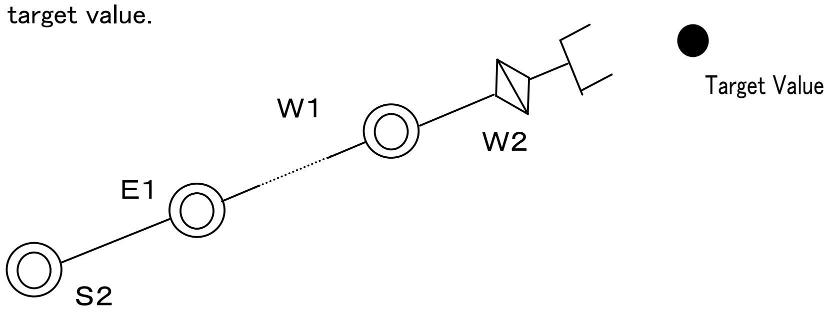


Elbow Singularity…the intersecting point of E2,W1 and W2 rotational axis is on the plane including the S2 and E1 rotational axis.



＜Outer Singularity＞

the target position/orientation are designated outside the movable range. It is impossible to actuate the arm. It usually stops motion with an error indication or cuts the target value.



6. 4. 2. 2　Singularity Avoidance Motion

Singularity avoidance algorism in PA10 customized on the basis of the SC (singularity – Consistency) method discoursed by Professor Tsumaki, Tohoku university.　Its outline is explained below.

If needed exceeding velocity to any axis during RMRV control, the SC method – the algorism – lowers the tip velocity and maintains its position and posture.　During RMRC control, in PA10, the operation is always controlled by the SC method. If any axis exceeds the rated velocity, the tip velocity is decelerated without any alert.　It is not good for the operations needed to maintain velocity.

Conditions	Contents
Wrist Singularity W1 axis angle 0 singularity	If the W1-axis passes through around 0 degree, the E2 and the W2-axis are laid in a straight line.　It creates an enormous reverse velocity command. To previously find this singularity, the W1-axis angle is always observed.　If entering into the range designated by the parameter, a limit velocity defined by the SC method is lowered. The lowering range is designated in the separated section "Parameter." (As the result of lowering a limited velocity, the arm tip motion velocity is affected.　But, the position and the posture are maintained.)
Shoulder Singularity W1 axis position singularity	If the W1-axis locates around the S1-axis position, it is needed to actuate the S1-axis to alter the posture.　The low velocity S1-axis becomes the standard for motion velocity. To previously find this singularity, W1-axis angle is always observed. If entering into the range designated by the parameter, a limit velocity defined by the SC method is lowered. The lowering range is designated in the separated section "Parameter." (As a result of lowering a limit velocity, the arm tip motion velocity is affected. But, the position and the posture are maintained.)
Elbow Singularity E1 axis angle 0 singularity	If the E1-axis passes through 0 degree, it creates an enormous velocity command for the E1-axis. By restricting the arm movable range in the RMRC control, this singularity can be avoided. It stops in error with "exceeded arm length (*1)."

Remark

The singularity avoidance processing acs avoiding an undesirable emergency such as arm hazardous motion.　If arm motion is in teach and playback mode, it is most important NOT TO TAKE those positions and posture.

Around a singularity it is not always possible to make all avoidance motions. At a singularity below, arm stops in error.

＜Wrist Singularity＞

Around the wrist singularity, in unstable areas, the velocity command sends an error signal to the brake to stop.

＜Elbow Singularity＞　　**Exceeded arm length:**

If E1-axis passes through 0[deg] (the length from S2 rotation origin to W1 rotation origin: 930 [mm],) the RMRC control is not allowed to enter.

For RMRC control, when creating the current value and the target one, it is checked whether arm length is exceeded or not.

When acquiring teach data other than PTP axis interpolation data, if arm length is exceeded, data cannot be obtained.

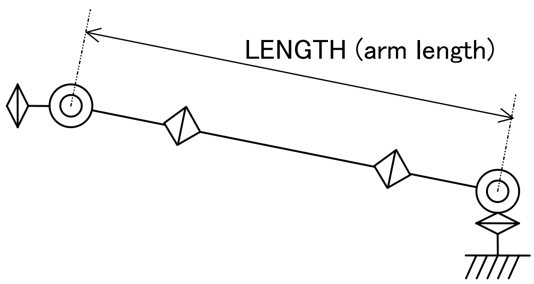
In the error message, LENGTH is indicated as "Arm Length."

- **ERR_NOT_ENUGH**: The arm length target value is exceeded more than 925 [mm]. In this case, in interpolation calculation, the target values are automatically corrected. The arm does not stop.

- **ERR_OVER900** : During operation, when the arm length becomes 930 [mm], the brake stops it.

- **ERR_CANT_MOVE**: If the arm length current value is exceeded more than 925 [mm], the RMRC control is not allowed to enter.

(Example) at the basic orientation, E1 = 0. The RMRC control is not allowed to enter.



6. 4. 2. 3 Control around Angle Limit

Entry protection to the angle limit:

The SC method is the algorism built-in originally for singularity avoidance. In PA10, using this algorism, processing to decelerate the whole motion of a manipulator just before the angle limit.
Conditional analyses are performed to all moving axes. If any of them approaches to the angle limit, it is forcefully decelerated following SC method.

The deceleration range is from 3 degrees before axis angle limit, where starts decelerating linearly, to the angle limit where the velocity is reduced up to 10% (the rated velocity.)

Teach mode motion

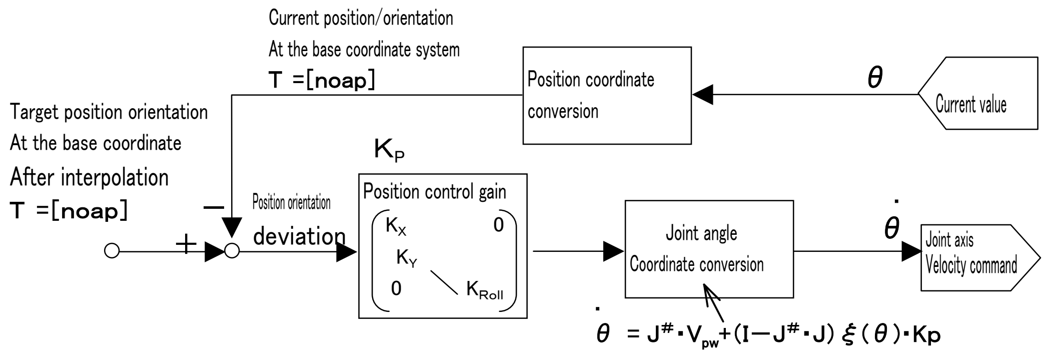
In teach mode the velocity limit is lowered by force. As the velocity limit in the SC method is basically lowered.

6. 5 Tip Position/Orientation (RMRC) Control: 7-axis arm

The tip position/orientation control for the 7-axis arm is as follows:

6. 5. 1 Tip Position/Orientation (RMRC) Control

PA10 tip position/orientation (RMRC) control method to control arm providing its tip position/orientation as the target value from the operation control section. The motion control section calculates interpolation of each tip position/orientation and controls the position feedback.



Memo

In PA10, the tip position/orientation control is called RMRC control.

As target value, there are input values below:

- Tip position deviation(ΔX, ΔY, ΔZ)
- Tip orientation deviation(ΔYaw, ΔPitch, ΔRoll)
- Tip position/orientation $\begin{pmatrix} nx & ox & ax & px \\ ny & oy & ay & py \\ nz & oz & az & pz \end{pmatrix}$

Axis value for restriction data during a redundant axis control(θS1, θS2, ··· θW2)

In the 7-axis arm, when the RMRC control, chooses a redundant axis control mode, a redundant axis (elbow) can be controlled.

In 7-axis arm, the tip position/orientation (RMRC) control can be classified in two on a large scale.

① Elbow control changing the tip position/orientation.
- Tip position deviation control
- Tip orientation deviation control
- Designated absolute position/orientation control
- Designated position/orientation/velocity control
- Current point motion control (tip linear motion)
- Playback control (except data for PTP axis interpolation)
- RMRC real-time control mode

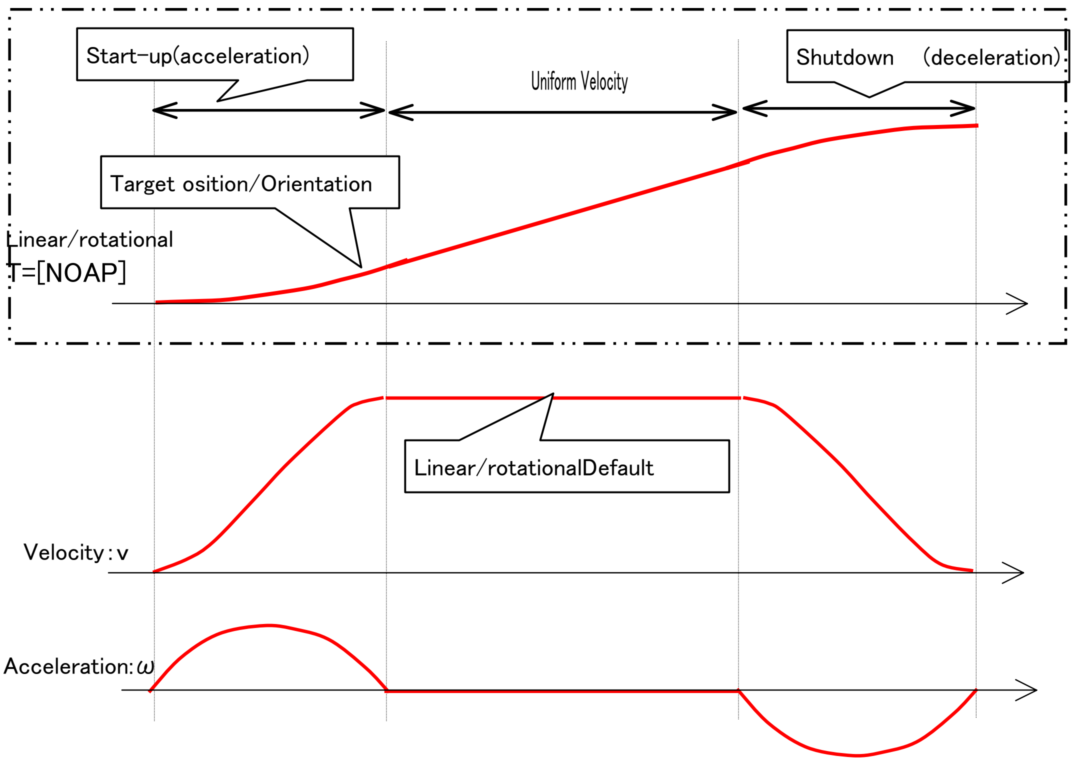
② Elbow control not changing the tip position/orientation.
- Redundant axis velocity control
- Redundant axis restriction parameter control
- Redundant axis motion control

Tip Position/Orientation Interpolation Method:

This method calculates the tip position/orientation interpolation and controls the tip to the input target position/orientation.

This method interpolates the velocity command to form a letter "S" shape.

The motion velocity, adjusting to the position/orientation default velocity, is interpolated to form a letter "S" shape.



6. 5. 2 Elbow Control changing the tip position/posture

(1) Tip Position Deviation Control

Position deviations (ΔX, ΔY, ΔZ) from the current tip position are provided to each axis in the selected coordinate system.

・Base coordinate tip position control: pa_mov_XYZ(ARM0, dX, dY, dZ, WM_WAIT)

・Mechanical interface coordinate tip position control: pa_mov_xyz(ARM0, dx, dy, dz, WM_WAIT)
(Visual BASIC: pa_mov_XYZ0(ARM0,dx,dy, dz, WM_WAIT))
In Visual BASIC, there is no distinction between capital and small letters.

Control Method:
・The target position is defined by adding the current tip position to the input position deviation.
・The tip position is interpolated linearly.
・The arm parameter default tip linear velocity is interpolated to form the letter "S" shape
・The tip orientation does not change.

Program Description:

① Adjusts the axis value to the RMRC controllable one.: pa_exe_esc
The possible start range for RMRC control is limited.
The entry to the RMRC control is not allowed when E1=0[deg].
The entry to the RMRC control from the basic orientation is not allowed. One of the ways to enter the RMRC control is to shift to the escape orientation.

② **Chooses the coordinate system and provides deviation.** : **pa_mov_XYZ**
It moves 100 (mm) toward X (axis) in the base coordinate.
A coordinate system selection depends on the intended direction to shift. The one to be applied should be chosen.

Example: for Visual C++

```
                    :
    pa_exe_esc( ARM0, WM_WAIT );          ･･･to RMRC controllable orientation
    pa_mov_XYZ( ARM0, 100.0, 0.0, 0.0,WM_WAIT );
        :                       ･･･Proceed X=100.0 in the base coordinate.
```

Example: for Visual BASIC

```
    Dim ret As Long
          :
     ret = pa_exe_esc( ARM0, WM_WAIT )
     ret = pa_mov_XYZ( ARM0, 100.0, 0.0, 0.0,WM_WAIT )
```

(2) Tip Orientation Deviation Control

Orientation deviations (ΔYaw, ΔPitch, ΔRoll) from the current tip orientation are provided to each axis in the selected coordinate system.

・Base coordinate tip position control: pa_mov_YPR(ARM0, dYaw,dPitch,dRoll,WM_WAIT)

・Mechanical interface coordinate tip orientation control:

pa_mov_ypr(ARM0,dyaw,dpitch,droll, WM_WAIT)

(In the case of Visual BASIC: pa_mov_YPR0(ARM0,dyaw,dpitch, droll, WM_WAIT))

Control Method:

・The tip position does not change.
・The target orientation is defined by adding the current tip orientation to the input orientation deviation.
・The rotation angle deviation of the tip orientation is interpolated.
・The arm parameter default tip rotational velocity – the rotation velocity – is interpolated to form the letter "S" shape

Program Description:

① Adjusts the axis value to the RMRC controllable one.: pa_exe_esc

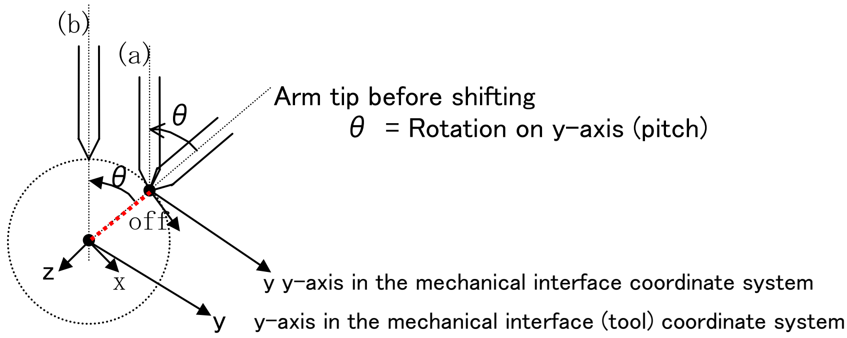
The possible start range for RMRC control is limited.
The entry to the RMRC control is not allowed when E1＝0[deg].
The entry to the RMRC control from the basic orientation is not allowed. One of the ways to enter the RMRC control is to shift to the escape orientation.

② Chooses the coordinate system and provides deviation.: pa_mov_ypr

It moves around an axis in a mechanical interface coordinate. The tip position does not change. If tool information/offset values are set, it rotates around the tip.
A coordinate system selection depends on the intended direction to shift. The one to be applied should be chosen.

Example: for Visual C++

```
                         :
pa_exe_esc(ARM0,WM_WAIT);
pa_mov_ypr(ARM0,0.0,20.0*PI/180.0,0.0,WM_WAIT); ・・・ (a)
 : A 20[deg] rotation on Y-axis in the mechanical interface coordinate system
                 :
pa_set_tol(ARM0,0.0,0.0,0.0,0.0);     ・・・ Set tool offset (float type)
pa_mov_ypr(ARM0,0.0,20.0*PI/180.0,0.0,WM_WAIT); ・・・ (b)
     : A 20[deg] rotation on y-axis in the mechanical interface (tool) coordinate system
```



Setting tool information/offset values, the position will be changed even with the tip orientation conversion function. To shift the tip to the work face intended, use "pa_set_tol."

Example: for Visual C++

```
Dim ret As Long

ret = pa_exe_esc(ARM0,WM_WAIT)
ret = pa_mov_YPRO(ARM0,0.0,20.0*PAI/180.0,0.0,WM_WAIT)
                      :
                      :
ret = pa_set_tol(ARM0,0.0,0.0,0.0,0.0)
ret = pa_mov_YPR0(ARM0,0.0,20.0*PAI/180.0,0.0,WM_WAIT)
```

(3) Designated Absolute Position/Orientation Control

The tip matrix (T-matrix) on the base coordinate system and axis value for restriction data is provided for the target tip orientation.

$$\text{T-matrix}: \begin{pmatrix} nx & ox & ax & px \\ ny & oy & ay & py \\ nz & oz & az & pz \end{pmatrix}$$

axis value for restriction data : (θS1, θS2, ･･･ θW2)

Target matrixes are as follows:

- Absolute position target matrix: controls only positions. Orientations do not change.
- Absolute orientation target matrix: controls only orientation. Positions do not change.
- Absolute position/orientation matrix: controls positions and orientations.

Axis value for restriction data

Due to the redundant axis control mode selected before performing the designated absolute position/orientation control, axis value for restriction data will be effective as follows:

Redundant axis control mode (JOUMODE)	Relation between each mode and axis value for restriction data
No restriction (JM_OFF)	Not depending on provided axis values for restriction data at all.
All axes restricted (JM_ON)	All axes are restricted by provided axis values for restriction data
S3-axis restricted (JM_S3ON)	At first, interpolates the S3-axis restriction value, then, the S3-axis is restricted by the interpolated target S3-axis value as the restriction axis value.
S3-axis interpolation (JM_S3DIV)	S3-axis is interpolated to come to the input S3-axis restriction value.
S3-axis fixed (JM_S3HOLD)	Not depending on provided axis values for restriction data at all. Keep the S3-axis angle when the designated absolute position/orientation control is issued. It is controlled by other 6-axes, only.

Reference

For further information, refer to "Redundant axis control."

Control method:・・・

＜NOT S3-axis Interpolation Mode＞

・The input tip position/orientation becomes the target position/orientation
・The tip position trajectory is interpolated linearly.
・The tip orientation/rotation angle is interpolated.
・Calculates the shifting and rotation velocity from the arm parameter default tip linear/ rotational velocity.

Vxyz　:Default tip linear velocity
Vypr　: Default tip rotational velocity
△xyz :Tip position shifting value
△ypr :Tip orientation/rotation angle

Txyz = △xyz／Vxyz :　　Time taken for tip shifting.
Typr = △ypr／Vypr :　　Time taken for tip rotation.

If “Txyz ≧ Typr”, “Vxyz” becomes the standard.
If “Txyz ＜ Typr”, “Vypr” becomes the standard.

＜S3-axis interpolation mode＞

Interpolates, taking into account of S3-axis rotation angle as the interpolation standard.

・The input tip position/orientation becomes the target position/orientation
・The tip position trajectory is interpolated linearly..
・The tip orientation/rotation angle is interpolated.
・The S3-axis rotation angle is interpolated linearly..
・Calculates the shifting and rotation velocity from the arm parameter default tip linear/ rotational velocity.
・Calculates S3-axis shifting angle from the default S3-axis angle velocity.

Vxyz　:Default tip linear velocity
Vypr　: Default tip rotational velocity
VS3　　: Default S3-axis angle velocity
△xyz :Tip position shifting value
△ypr :Tip orientation/rotation angle
△s3　　:S3-axis rotation angle

Txyz　　= △xyz／Vxyz : Time taken for tip shifting.
Typr　　= △ypr／Vypr : Time taken for tip rotation.
Ts3　　= △s3 ／Vs3 　: Time taken for S3-axis rotation.

If “Txyz“ is the maximum, “Vxyz” becomes the standard.
If “Typr” is the maximum, “Vypr”　becomes the standard.
If “Ts3is” is the maximum, “Vs3”　becomes the standard.

Program Description:

① Adjusts the axis value to the RMRC controllable one.: pa_exe_saf

The possible start range for RMRC control is limited.
The entry to the RMRC control is not allowed when E1＝0[deg].
The entry to the RMRC control from the basic orientation is not allowed. One of the ways to enter the RMRC control is to shift to the safety orientation.

② sets the redundant axis control mode: pa_mod_jou

A default is not restricted.

③ The tip position/orientation matrix described in the base coordinate system is provided.: pa_mov_mat

It moves toward the tip matrix (T-matrix) indicated in the base coordinate.
A coordinate system selection depends on the intended direction to shift. The one to be applied should be chosen.

MOVEMODE types are:

MM_XYZ : Absolute position target matrix
MM_NOA : Absolute orientation target matrix
MM_XYZNOA : Absolute position/orientation matrix

Example: for Visual C++

```
MATRIX mat;
ANGLE  an;

pa_exe_saf(ARM0);

Tip T-matrix : mat set
Axis value for restriction data :an      set

pa_mod_jou(ARM0,JM_ON);
                        … the redundant axis control mode setting (all axes are restricted)
pa_mov_mat(ARM0,MM_XYZNOA,mat,&an,WM_WAIT);

Shifts from the current position to the tip position/orientation indicated in
"mat" with RMRC interpolation in the selected redundant axis control
mode (all axes are restricted).
```

Example: for Visual BASIC

```
Dim mat As MATRIX
Dim an As ANGLE
Dim ret As Long

ret = pa_exe_saf(ARM0)

ret = pa_mod_jou(ARM0,JM_ON)
ret = pa_mov_mat(ARM0,MM_XYZNOA,mat,an,WM_WAIT)
```

(4) Tip linear/rotational velocity Control

Method to control linear motion velocity (Vx, Vy and Vz) and rotational velocity (Vyaw, Vpitch and Vroll.) on each coordinate axis in the selected coordinate system

Reference

For further information, refer to “Velocity Control” in the section 6.6

(5) Current Point Motion Control (Tip Linear Motion)

Shifts, interpolating the tip position/orientation linearly with the RMRC control to the current point.

Reference

For further information, refer to “shift to the current point” in the section 6.10.3

(6) Playback Control

The playback control is performed using teach data acquired in various control situations.

Reference

For further information, refer to “Playback Control” in the section 6.10 ~ 6.11

(7) RMRC Real-Time Control Mode

The control method providing target axis angles and T-matrix indicating the target tip linear motion and rotation in the maximum 1000msec cycle.

Reference

For further information, refer to “Real-Time Control” in the section 6.8

6. 5. 3 Elbow Control NOT changing the tip position/orientation

(1) Redundant Axis Velocity Control

One of the methods to control elbow position without changing the tip position/ orientation. In this PA10 link composition, the S3-axis is the KEY axis for elbow control. In this control, the rotation shift velocity (V θ s3) is provided to the S3-axis to actuate the elbow.

Reference

For further information, refer to "Redundant axis Control" in the section 6.6

(2) Redundant Axis Restriction Parameter Control

The control method is as similar as (1).

Reference

For further information, refer to "Redundant axis Control" in the section 6.5.5

(3) Redundant Axis Shifting Control

The control method is as similar as (1).

Reference

For further information, refer to "Redundant axis Control" in the section 6.5.5

6. 5. 4　Notes on RMRC Control

Precautions on the RMRC control are described below.

Exceeded Arm Length:

Regarding the RMRC control in PA, there are uncontrollable areas. When the current and target value exist out of the motion area, if the E1-axis passes through the 0[deg] point (the length from S2 rotation origin to W1 rotation origin: 930 [mm]), called a singularity, the RMRC control is not allowed to enter.
In the case of RMRC control, when creating the current value and the target one, the RMRC checks whether arm length is exceeded or not.

When acquiring teach data other than PTP axis interpolation data, if arm length exceeds, data cannot be obtained.

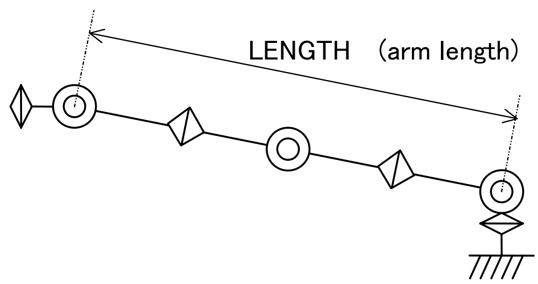
In the error message, LENGTH is indicated as “Arm Length.”

・**ERR_NOT_ENUGH**: The arm length target value exceeds more than 925 [mm]. In this case, in interpolation calculation, the target values are automatically corrected. The arm does not stop.

・**ERR_OVER900**: During operation, when the arm length becomes 930 [mm], the brake stops.

・**ERR_CANT_MOVE**: If the arm length current value exceeds more than 925 [mm], the RMRC control is not allowed to enter.

(Example) at the basic orientation, E1 = 0. The RMRC control is not allowed to enter.



6. 5. 5　Redundant Axis Control

The redundant axis control is the restriction mode to control each 7-axis value to a certain direction in the RMRC and playback control.
There are two meanings in these redundant controls below.

① **Redundant axis control mode**
- No restriction (Tip position/orientation restricting control)
- All axes restricted (All axes control)
- S3-axis restricted (S3-axis restricting control)
- S3-axis interpolation (S3-axis interpolation control)
- S3-axis fixed (S3-axis fixing control)

The mode to choose how much restriction should be made or not make it at all for a redundant axis (elbow) while in operation.

② **Redundant axis operation control**
- Redundant axis velocity control (The redundant axis control mode changes into S3-axis interpolation.)
- Redundant axis parameter alteration (The redundant axis control mode changes into S3-axis restriction.)
- Redundant axis parameter reset (The redundant axis control mode is changed without restriction.)
- S3-axis angle control (The redundant axis control mode changes into S3-axis interpolation.)

Control to actuate the redundant axis (elbow) without changing the tip position and posture.

6. 5. 5. 1 redundant Axis Control Mode

The redundant axis control mode is available for the controls below:

- When in the RMRC position/orientation control
- When in the designated absolute position/orientation control
- when in the playback control (except data for PTP axis interpolation)

Redundant axis control mode restriction is as follows:

Restriction	None	Low ◄		► High	Fixation
Redundant axis control mode	No restriction	All axes Restriction	S3-axis Restriction	S3-axis Interpolation	S3-axis Fixed

The following are advantages and disadvantages of each mode.

(a) Redundant Axis Control – No Restriction

This control creates the most stable angles for all 7 axes (reliable orientation for the arm)

Advantages: On account of no axis restriction, it has a more tip position/orientation motion ability than other redundant axis control mode.

Disadvantages: If this mode is chosen even though the target axis angle or axis value for restriction data is input, the target axis angle and axis value for restriction data are ignored.

(b) Redundant Axis Control – All Axes Restriction Mode

This controls for all 7 axes to approach the target axis angle as much as possible.

Advantages: Restriction is not strict. It has a tip position/orientation motion ability.

Disadvantages: As this control restricts the 7 axes, all axes usually do not move to the target axis angle. (especially when the target orientation shows arm malfunction.)

(c) Redundant Axis Control – S3-axis Restriction Mode

This control has some strong restrictions for the S3-axis to move to the target angle.

Advantages: As this control has some strong restrictions, the axis has much possibility to approach the target orientation. This is most balanced control method among these five modes.

Disadvantages: The arm might be shifted faster toward the target angle. If the S3-axis angle deviation is large, the tip position/orientation and the S3-axis are interpolated with the interpolation value calculated by "S3-axis deviation divided by S3-axis default velocity." The tip position/orientation/velocity becomes invalid.

(d) Redundant Axis Control – S3-axis Interpolation Mode

Interpolating the S3-axis deviation (difference between the current and the target angle), when the tip position/orientation is reached the target value, the S3-axis is controlled to reach the target angle at the same time. This restriction is stricter than (c).

Advantages: The S3-axis surely arrives to the target angle. This gives much possibility for all seven axes to get to the target angle. To summarize, arm can obtain the target posture and can be controlled holding its posture following exactly the teach data.

Disadvantages: As this mode has rather strict restriction, the tip position/orientation motion capability is low. If the S3-axis angle deviation is significant, the tip position/orientation and the S3-axis are interpolated with the interpolation quantity calculated by "S3-axis deviation divided by S3-axis default velocity." The tip position/orientation/velocity becomes invalid.

(e) Redundant Axis Control – fixed S3-axis Restriction Mode

Fixing the S3-axis angle is controlled by the axes, except the S3-axis, as a 6 axes manipulator. Choosing the fixed mode, keeps the S3-axis at the angle of the RMRC control starting.

Advantages: It is available when chosen to control the elbow without changing its position

Disadvantages: One (S3-axis) of the 7 axes is fixed to use as the 6 axes manipulator. It loses the advantages of the 7 axes manipulator.

(1) Redundant axis control mode as of RMRC position/orientation/deviation control

Selects to restrict the input axis value for restriction data or not when in the RMRC position control. In the S3-axis fixed mode, regardless of input axis value for restriction data, fix the S3-axis at the angle of the RMRC position/orientation deviation control start. The arm is controlled as the 6 axes manipulator.

In other redundant axis control mode, axis value at the RMRC position/orientation deviation control starting is defined as a value for restriction data. Therefore, the S3-axis interpolation mode used only the restricted S3-axis value and the S3-axis fixed mode make the same motion.

(2) Redundant axis control mode as of designated absolute position/orientation/ deviation control

Selects to restrict the input axis value for restriction data or not, when in the designated absolute position/orientation control. In the S3-axis fixing mode, however, regardless of input axis value for restriction data, fixes the S3-axis at the angle of the designated absolute position/orientation control starting, the arm is controlled as the 6 axes manipulator.

The S3-axis restriction mode and the S3-axis interpolation mode are controlled using only axis value for restriction data. Other axis value for restriction data becomes invalid.

(3) Redundant axis control mode as of playback control

Selects whether or not to restrict teach data axis value when in playback control. In S3-axis fixing mode, however, regardless of input axis value for teach data, fix the S3-axis at the angle of the playback control start or when axis angle control changed to the RMRC control during playback. The arm is controlled as the 6 axes manipulator, not using the S3-axis.

The S3-axis interpolation mode controls, using only each S3-axis value for restriction data. Other axis values for restriction data become invalid.

Program Description:

① Choose the redundant axis control mode : pa_mod_jou

JOUMODE of pa_mod_jou uses the macro-definitions below:

JM_OFF	No restriction
JM_ON	All axes restriction
JM_S3ON	S3-axis restriction
JM_S3DIV	S3-axis interpolation
JM_S3HOLD	S3-axis fixation

The default is JM_OFF (no restriction)

In any mode, each tip trajectory is the same. However, each elbow makes a different motion.

② Shifts to the current point with axis angle control.: pa_axs_pnt

③ Performs the playback control.: pa_ply_pnt

Example: for Visual C++

```
pa_mod_jou(ARM0, JM_S3ON); redundant axis control mode setting (S3-axis restriction

pa_axs_pnt(ARM0, WM_WAIT);   Shifts to the current point with axis angle control.

pa_ply_pnt(ARM0, PB_FORE, WM_WAIT);        Starting forward playback
```

Example: for Visual BASIC

```
Dim ret As Long

ret = pa_mod_jou(ARM0, JM_S3ON)

ret = pa_axs_pnt(ARM0, WM_WAIT)

ret = pa_ply_pnt(ARM0, PB_FORE, WM_WAIT)
```

When to alter the redundant axis control mode during the playback control:

During the playback control, makes the temporary stop (pa_sus_arm), then, sets the redundant axis control mode with pa_mod_jou. It can be altered.

Except the case explained below, after mode alteration, if a temporary stop is put in motion (pa_rsm_arm), the control is restarted.

The reason why a temporary-stop-release does not work after a mode alteration is on account of altering the redundant axis control mode to the "S3-axis restriction mode" or the "S3-axis interpolation mode" during performing playback in RMRC feedback control, After the mode alternation, the playback control is terminated.

Why the playback control stops when changes to "S3-axis restriction/interpolation mode" during playback performance in RMRC feedback control? There are two:

First of all, the redundant axis control mode can be employed for RMRV feedback control. During a playback performance of axis feedback control, any redundant axis control mode is invalid. Next, for example, as explained in the section 6.5.5, if the "S3-axis interpolation mode" is chosen, not only the tip position/orientation target value, but also the S3-axis target value at every controlling cycle are provided. So that this mode is more strict than others. If changes suddenly to the "S3-axis interpolation mode," the playback cannot be performed as the current and target S3-axis value are not equivalent.

To perform the playback control again, alter the current point (if needed), shift (pa_mov_pnt) to the current point, then, start (pa_ply_pnt) the playback.

6. 5. 5. 2 Redundant Axis Operation Control

The redundant axis control has the advantage of a 7-axis manipulator. It controls elbow position, only, without changing the tip position/orientation.

To shift the redundant axis control, choose JMMODE in "pa_mod_jouin," use the macro-definition as follows:

JM_VSET	Redundant axis velocity control
JM_SET	Redundant axis parameter alteration
JM_RESET	Redundant axis parameter resetting

(1) Redundant axis velocity control

The parameter of the redundant axis control is operated at a constant velocity
The parameter operation method uses "pa_odr_vel."

Reference

For further information, refer to "velocity Control" in the section 6.6

In this control, redundant axis control mode is automatically shifted to the S3-axis interpolation mode.

Example: for Visual C++

```
float    spd[7];

pa_mod_jou(ARM0, JM_VSET);              Shifts to the redundant axis velocity control

spd[0] = 20.0 * M_PI / (double)180.0;     ･･･Unit [rad/sec]
                              In the case of the redundant axis velocity control, "spd[0]" can be
                              used.      Control the redundant axis at 20 [deg/sec] velocity.
pa_odr_vel(ARM0, spd);                  Velocity alteration
```

Example: for Visual BASIC

```
Dim spd(6) As Single
Dim ret As Long

ret = pa_mod_jou(ARM0, JM_VSET)

spd(0) = 20.0 * PAI / 180.0
ret = pa_odr_vel(ARM0, spd(0))
```

In this control, after "pa_mod_jou" is issued, "pa_odr_vel" has to be issued every 1000msec. at maximum.

Reference

For further information, refer to "velocity control" in the section 6.6 and "(4) Redundant axis velocity control.)

(2) redundant axis parameter alteration

Here, operates the redundant axis control parameter.
(Axis value needed to be restricted is operated. In the case here, the S3-axis value for restriction data is operated.)

In this control, redundant axis control mode is automatically shifted to the S3-axis interpolation mode.

Example: for Visual C++

```
pa_mod_jou(ARM0, JM_SET); Shifts to the redundant axis parameter alteration

pa_odr_jou(ARM0, JM_RIGHT); Swings the redundant axis to the right
                    :
                    :
pa_odr_jou(ARM0, JM_HOLD); maintains the redundant axis position
```

Example: for Visual BASIC

```
Dim ret As Long

ret = pa_mod_jou(ARM0, JM_SET)

ret = pa_odr_jou(ARM0, JM_RIGHT)
                :
                :
ret = pa_odr_jou(ARM0, JM_HOLD)
```

(3) Redundant axis parameter reset

If resets, parameter value in the redundant axis control returns to the default value.
When the elbow position is strongly restricted, if resets, the elbow position get stable and might happen to slowly approach the arm moving range center.

If issues parameter reset, the redundant axis control mode is automatically shifted to the non restriction mode.

(4) S3-axis angle control

Method to shift the elbow without changing the tip position/orientation commanding S3-axis absolute angle [rad] - the "KEY" of the redundant axis (elbow) control.) It is interpolated with the provided angle command and S3-axis angle deviation using the S3-axis default velocity, and controlled.

In this S3-axis angle control, the redundant axis control mode is automatically shifted to the S3-axis interpolation mode.

Example: for Visual C++

```
float S3;

S3 = 80.0 * M_PI / (double)180.0;

pa_mov_jou(ARM0, S3, WM_WAIT);     Move the elbow until 80[deg]
                :
                :
pa_mov_xyz(ARM0, 0.0, 100.0, 0.0 WM_WAIT);
        S3-axis moves maintaining 80 [deg] angles in the S3-axis interpolation mode without
        changing modes.
```

Example: for Visual BASIC

```
Dim axsS3 As Single
Dim ret As Long

axsS3 = 80.0 * PAI / 180.0

ret = pa_mov_jou(ARM0, axsS3, WM_WAIT)
                :
                :
ret = pa_mov_XYZ0(ARM0, 0.0, 100.0, 0.0 WM_WAIT)
```

6. 6 Velocity Control

Velocity controls are as follows:

・Axis velocity control（ VS1, VS2, ･･･ VW2 ）
・Tip linear velocity（ Vx, Vy, Vz ）
・Tip rotational velocity（ Vyaw, Vpitch, Vroll ）
・Tip position/orientation velocity（ Vx, Vy, Vz ）,（ Vyaw, Vpitch, Vroll ）

・Redundant axis velocity control（ VS3 ）

⚠ CAUTION　Pay attention to initialize the velocity command value before entering the velocity control mode.

During the velocity control, from the entry to the end of the mode, the velocity command library (pa_odr_vel) has to be issued every time-out (set with "pa_set_tim".) The default value of the time-out is 1000 msec.

6. 6. 1 Axis Velocity Control

Choosing the control axis from S1 to W2, the velocity command (v) is provided.

Program Description:

① Sets time-out　: pa_set_tim
The default time-out is 1000 msec. This time can be issued only when it needs to be altered.

② Initializes velocity command: pa_odr_vel
All has to be set " 0 " using "spd[0]～spd[6]" located in "float spd[7]" inside "pa_odr_vel."

③ Chooses "motion axis = S1, W2" in the axis velocity control mode.　: pa_mod_vel
"VELMODE" in "pa_mod_vel" has to be set in "VM_ONE" (the axis velocity control mode).　Plural axes can be controlled simultaneously.

Remark

If this PA library is issued, only the control mode is changed.　The arm does not move.　ATTENTION! Within a set time-out, if the velocity command ("pa_odr_vel" and "pa_chk_cnt" can be used) is not issued until the velocity control termination, after issuing Pa library.　It causes a brake-stop, responding as if an accident occurred during control.

④ Input velocity command: pa_odr_vel
"spd[0]～spd[6]" located in "float spd[7]" inside "pa_odr_vel" is used.

S1 axis　―　rotates at 5[deg/sec]velocity.
W2 axis　―rotates at 10[deg/sec]velocity.

The velocity command value has to be designated with[rad/sec].

COVERS1	-1070	S1axis　Velocity Control　Angle exceeded
COVERS2	-1071	S2 axis　Velocity Control　Angle exceeded
COVERE1	-1073	E1 axis　Velocity Control　Angle exceeded
COVERE2	-1074	E2 axis　Velocity Control　Angle exceeded
COVERW1	-1075	W1 axis　Velocity Control　Angle exceeded
COVERW2	-1076	W2 axis　Velocity Control　Angle exceeded

⑤ Input velocity command:　pa_odr_vel
S1 axis　―　rotates at 10[deg/sec]velocity.
W2 axis　―rotates at 5[deg/sec]velocity.

⑥ Terminates velocity control: pa_sus_arm
This command terminates velocity control with a brake-stop (pa_stp_arm) or temporary-stop（pa_sus_arm).

Example: for Visual C++

```
float    spd[7];
              :
pa_set_tim(ARM0, 20);                    Time-out setting(200msec)
              :
for(i=0;i<7;i++)     spd[i] = 0.0;
pa_odr_vel(ARM0, spd);                   Velocity command initialization

pa_mod_vel(ARM0, VM_ONE, S1 | W2); M motion axis selection (S1 & W2-axis)
              :
From here to "pa_sus_arm," "pa_odr_vel" or "pa_chk_cnt"  has to be issued within 200
                                                                     msec cycle.
              :
spd[0] =  -5.0 * M_PI / (double)180.0;
spd[6] = -10.0 * M_PI / (double)180.0;
pa_odr_vel(ARM0, spd);                   Velocity command input

spd[0] = 10 * M_PI / (double)180.0;
spd[6] =  5 * M_PI / (double)180.0;
pa_odr_vel(ARM0, spd(0));                Velocity command input
              :
pa_sus_arm(ARM0, WM_WAIT);               Velocity control termination
```

Example: for Visual BASIC

```
Dim spd(6) As Single
Dim ret As Long

ret = pa_set_tim(ARM0, 20)

For i=0 To 6 Step 1
    spd(i) = 0.0
Next i
ret = pa_odr_vel(ARM0, spd(0))          Velocity command initialization

ret = pa_mod_vel(ARM0, VM_ONE, S1+W2)
        :
spd(0) =  -5 * PAI / 180.0
spd(6) = -10 * PAI / 180.0
ret = pa_odr_vel(ARM0, spd(0))
                          :
spd(0) = 10 * PAI / 180.0
spd(6) =  5 * PAI / 180.0
ret = pa_odr_vel(ARM0, spd(0))
ret = pa_sus_arm(ARM0, WM_WAIT)
```

6. 6. 2 *Tip linear velocity Control:*

In this control, tip linear motion velocity (Vx, Vy, Vz) on each coordinate axis, in the selected coordinates, is provided. The tip posture does not change.

For Visual C++

・Base coordinates tip linear velocity control : pa_mod_vel(ARM0, VM_XYZ, 0)

・Mechanical Interface coordinate tip linear velocity control

: pa_mod_vel(ARM0, VM_xyz, 0)

For Visual BASIC

・Base coordinates tip linear velocity control : pa_mod_vel(ARM0, VM_XYZ1, 0)

・Mechanical Interface coordinate tip linear velocity control

: pa_mod_vel(ARM0, VM_XYZ2, 0)

Program description:

① Sets time-out : pa_set_tim

The default time-out is 1000 msec. This time can be issued only when it needs to be altered.

② Initializes velocity command : pa_odr_vel

All has to be set " 0 " using "spd[0]～spd[3]" located in "float spd[7]" inside "pa_odr_vel."

③ Chooses the base coordinate linear velocity control mode. : pa_mod_vel

"VELMODE" in "pa_mod_vel" has to be set in "VM_XYZ*" (the base coordinate linear velocity).

Remark

If this PA library is issued, only the control mode is changed. The arm does not move. ATTENTION! Within a set time-out, if the velocity command ("pa_odr_vel" and "pa_chk_cnt" can be used) is not issued until the velocity control termination, after issuing Pa library. It causes a brake-stop, responding as if an accident occurred during control.

※ For Visual Basic, "VM_XYZ1" it has to be set.

④ Input command orders : pa_odr_vel

"spd[0]～spd[2]" located in "float spd[7]" inside "pa_odr_vel" Is used.

This order controls the tip position moving linearly at the velocity of X=10.0[mm/s], Y=-20.0[mm/s], Z=30.0[mm/s].

Velocity command values have to be set with [mm/sec].

⑤Input velocity command orders. : pa_odr_vel

This order controls the tip position moving linearly at the velocity of Y=-20.0[mm/s]. Velocity command values have to be set with [mm/sec].

⑥ Terminates a velocity control. : pa_sys_arm

This command terminates the velocity control with a brake-stop (pa_stp_arm) or temporary-stop (pa_sus_arm).

Reference

As this method is the RMRC control, regarding errors, refer to "RMRC control (6-axis arm)" in the section 6.4 and "RMRC control (7-axis arm)" in the section 6.5.

Example: for Visual C++

```
float     spd[7];
            :
pa_set_tim(ARM0, 20);                Time-out setting(200msec)

for(i=0;i<7;i++)    spd[i] = 0.0;
pa_odr_vel(ARM0, spd);               Velocity command initialization

pa_mod_vel(ARM0,VM_XYZ,0);           Velocity mode  Base position selection
            :
From here to "pa_sus_arm," "pa_odr_vel" or "pa_chk_cnt" has to be issued within 200 msec. cycle.
            :
spd[0] =   10.0;
spd[1] = -20.0;
spd[2] =   30.0;
pa_odr_vel(ARM0, spd);               Velocity command input
            :
spd[0] =    0.0;
spd[1] =   20.0;
spd[2] =    0.0;
pa_odr_vel(ARM0, spd);               Velocity command input
            :
pa_sus_arm(ARM0, WM_WAIT);           Velocity control termination
```

Example: for Visual BASIC

```
Dim spd(6) As Single
Dim ret As Long

ret = pa_set_tim(ARM0, 20)
For i=0 To 6 Step 1
     spd(i) = 0.0
Next i
ret = pa_odr_vel(ARM0, spd(0))               Velocity command initialization
ret = pa_mod_vel(ARM0,VM_XYZ1,0)
                    :
spd(0) =   10.0
spd(1) = -20.0
spd(2) =   30.0
ret = pa_odr_vel(ARM0, spd(0))
                    :
spd(0) =    0.0
spd(1) =   20.0
spd(2) =    0.0
ret = pa_odr_vel(ARM0, spd(0))
                    :
ret = pa_sus_arm(ARM0, WM_WAIT)
```

6. 6. 3 *Tip rotational velocity control:*

In this control, the tip linear motion velocity (Vyaw, Vpitch, Vroll) on each coordinate axis in the selected coordinates, is provided. The tip position does not change.

For Visual C++
- ･Base coordinates tip rotational velocity control：pa_mod_vel(ARM0, VM_YPR, 0)
- ･Mechanical Interface coordinate tip rotational velocity control
：pa_mod_vel(ARM0, VM_ypr, 0)

For Visual BASIC
- ･Base coordinates tip rotational velocity control：pa_mod_vel(ARM0, VM_YPR1, 0)
- ･Mechanical Interface coordinate tip rotational velocity control
：pa_mod_vel(ARM0, VM_YPR2, 0)

Program description:

① Sets time-out　：pa_set_tim
The default time-out is 1000 msec. This time can be issued only when it needs to be altered.

② Initializes velocity command：　pa_odr_vel
All has to be set “ 0 ” using “spd[0]～spd[3]” located in “float spd[7]” inside “pa_odr_vel.”

③ Chooses the base coordinate rotational velocity control mode.：　pa_mod_vel
“VELMODE” in “pa_mod_vel” has to be set in “VM_XPR*” (the base coordinate rotational velocity control mode).

Remark

If this PA library is issued, only the control mode is changed.　The arm does not move.　ATTENTION! Within a set time-out, if the velocity command (“pa_odr_vel” and “pa_chk_cnt” can be used) is not issued until the velocity control, termination, after issuing Pa library. It causes a brake-stop, responding as if an accident occurred during control.

※ For Visual Basic, “VM_YPR1” it has to be set.

④ Input command orders：　pa_odr_vel
“spd[0]～spd[2]” located in “float spd[7]” inside “pa_odr_vel” is used.
The tip position is, for instance, controlled to rotate on the Y-axis at the velocity of pitch=0.5[rad/s].　Velocity command values have to be set with [rad/sec].

⑤ Input velocity command orders.：　pa_odr_vel
The tip position is, for instance, controlled to rotate on the Y-axis at the velocity of pitch=1.0 [rad/s].　Velocity command values have to be set with [rad/sec].

⑥ Terminates a velocity control.：　pa_sus_arm
This command terminates the velocity control with a brake-stop (pa_stp_arm) or temporary-stop (pa_sus_arm).

Reference

As this method is the RMRC control, regarding errors, refer to “RMRC control (6-axis arm)” in the section 6.4 and “RMRC control (7-axis arm)” in the section 6.5.

Example: for Visual C++

```
float     spd[7];
pa_set_tim(ARM0, 20);                 Time-out setting(200msec)

for(i=0;i<7;i++)     spd[i] = 0.0;
pa_odr_vel(ARM0, spd);                Velocity command initialization

pa_mod_vel(ARM0,VM_YPR,0); Velocity mode  Base position/orientation selection
                :
From here to "pa_sus_arm," "pa_odr_vel" or "pa_chk_cnt" has to be issued within 200 msec. cycle.
                              :
spd[0] =   0.0;
spd[1] =    0.5;
spd[2] =   0.0;
pa_odr_vel(ARM0, spd);        Velocity command input
spd[0] =   0.0;
spd[1] =   1.0;
spd[2] =   0.0;
pa_odr_vel(ARM0, spd);        Velocity command input
                              :
pa_sus_arm(ARM0, WM_WAIT);            Velocity control termination
```

Example: for Visual BASIC

```
Dim spd(6) As Single
Dim ret As Long

ret = pa_set_tim(ARM0, 20)
For i=0 To 6 Step 1
      spd(i) = 0.0
Next i
ret = pa_odr_vel(ARM0, spd（0）)                    Velocity command initialization
ret = pa_mod_vel(ARM0,VM_YPR1,0)

spd(0) = 0.0
spd(1) = 0.5
spd(2) = 0.0
ret = pa_odr_vel(ARM0, spd(0))
spd(0) = 0.0
spd(1) = 1.0
spd(2) = 0.0
ret = pa_odr_vel(ARM0, spd(0))
                          :
ret = pa_sus_arm(ARM0, WM_WAIT)
```

6. 6. 4 Tip linear/rotational velocity control

In this control, tip linear motion velocity (Vx, Vy and Vz) and rotational velocity (Vyaw, Vpitch and Vroll) on each coordinate axis in the selected coordinates system are simultaneously provided.

for Visual C++

・Base coordinate system tip linear velocity control:

pa_mod_vel(ARM0, VM_XYZYPR, 0)

・Mechanical Interface coordinate tip linear/rotational velocity control:

pa_mod_vel(ARM0, VM_xyzypr, 0)

for Visual BASIC

・Base coordinate system tip linear velocity control:

pa_mod_vel(ARM0, VM_XYZYPR1, 0)

・Mechanical Interface coordinate tip linear/rotational velocity control:

pa_mod_vel(ARM0, VM_XYZYPR2, 0)

Program description:

① Sets time-out : pa_set_tim

The default time-out is 1000 msec. This time can be issued only when it needs to be altered.

② Initializes velocity command: pa_odr_vel

All has to be set " 0 " using "spd[0]～spd[5]" located in "float spd[7]" inside "pa_odr_vel."

③ Chooses the base coordinate linear motion/rotational velocity control mode.: pa_mod_vel

"VELMODE" in "pa_mod_vel" has to be set in "VM_XYZYPRI*" (the base coordinate linear motion/rotational velocity control mode).

Remark

If this PA library is issued, only the control mode is changed. The arm does not move. ATTENTION! Within a set time-out, if the velocity command ("pa_odr_vel" and "pa_chk_cnt" can be used) is not issued until the velocity control termination, after issuing Pa library. It causes a brake-stop, responding as if an accident occurred during control.

For Visual Basic, "VM_XYZYPRI" it has to be set.

④ Input a velocity command orders.: pa_odr_vel

"spd[0]～spd[5]" located in "float spd[7]" inside "pa_odr_vel" Is used.

The tip is controlled at the linear motion velocity: X=100.0[mm/s], Z=50.0[mm/s] and the rotation velocity: pitch=0.5[rad/s]. Velocity command values have to be set with [rad/sec].

⑤ Terminates a velocity control.: pa_sus_arm

This command terminates the velocity control with a brake-stop (pa_stp_arm) or temporary-stop (pa_sus_arm).

Reference

As this method is the RMRC control, regarding errors, refer to "RMRC control (6-axis arm)" in the section 6.4 and "RMRC control (7-axis arm)" in the section 6.5.

Example: for Visual C++

```
float    spd[7];

pa_set_tim(ARM0, 20);        Time-out setting(200msec)

for(i=0;i<7;i++)    spd[i] = 0.0;
pa_odr_vel(ARM0, spd);        Velocity command initialization

pa_mod_vel(ARM0,VM_XYZYPR,0);Velocity mode  Base position/orientation selection
        :
From here to "pa_sus_arm," "pa_odr_vel" or "pa_chk_cnt" has to be issued within 200 msec. cycle.
        :
spd[0] =   100.0;              Base coordinate system  toward X   [mm/s]
spd[2] =    50.0;                    〃                 toward Z    [mm/s]
spd[4] =     0.5;                    〃                 toward Pitch   [rad/s]
pa_odr_vel(ARM0, spd);                 Velocity command input
        :
pa_sus_arm(ARM0, WM_WAIT);             Velocity control termination
```

Example: for Visual BASIC

```
Dim spd(6) As Single

ret = pa_set_tim(ARM0, 20)
For i=0 To 6 Step 1
    spd(i) = 0.0
Next i
ret = pa_odr_vel(ARM0, spd(0))                 Velocity command initialization

ret = pa_mod_vel(ARM0,VM_XYZYPR1,0)
        :
spd(0) =   100.0
spd(2) =    50.0
spd(4) =     0.5
ret = pa_odr_vel(ARM0, spd(0))
        :
ret = pa_sus_arm(ARM0, WM_WAIT)
```

6. 6. 5 Redundant axis velocity control

7-axis arm function

The S3-axis rotation velocity (Vs3) is provided for the S3-axis. At this moment, the tip position/orientation does not change.

Program description:

① Sets time-out :pa_set_tim

The default time-out is 1000msec. This time can be issued only when it needs to be altered.

② Initializes velocity command: pa_odr_vel

In the case of the redundant axis velocity control, only "spd[0]" in "float spd[7]" can be used and has to be set " 0. "

③ Chooses the control axis in the redundant axis velocity control mode.: pa_mod_jou

"VELMODE" in "pa_mod_vel" has to be set in "VM_XPR*"

Remark

If this PA library is issued, only the control mode is changed. The arm does not move. ATTENTION! Within a set time-out, if the velocity command ("pa_odr_vel" and "pa_chk_cnt" can be used) is not issued until the velocity control termination, after issuing Pa library. It causes a brake-stop, responding as if an accident occurred during control.

④ Input command orders : pa_odr_vel

For the redundant axis velocity control, only "spd[0]" in "float spd[7]" can be used. Without changing the tip position/orientation, the redundant axis is controlled at -5 [deg/sec] (S3-axis motion velocity).

Velocity command values have to be set with [rad/sec].

⑤ Input velocity command orders. : pa_odr_vel

Without changing the tip position/orientation, the redundant axis is controlled at 30 [deg/sec] (S3-axis motion velocity).

⑥ Terminates a velocity control. : pa_sus_arm

This command terminates the velocity control with a brake-stop (pa_stp_arm) or temporary-stop (pa_sus_arm).

Example: for Visual C++

```
float    spd[7];
            :
pa_set_tim(ARM0, 20);              Time-out setting(200msec)

for(i=0;i<7;i++)    spd[i] = 0.0;
pa_odr_vel(ARM0, spd);             Velocity command initialization

pa_mod_jou(ARM0, JM_VSET);   Redundant axis velocity control mode selection
            :
   From here to "pa_sus_arm," "pa_odr_vel" or "pa_chk_cnt" has to be issued within 200
   msec. cycle.
            :
            :
spd[0] = -5.0 * M_PI / (double)180.0;
pa_odr_vel(ARM0, spd);                       Velocity command input
            :
spd[0] = 30.0 * M_PI / (double)180.0;
pa_odr_vel(ARM0, spd);                       Velocity command input
            :
pa_sus_arm(ARM0, WM_WAIT);                   Velocity command termination
```

Example: for Visual BASIC

```
Dim ret As Long
Dim spd(6) As Single

ret = pa_set_tim(ARM0, 20)
For i=0 To 6 Step 1
    spd(i) = 0.0
Next i
ret = pa_odr_vel(ARM0, spd(0))               Velocity command initialization

ret = pa_mod_jou(ARM0, JM_VSET)
            :
spd(0) = -5.0 * PAI / 180.0
ret = pa_odr_vel(ARM0, spd(0))
            :
spd(0) = 30.0 * PAI / 180.0
ret = pa_odr_vel(ARM0, spd(0))

ret = pa_sus_arm(ARM0, WM_WAIT)
```

6. 7 Direct Control …. Optional function

This mode is to control playback performance reviving memorized each axis data, as teach data, when in a manual operation. If "pa_chk_cnt" is not issued every 1000 msec. (time-out) during direct control, it is recognized as malfunction. The brake stops the operation.

Program Description:

① Sets time-out. : pa_set_tim

The default time-out is 1000 msec. This time can be issued only when itneeds to be altered.

② Switchs to the direct control. : pa_mod_dir

DM_START : It becomes at servo-stop status

③ Chooses the axis to be controlled, starts the self weight compensated control : pa_wet_ded

For the control axis selection, choose the axis of pa_wet_ded, then, use macro-definitions below:

For the 6-axis, it is: "**LOCKAXIS_S3 : S1 | S2 | E1 | E2 | W1 | W2.**"

In the case of Visual BASIC:

LOCKAXIS_S3 : S1＋S2＋E1＋E2＋W1＋W2

The default is: LOCKAXIS_S3.

Remark

After issuing this library, if "pa_chk_cnt" is not issued every 1000 msec. (time-out), it is recognized as malfunction. The brake stops the operation.

If axis angle limit is exceeded during direct control, the following errors occur and the brake stops the operation. The direct control is automatically terminated.

DOVERS1	-2030	Direct control S1 axis angle exceeded
DOVERS2	-2031	Direct control S2 axis angle exceeded
DOVERS3	-2032	Direct control S3 axis angle exceeded
DOVERE1	-2033	Direct control E1 axis angle exceeded
DOVERE2	-2034	Direct control E2 axis angle exceeded
DOVERW1	-2035	Direct control W1 axis angle exceeded
DOVERW2	-2036	Direct control W2 axis angle exceeded

④ Terminate the direct control. : pa_mod_dir

DM_STOP: It terminates the direct control.

Example: for Visual C++

```
            :
    pa_set_tim(ARM0, 20);                  Time-out setting(200msec)

    pa_mod_dir(ARM0, DM_START);            Direct control mode selection
    pa_wet_ded(ARM0, LOCKAXIS_S3);         Control axis selection
            :
    (The arm, except S3-axis, is operated with a self weight compensated control.
      The arm is manually operated.  Acquires PTP data.
       In the meantime, "pa_chk_cnt" has to be issued less than every 200msec.
            :
    pa_mod_dir(ARM0, DM_STOP);             terminates the direct control.
```

Example: for Visual C++

```
    Dim ret As Long

    ret = pa_set_tim(ARM0, 20)
    ret = pa_mod_dir(ARM0, DM_START)
    ret = pa_wet_ded(ARM0, LOCKAXIS_S3)
            :
            :
    ret = pa_mod_dir(ARM0, DM_STOP)
```

6. 8 Real-time Control

This control is for complex applications. As it is explained below, if the tip position/ orientation and each axis angle in every control cycle are provided, the arm performs exactly as it is mentioned. With this method, interpolation and coordinate conversion, not used in the motion control section, can be freely employed in the operation control section.

Remark

In a real-time control, if PA library (pa_odr_axs or pa_odr_dpd), providing command value every 1000msec (time-out) maximum, is not issued, the brake stops the operation as if an accident occurred during control. The default time-out is 1000 msec. This time can be set with "pa_set_tim" when it is needed.

There are two real control modes as follows:

・**Axis real-time control mode**・・・controls arm providing axis target angle more than 2msec cycle without interpolation.

・**RMRC real-time control mode**・・・controls arm providing T-matrix indicating the target tip position/orientation in every cycle (more than 2msec.) and axis value for restriction data without interpolation.

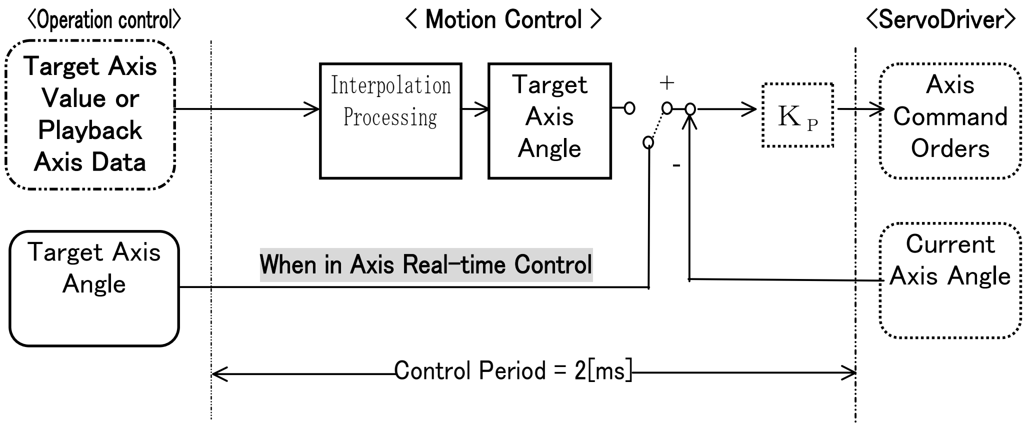
Taking into account the limit value to, to maintain motion, the providing value cannot exceed the control cycle (2msec) of the motion control CPU.

	Limit value	Maximum command value
Tip position	1000 mm/sec	2 mm/ 2 msec
Tip orientation	0.785 rad/sec	0.00157 rad/ 2 msec
Axis velocity (each axis has a different value)		
S1 axis S2 axis	1.0 rad/sec	0.002 rad/ 2msec
S3 axis W1 axis	2.0 rad/sec	0.004 rad/ 2msec
E2 axis W1 axis W2 axis	6.28 rad/sec	0.01256 rad/ 2msec

6. 8. 1 Axis Real-time Control Mode

If the target axis value is issued as the command, every 2msec or more cycles, the axis angle (feedback) control is performed without interpolation.

Axis Real-time Control Mode



Program description:

① Sets the time-out. :pa_set_tim

The default time-out is 1000 msec. This time can be issued only when it needs to be altered.

② Designates the current angle to the target angle. :pa_odr_axs

Sets the target angle acquiring current target angle or current angle.
If the target angle is beyond the limit, errors below occur and the brake automatically stops the arm.

③ Sets the axis real-time control mode. :pa_mod_axs

It shifts to the real axis control mode. After this PA library is issued, until terminating axis real-time control mode, the command (pa_odr_axs or pa_chk_cnt) has to be issued within time-out.

If it is longer than time-out, an error occurs and the brake stops the operation as if an accident happened during control.

④ Designates the target axis angle. :pa_odr_axs

As it becomes the 2msec cycle target value, the command should be taken into account the axis limit angle. If the target axis angle is beyond the limit, the following errors occur and the brake might, automatically, stop the arm.

ERR_SYNC_S1	S1-axis sychronization error in axis control
ERR_SYNC_S2	S2
:	:
ERR_SYNC_W2	W2

④ terminates the axis real-time control mode.

The axis real-time control mode is terminated by the brake-stop (pa_stp_arm) or the temporary stop (pa_sus_arm).

Example: for Visual C++

```
ANGLE an;

pa_set_tim(ARM0, 20);        Time-out setting (200msec)

pa_get_agl(ARM0,&an);                  Current angle acquisition
pa_odr_axs(ARM0, &an);       Target initial axis angle setting

pa_mod_axs(ARM0);                      Axis real-time control mode selection
                    :
   From here to "pa_sus_arm," "pa_odr_axs" or "pa_chk_cnt" has to be issued within
   200 msec. cycle.
                    :
while (Conditional text){
                  :
    an.s1 = ...
    an.s2 = ...
    an.s3 = ...                  Creates a target axis angle here.
    an.e1 = ...
    an.e2 = ...
    an.w1 = ...
    an.w2 = ...
     pa_odr_axs(ARM0, &an);             Target axis angle setting
 }
pa_sus_arm(ARM0, WM_WAIT);   Axis angle real-time control mode termination
```

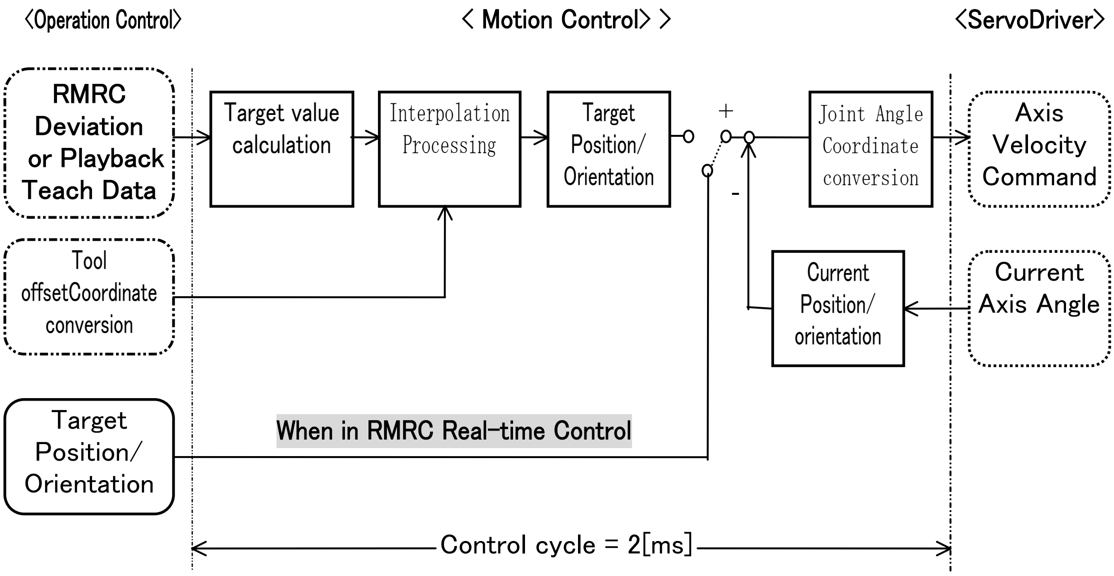
Example: for Visual BASIC

```
Dim ret As Long
Dim an As ANGLE

ret = pa_set_tim(ARM0, 20)
ret = pa_get_agl(ARM0, an)             Current angle acquisition
ret = pa_odr_axs(ARM0, an)             Target initial axis angle setting
ret = pa_mod_axs(ARM0)
            :
Do While Conditional text
            :
   an.s1 = ...
   an.s2 = ...
   an.s3 = ...
   an.e1 = ...
   an.e2 = ...
   an.w1 = ...
   an.w2 = ...
   ret = pa_odr_axs(ARM0, an)
Loop
ret = pa_sus_arm(ARM0, WM_WAIT)
```

6. 8. 2 RMRC Real-time Control Mode

Providing each axis value for restriction data and T-matrix indicating the target position/ orientation every 2msec or more cycles, the axis angle (feedback) control is performed without interpolation.

RMRC Axis Real-time Control Mode:

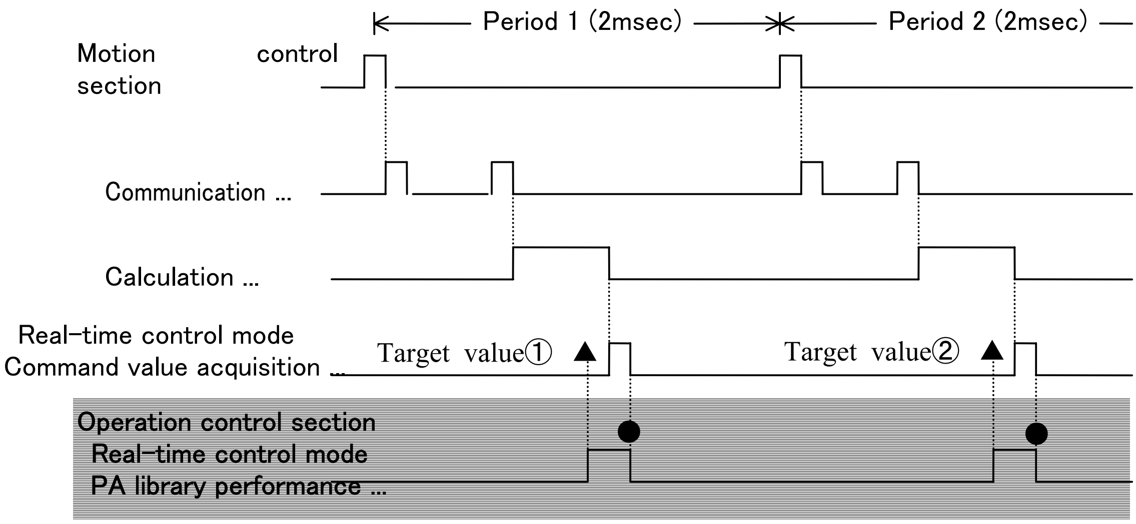


Remark

The advantage of this real-time control mode is to receive a 2 msec command. To send this command every 2 msec, it is needed to take into account the timing when the PA library (pa_odr_axs、pa_odr_dpd) is issued and when the motion control section should obtain the PA library.

Current timings are as follows:

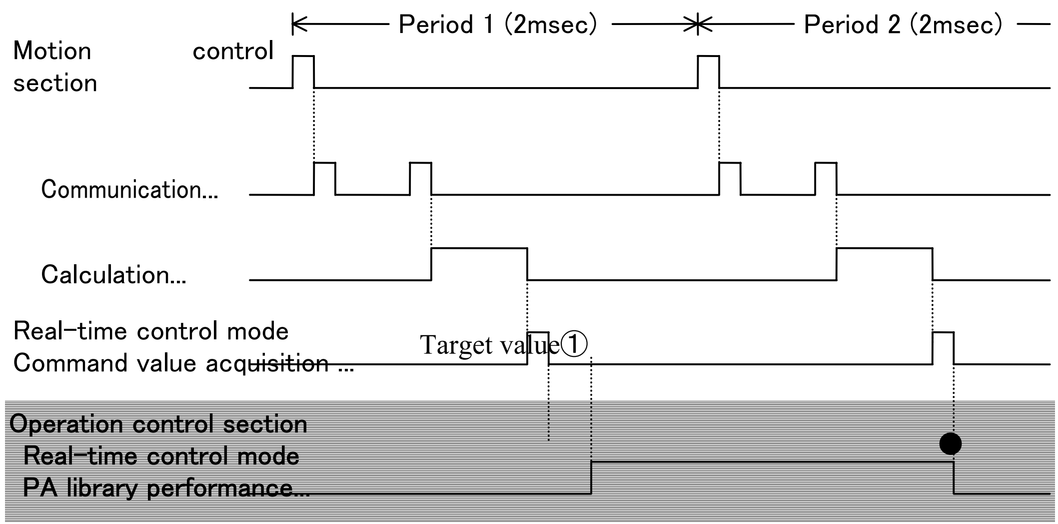
① When PA library is issued just before the calculation in motion control section is completed.



▲ : PA library issuing
● : Release from issued PA library

With this processing, the motion control section acquires the target value. When "count-up" is on time in the final processing (count-up data is reflected on the memory in the final processing.) , with this " ● " timing PA library is released from "count-up-wait." The target value ① acquired at this moment is reflected on the control in the period 2.

② When PA library is issued just after the calculation in motion control section is completed.



▲ : PA library issuing
● : Release from PA library issuing

As target value ① acquisition is completed at this ● timing in the period 2 and reflected on the control, count-up can be confirmed in the PA library, only after final processing is completed.in the cycle 2.

Program Description: *for 6-axis arm*

① Sets the time-out. : pa_set_tim

The default time-out is 1000 msec. This time can be issued only when it needs to be altered.

② Controls to the RMRC controllable position/orientation (each axis angl).: pa_exe_saf

③ Initializes the target position/orientation.: pa_odr_dpd

If there is not a current target position/orientation, loads and sets the current ones.

④ Sets the RMRC real-time control mode.: pa_mod_dpd

Here comes the RMRC real-time control mode.

After issuing this PA library, until the RMRC real-time control mode is completed, the command (pa_odr_dpd or pa_chk_cnt) has to be issued.

⑤ Designates the target tip position/orientation: pa_odr_dpd

For the target value is 2msec cycle, commands should be taken into account the RMRC limit velocity (both position and orientation).

ERR_RMRC_X	X-axis synchronization error in RMRC control
ERR_RMRC_Y	Y-axis synchronization error in RMRC control
ERR_RMRC_Z	Z-axis synchronization error in RMRC control

⑥ Terminates the RMRC real-time control mode.

The RMRC real-time control mode is terminated by the brake-stop (pa_stp_arm) or the temporary stop (pa_sus_arm).

Example: for Visual C++

```
MATRIX mat;
ANGLE an;

pa_set_tim(ARM0, 20);              Time-out setting (200msec)

pa_exe_saf(ARM0, WM_WAIT);         Moves to safe orientation

an.s1=0.0;                         Restricted axis value intialization
          :                  (Initialize "an" to "0" in the case of the 6-axis)
pa_get_noa(ARM0, mat);             Current position/orientation loading
pa_odr_dpd(ARM0, mat, &an);        Target position/orientation initialization
pa_mod_dpd(ARM0);                  RMRC real-time control mode selection
                    :
   From here to "pa_sus_arm," "pa_odr_axs" or "pa_chk_cnt" has to be issued within
   200 msec. cycle.
                    :
while (Conditional text){
                    :
   Target position/orientation T-matrix creation      :mat
   "0" initialization or
   creation of axis value for the redundant axis restriction data  :an
                    :
   pa_odr_dpd(ARM0, mat, &an);
         Setting for Target position/orientation T-matrix and axis value for the
         restriction data
}
pa_sus_arm(ARM0, WM_WAIT);      RMRC real-time control mode termination
```

Example: for Visual BASIC

```
Dim mat(3,2) As Single
Dim an As ANGLE
Dim ret As Long

ret = pa_set_tim(ARM0, 20)
ret = pa_exe_saf(ARM0, WM_WAIT)

ret = pa_get_noa(ARM0, mat(0,0))
ret = pa_odr_dpd(ARM0, mat(0,0), an)   Target position/orientation initialization
          :                 (Initialize "an" to "0" in the case of the 6-axis)
ret = pa_mod_dpd(ARM0)
          :
Do While  (Conditional text){
          :
   ret = pa_odr_dpd(ARM0, mat(0,0), an)
Loop
ret = pa_sus_arm(ARM0, WM_WAIT)
```

7- axis arm function

The redundant axis control mode can be chosen on account of RMRC control. But, depending on a redundant axis control mode to choose, each axis value for the restriction data
– a parameter of "pa_odr_dpd" – has a different significance.

＜Redundant axis control mode＞

[No restriction]　: For all axes restrictively controlled by 0.0[deg], a provided axis value for the restriction data is ignored.

[All axes restriction]　: All axes are restrictively controlled by a provided axis values for the restriction data.

[S3-axis restriction] : In this mode, axis value means the one for the restriction data when "pa_odr_dpd" is issued. The S3-axis is controlled by a S3 restriction axis value inside the axis values for restriction data. For this reason, a movable angle issued within a cycle has to be taken into account. Other axis values (except S3 axis value) for restriction data are ignored and restricted to 0.0[deg].

[S3-axis interpolation] : In this mode, axis value means the target angle of S3-axis when "pa_odr_dpd" is issued. The S3-axis is controlled by a S3 restriction axis value inside the axis values for restriction data. For this reason, a movable angle issued within a cycle has to be taken into account. Other axis values (except S3 axis value) for restriction data are ignored.

[S3-axis fixation] : S3 axis angle is maintained as it is when RMRC real-time control was started. For this reason, provided axis value for the restriction data is ignored.

Program Description:　　　　*For 7-axis arm*

① Sets the time-out.　　: pa_set_tim

The default time-out is 1000 msec. This time can be issued only when it needs to be altered.

② Controls to the RMRC controllable position/orientation (each axis angl). : pa_exe_saf

③ Initializes the target position/orientation. :　pa_odr_dpd

If there is not a current target position/orientation, loads and sets the current ones.

④ Chooses the redundant axis control mode. :　pa_mod_jou

If not setting this mode, the prior set redundant axis control mode becomes available.

⑤ Sets the RMRC real-time control mode. :　pa_mod_dpd

Here comes the RMRC real-time control mode.

After issuing this PA library, until the RMRC real-time control mode is completed, the command (pa_odr_dpd or pa_chk_cnt) has to be issued within time-out.

⑥ Designates the target tip position/orientation.: pa_odr_dpd

As the target value becomes 2msec cycle, commands should be taken into account RMRC limit velocity (both Linear and rotational velocity). If the target axis angle comes off- limits, following errors occur and the brake, might automatically stop arm.

ERR_RMRC_X　X-axis synchronization error in RMRC control
ERR_RMRC_Y　Y-axis synchronization error in RMRC control
ERR_RMRC_Z　Z-axis synchronization error in RMRC control

⑦ Terminates the axis real-time control mode.

The axis real-time control mode is terminated by the brake-stop (pa_stp_arm) or a temporary stop (pa_sus_arm).

Example: for Visual C++

```
    MATRIX mat;
    ANGLE an;

    pa_set_tim(ARM0, 20);          Time-out setting (200msec)

    pa_exe_saf(ARM0, WM_WAIT);             Move to safe orientation

    pa_get_agl(ARM0,&an);                  Current angle loading
    pa_get_noa(ARM0, mat);         Current position/orientation loading
    pa_odr_dpd(ARM0, mat, &an); Target position/orientation initialization

  pa_mod_jou(ARM0, JM_ON);Redundant axis control mode setting (all axes restriction)

    pa_mod_dpd(ARM0);              RMRC real-time control mode selection
                      :
        From here to “pa_sus_arm,” “pa_odr_axs” or “pa_chk_cnt” one has to be issued
        within 200 msec. cycle.    。
                      :
    while (Conditional text){
            Target position/orientation T-matrix creation        :mat
            Creation of axis value for the redundant axis restriction data  :an
                      :
            pa_odr_dpd(ARM0, mat, &an);
                  Setting for Target position/orientation T-matrix and
                  axis value for the restriction data
    }
    pa_sus_arm(ARM0, WM_WAIT);      RMRC real-time control mode termination
```

Example: for Visual BASIC

```
Dim mat(3,2) As Single
Dim an As ANGLE
Dim ret As Long

ret = pa_set_tim(ARM0, 20)

ret = pa_exe_saf(ARM0, WM_WAIT)

ret = pa_get_noa(ARM0, mat(0,0))
ret = pa_get_agl(ARM0, an)
ret = pa_odr_dpd(ARM0, mat(0,0), an)   Target position/orientation initialization
            :
ret = pa_mod_jou(ARM0, JM_ON)

ret = pa_mod_dpd(ARM0)
            :
Do While   Conditional sentence
            :
    ret = pa_odr_dpd(ARM0, mat(0,0), an)
Loop
ret = pa_sus_arm(ARM0, WM_WAIT)
```

6. 9 DIO control

The Digital Input/Output (DI/O) board is equipped as the standard system for PA. The PA library is provided only for the DI/O control of this board. Channel numbers are as follows:

The Digital Input/Output (DI/O) board is directly controlled by the motion control section. Its input/output control can be performed by setting data in the designated area, from the operation control section.

Port No.	channel No.	
DP_PORT1	DC_CH1 DC_CH2 DC_CH3 DC_CH4 DC_CH5 DC_CH6 DC_CH7 DC_CH8	System Reservation
DP_PORT2	DC_CH1 DC_CH2 DC_CH3 DC_CH4 DC_CH5 DC_CH6 DC_CH7 DC_CH8	Tool 1
DP_PORT3	DC_CH1 DC_CH2 DC_CH3 DC_CH4 DC_CH5 DC_CH6 DC_CH7 DC_CH8	Tool 2
DP_PORT4	DC_CH1 DC_CH2 DC_CH3 DC_CH4 DC_CH5 DC_CH6 DC_CH7 DC_CH8	Tool 3

Input/output libraries are as follows:

pa_inp_dio	Digital input (Input with 32 ch.units)
pa_oup_dio	Digital output (Output with 32 ch.units)
pa_get_dio	Digital input (Input with 1 ch.unit)
pa_set_dio	Digital output (Sets with 1 ch.unit)
pa_rst_dio	Digital output (Resets with 1 ch.unit)

Program description:

Example: for Visual C++

```
The output channel 4 of tool1 (port 1) has to be switched ON.
When the input channel 3 turns ON, channel 4 has to be OFF.

UBYTE   io;

pa_set_dio(ARM0, DP_PORT1, DC_CH4);
while(1){
        pa_get_dio(ARM0, DP_PORT1, DC_CH3, &io);
         if(io<>0)     break;
}
pa_rst_dio(ARM0, DP_PORT1, DC_CH4);
```

Example: for Visual BASIC

```
Dim io As Byte
Dim ret As Long

io = 0
ret = pa_set_dio(ARM0, DP_PORT1, DC_CH4)
Do While io = 0
        ret = pa_get_dio(ARM0, DP_PORT1, DC_CH3, io)
Loop

ret = pa_rst_dio(ARM0, DP_PORT1, DC_CH4);
```

《Playback control teach point "DO" status selection》

Setting "DO" data attribution at the teaching point, this can be performed by choosing its DO information (valid/invalid) or (stop/non-stop) when the arm is stopped.

Setting & acquisition of teach point "DO" output – valid/invalid – while in playback control.

```
pa_swt_dio(ARM armno, long sw)
pa_get_pdo(ARM armno, long* stat)
```

Choose to make valid (output) or invalid (no output) for DO data attribution set at teach point, while in playback control.

Setting & acquisition of teach point "DO" output – valid/invalid – when the arm is stopped while in playback control.

```
pa_set_dlc(ARM armno, long data)
pa_get_dlc(ARM armno, long* stat)
```

The pre-condition is: the teach point DO output in the playback control, has to be set to be valid. When DO information is output while in playback control, if the arm is temporarily stopped or brake-stop, choose to stop output DO information or continue.

Program description:

Example: for Visual C++

While in playback control, make teach point DO information valid. When an arm is not in motion, stop DO output.

```
DIOSTATUS    dis, dio;

pa_swt_dio(ARM0, 1);        Teach point DO information available
pa_set_dlc(ARM0, 1);        When in arm-stop, DO-stop available.
```

Example: for Visual BASIC

```
Dim dis As DIOSTATUS
Dim dio As DIOSTATUS
Dim ret As Long

ret = pa_swt_dio(ARM0, 1)
ret = pa_set_dlc(ARM0, 1)
```

6. 10 Teach/Playback Motion

Playback motion is performed using teach data acquired in various control conditions. To perform playback motion it usually needs the following four step procedures.

・*1st….Teach data creation*

Acquires teach points and creates a set.

・*2nd….Current teach point shifting*

The moment when teach point is acquired, it instantly becomes the current point. For this reason, the teach point where intended to start the motion, has to be shifted to the current teach point.

・*3rd….Shiftin g to the current point*

Actuates arm to the position (angle) indicated at the current point.

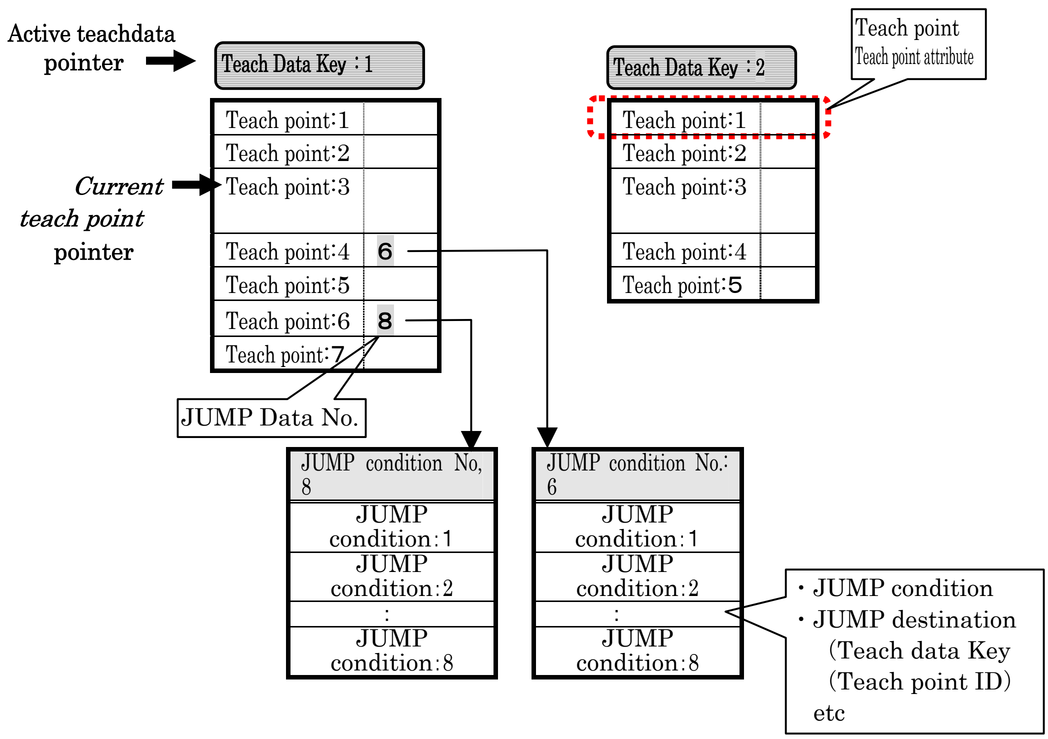
・*4th….Playback starts*

Starts the playback motion.

To acquire teach data and actualize playback motion (replay), all data and information are managed by the motion control program.
Before starting the control method, see important terms below:

Technical Terms

Terms	Explanation
Teach point	Minimum data unit retaining arm angles and motion data, etc.
Teach data	Work unit to set to work one operation linking plural teach data.
Teach data Key	Integer that never overlaps, provided to distinguish plural teach data.
Active teach data	Teach data to operate playback and edition (addition, insertion, deletion and data alteration).
Teach point attribute	Significant data in teach point.
JUMP	Method to actuate arm through plural data as if the motion were created through one teach data.
JUMP data	Teach data attribution information to perform JUMP motion between teach data.
JUMP data number	Integer that never overlaps, set to control plural JUMP data. It is also set as attribute in the teach point to be referred when in playback.
JUMP condition	Command group to be set to actualize JUMP.



6. 10. 1 Teach Point & Teach Data Control

How to manage teach data in the teach data structure and the motion control program:

(1) Teach point attribute

The teach point is the minimum unit of arm data needed to perform playback processing. Its attributes are shown below. Teach point data is initialized with appropriate value when teach points. are created. Then, it is processed and corrected by users.

Teach point attribute : Structure PNTDAT

Structure	Model	Name	Contents
PLAY	float	S1 angle	S1 axis angle [rad]
	float	S2 angle	S2 axis angle [rad]
	float	S3 angle	S3 axis angle [rad]
	float	E1 angle	E1 axis angle [rad]
	float	E2 angle	E2 axis angle [rad]
	float	W1 angle	W1 axis angle [rad]
	float	W2 angle	W2 axis angle [rad]
	float	Linear motion velocity	Linear motion velocity [mm/sec]
	float	Orientation、angle Motion velocity	Angular motion velocity when in axis control, orientation velocity when in RMRC control [rad/sec]
	long	Data type	PTP：1、PTP(with NOA)：2
	long	Interpolation method	Axis, linear, circle, arc
	long	Velocity type	Rated velocity, acceleration, deceleration, acceleration/deceleration
	long	Waiting hour	Motion-start delay time [msec]
	long	Serial numbers	Serial numbers setting the primary teach point as 1.
	long	ID number	User setting discrimination number
	long	JUMP data Number	Numbers specified JUMP conditions
	long	DO output	Digital output for outer operation
	long	Accuracy	Arm-stop accuracy *2
	long	Start-up time	Acceleration time designation *3
	long	Shutdown time	Deceleration time designation *3
	long	Spare	Not yet used
	char*32	comment	Comment with muximum 32 letters
NOAP	float*3	Position *1	Arm XYZcoordinate system [mm]
	float*3*3	Orientation *1	Arm NOA

*1 Position and orientation data are created, only, when data type is PTP (with NOA).

*2 On arm-stop accuracy, lower 16bit for axis motion attribution teach point and for upper_16bit motion attribution teach point, are used.

*3 If velocity type is acceleration & deceleration/acceleration/deceleration, each type refers to a necessary start-up and shut-down time attributions. If this attribute is “0”, start-up time and shut-down time in parameter are used.

Teach data types are as follows:

- Each axis ($\theta_{S1} \sim \theta_{W2}$) data
- Tip position/orientation (NOAP) data

(2) JUMP Data

JUMP data is the annexed information related to the teach point. It has attributes such as JUMP condition and JUMP destination, etc.

JUMP information numbers in the teach point attribute are referred when in playback. If its value is more than 1, JUMP condition search is performed. If the JUMP condition can be found, then, condition check will be performed.

When the condition is established, JUMP destination (teach data "Key" and teach point ID) indicated in JUMP condition is searched. If its destination is found, the interval from the current teach point to the discovered one is interpolated and motion starts. This status is called motion between teach points (RMRC) or motion between teach points (each axis).)

If motion between teach points is completed, the active teach data is replaced by the arrived teach data "Key." Hereafter, motion is controlled by its teach data.

JUMP condition data composition is as follows:

JUMP conditional data composition

Structure	Type	Designations	Details
	long	JUMP condition Number	Numbers designating JUMP conditions
JUDGE	long	JUMP condition	**JUMPcondition (refer to the next page (5))**
	long	Spare	Not used
	long	DI data	DI data for condition appraisal
	long	Time-out	Time-out when in wait No time-out with 0
	long	Teach data Key	JUMP destination teach data Key
	long	Teach point ID	JUMP destination teach point ID
	long	Reservation	Employed by a system
	Omitted. (There are 8 (eight) data from JUMP condition to the reservation.)		
JUDGE	long	JUMP condition	**JUMPcondition (refer to the next page (5))**
	long	Spare	Not yet used
	long	DI data	DI data for condition appraisal
	long	Time-out	Time-out when in wait No time-out with 0
	long	Teach data "Key"	JUMP destination teach data "Key"
	long	Teach point ID	JUMP destination teach point ID
	long	Reservation	Employed by a system

(3) JUMP Condition

JUMP condition divides 32bit positive numbers into four and gives them significance.

MSB
LSB

31 24	23 16	15 8	7 0
Valid flag	JUMP command	Logic	Reference destination DI

JUMP condition consists of four: valid flag, JUMP command, logic and reference destination DI. See below: these instructions are not automatically set at the motion control side. All are performed by setting orders from the upper point.

VALID FLAG : JUMPENABLEDISABLE

Designation	Value	Function
JMP_ON	0x01000000	Condition check performance (valid)
JMP_OFF	0x00000000	No condition check performance (invalid)

JUMP COMMAND : JUMPORDER

Designation	Value	Function
NO_JUMP	0x00010000	JUMP to the designated teach data and ID number. (Unconditional JUMP)
DI_JUMP	0x00020000	If DI condition is checked and established, JUMP. If not, playback has to be continued.
DI_WAITJUMP	0x00030000	If DI condition is checked and established, JUMP. If not, waits and rechecks at the next cycle.
DI_WAIT	0x00040000	Waits until DI condition is checked and established. (ATTENTION! This function does not perform the motion between teach points JUMP.)

LOGIC : JUMPDILOGIC

Designation	Value	Function
LEVEL_ON	0x00000100	DI condition is established when designated bit input is 1.
LEVEL_OFF	0x00000200	DI condition is established when designated bit input is 0.
EDGE_ON	0x00000400	DI condition is established when designated bit input is changed from 0 to 1.
EDGE_OFF	0x00000800	DI condition is established when designated bit input is changed from 1 to 0.

REFFERENCE DI : DIOKIND

Designation	Value	Function
DIO_INTERNAL	0x00000000	DI condition test is performed in the system DI.
DIO_EXTERNAL	0x00000001	DI condition test is performed in the extension DI.

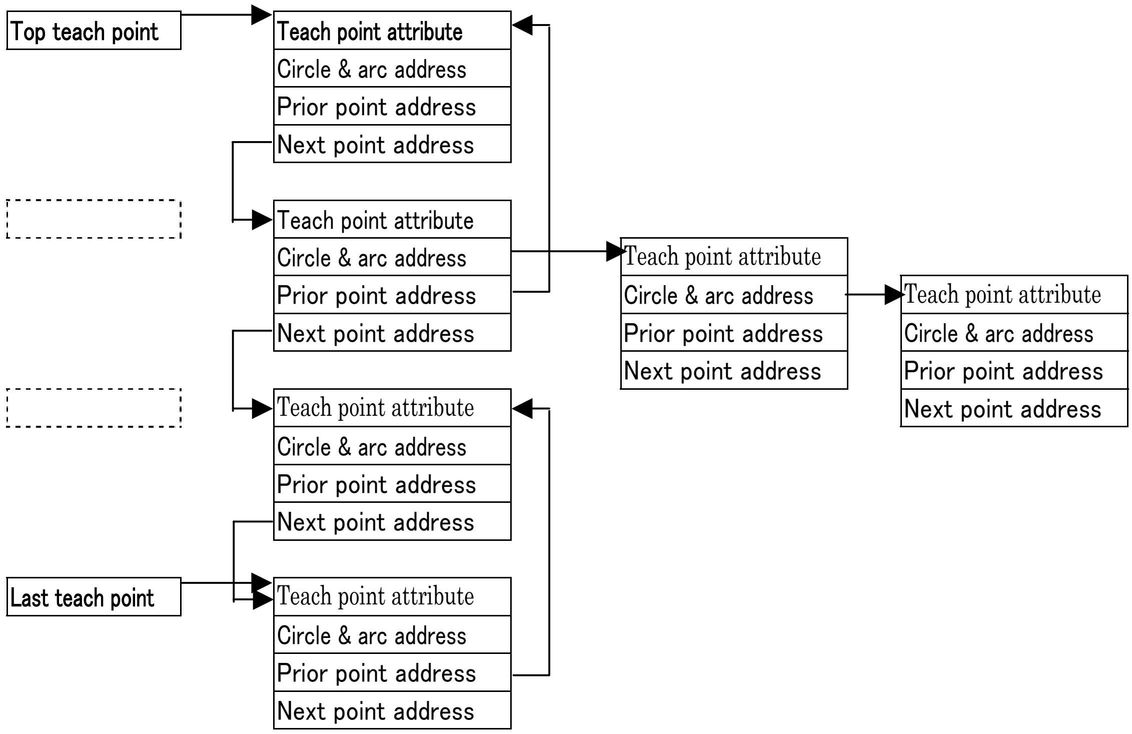
One teach data can obtain plural JUMP conditions. But, one JUMP condition cannot be obtained by plural teach data. For this reason, the same JUMP condition number 1 of two different teach data “Key” is recognized as a completely different one.

(4) Teach Point Control

How to control teach data in the motion control program:

One teach data consists of plural teach points. Here it is shown how each point composes teach data.

- Teach data consists of six teach points.
- Three of these points have circle or arc attribute.



Remark

Teach data control provides address data of before/after teach point to create smooth motion between points. On this address data, for top teach point, the prior point address is 0. For the last teach point, the next point address is 0.

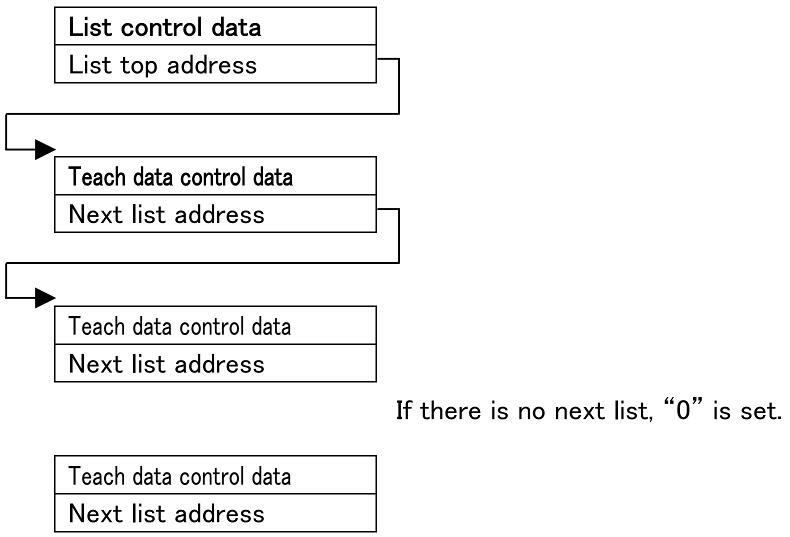
On circle and arc, to pass through the second and third teach point, these are linked adjacent to the first point.

The current teach point can be set at the top and the last teach point, or at the place indicated with [dashed box].

(For this reason, the circle and arc second and third point cannot be the current point.)

(5) Teach Data Control

Plural teach data is controlled by "teach data control list" as follows:



Teach data numbers, able to be controlled by teach data control list, are not particularly defined.　As far as memory space allows, plural teach data can be created.

List control data:

DATA	DETAILS
Numbers of teach data	Indicates how many teach data (not teach point) is controlled
Active teach data (ARM 0)	Teach data related to ARM 0 motion.*
Active teach data (ARM 1)	Teach data related to ARM 1 motion.*

*In active teach data, the same teach data can be obtained by ARM 0 and ARM 1.

Teach data control data:

DATA	DETAILS
Teach data "Key"	The control number for teach data manages not to let each teach data overlap.
Numbers of teach data	Numbers of teach point retained by this teach data.
Top teach point	Teach point indicating the top position in the teach data.
Last teach point	Teach point indicating the last position in the teach data.
Current teach point	Teach point indicated currently by the program in the teach data.
Temporary teach point	Supplemental area used for teach data research, etc.
JUMP data control address	It is the top in JUMP data list and is incidental to teach data.

To control each teach data, it is needed to have some information to not let each teach data overlap.　This non-overlap data is called "teach data Key."　Teach data "Key" is 32 bit integer.　But, for practical use, only a positive value can be used.

6. 10. 2 Teach Data Operation

Some libraries for teach data operation are as follows:

Teach data operation library:

Pointer operation

Active teach data "Key" alteration	pa_chg_key
Current point alteration at the teach point	pa_chg_pnt

Addition

Active teach data "Key" addition	pa_act_pnt
Teach point addition	pa_add_pnt

Deletion

Active teach data deletion	pa_del_pnt
Current teach point deletion	
Project deletion	
JUMP data deletion	pa_del_jmp

Replacement

Current teach data replacement	pa_rpl_pnt

Active teach data "Key" point:

Among plural teach data, the one indicated by the active teach data "Key" point is the active teach data one.

All teach data operation (acquisition, deletion and replacement) and playback control are performed for active teach data.

Teach point:

A teach point indicated by teach point pointer is called a current point.

All teach data operation (acquisition, deletion and replacement) and playback control are performed for teach point data indicated by this teach pointer.

Teach pointer is automatically renewed when:

- After acquiring teach data.
- when in playback control.
- After deleting teach data (deleting current point.)

6. 10. 2. 1 Current Point Alteration

(1) Active teach data alteration

Among plural teach data, to choose the teach data intended to work, the active teach data has to be altered as follows:

Active teach data alteration : pa_chg_key

Designation	Instructions
Active teach data alteration	The teach data retaining the designated teach data "Key" is defined as the active teach data. **Important exception:** Teach data is usually created from 1. If teach data is newly created, active teach data has to be set 0. Later on, if teach data is acquired, the motion control creates teach data "Key" which does not overlap with this acquired one (one point teach data). Then, it is added to the teach data control list.

(2) Current teach data alteration

If each teach point attribution is altered or intending to designate playback starting point, its operation has to be performed after altering the current teach point. Methods to alter the cuurent teach point are as follows:
(With the current teach point alteration, the real machine cannot be actualized. Also, this teach point cannot be changed during playback performance.)
On the current point shifting, for parameter: "PNTMOVE" of "pa_chg_pnt", there are the following types:

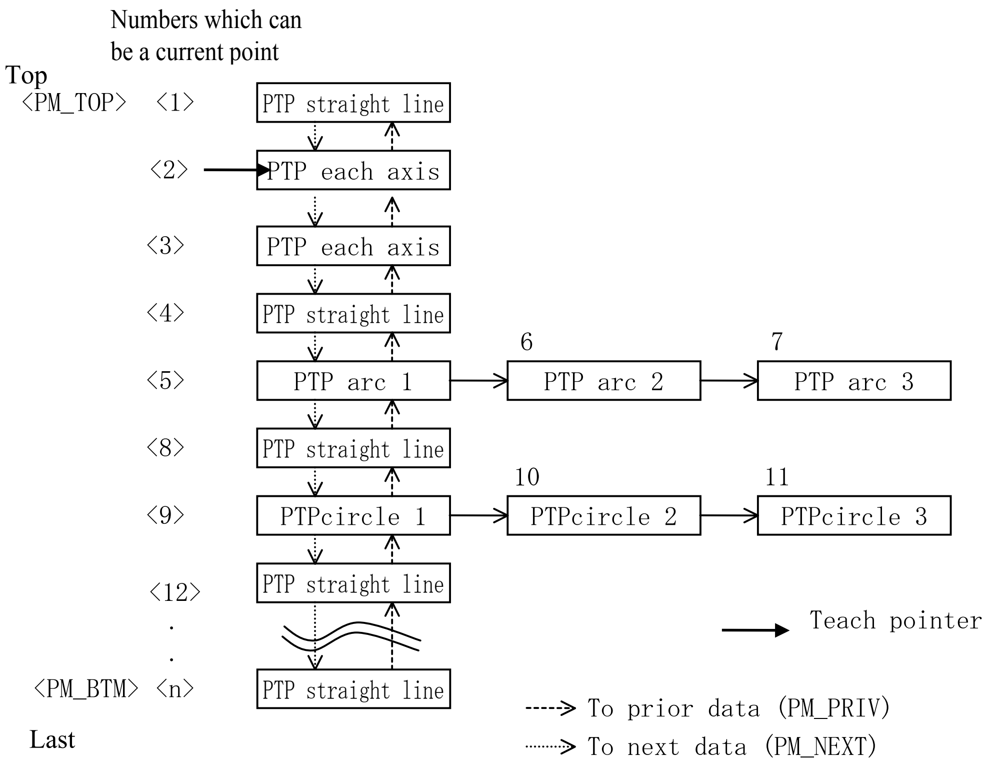
Current teach point alteration : pa_chg_pnt(, PNTMOVE、)

Designations	Details
PM_TOP (Top teach point)	Teach point placed at the top of teach data is defined as the current teach point.
PM_BTM (Last teach point)	Teach point placed at the bottom of teach data is defined as the current teach point.
PM_NEXT (Next teach point)	Teach point placed next to the current teach point is defined as the current teach point.
PM_PRIV (Prior teach point)	Teach point placed prior to the current teach point is defined as the current teach point.
PM_JMP (Designated ID)	Teach point retaining the designated teach point ID is defined as the current teach point.
(Designated comment)	Teach point retaining the designated comment is defined as the current teach point.

<<Current Teach Point Alteration>>

Now, the teach point is at <2>. Here, if the command is issued in the next parameter, the current pointis moved to →< >.

(a) PM_TOP	: to Top Data		→<1>
(b) PM_NEXT	: to the next data of the current point.		→<3>
(c) PM_PRIV	: to the prior data of the current point		→<1>
(d) PM_BTM	: to the last data		→<n>
(e) PM_JMP	: to the designated number by .jmp	jmp=4	→<4>
(f) PM_CIR	: the circle teach data first placed from the current point in forward direction		→<9>
(g) PM_ARC	: the arc teach data first placed from the current point in forward direction		→<5>



Remark

Arc/circle data is processed in each block.

6. 10. 2. 2 Teach Point Addition

For teach point acquisition one of following methods has to be employed:

Teach point addition : pa_add_pnt(,PNTTYPE)

Designation	Details
PTP- axis attribute addition	Adds teach data with each axis attribute in PTP.
PTP- axis attribute insertion	Inserts teach data with each axis attribute in PTP.
PTP-RMRC attribute addition	Adds teach data with RMRC straight-line attribute in PTP.
PTP-RMRC attribute insertion	Inserts teach data with RMRC straight-line attribute in PTP
PTP- Circle 1st point addition	Adds teach data with RMRC circle attribute in PTP
PTP- Circle 2nd point addition	If the current teach point has circle attribute, creates the second point in the circle /arc link area of its teach point.
PTP- Circle 3rd point addition	If the current teach point has circle attribute, creates the third point in the circle /arc link area of its teach point.
PTP- Arc 1st point addition	Adds teach data with RMRC arc attribute in PTP.
PTP- Arc 2nd point addition	If the current teach point has arc attribute, creates the second point in the circle /arc link area of its teach point.
PTP- Arc 3rd point addition	If the current teach point has arc attribute, creates the third point in the circle /arc link area of its teach point.
PTP-RMRC attribute addition (with NOA)	Acquires also NOAP data, when adding PTP – RMRC attribute.
PTP-RMRC attribute insertion (with NOA)	Acquires also NOAP data, when inserting PTP – RMRC attribute.
PTP- Circle 1st point addition (with NOA)	Acquires also NOAP data, when adding PTP – circle 1st point.
PTP- Circle 2nd point addition (with NOA)	Acquires also NOAP data, when adding PTP – circle 2nd point.
PTP- Circle 3rd point addition (with NOA)	Acquires also NOAP data, when adding PTP – circle 3rd point.
PTP- Arc 1st point addition (with NOA)	Acquires also NOAP data, when adding PTP – arc 1st point.
PTP- Arc 2nd point addition (with NOA)	Acquires also NOAP data, when adding PTP – arc 2nd point.
PTP- Arc 3rd point addition (with NOA)	Acquires also NOAP data, when adding PTP – arc 3rd point.

*"addition" and "insertion" meanings in the chart:

Addition — creates new teach point after the current teach point.

Insertion — creates new teach point before the current teach point.

If a current teach point does not exist, only, a new teach point is created.

6. 10. 2. 3　Teach point (Teach data) Deletion

(1) Teach point (teach data) Deletion

Teach point and teach data deletion are provided.

Teach point (teach data) Deletion　:　pa_del_pnt(　,PNTDEL)

Designations	Instructions
PD_CUR (Teach point deletion)	Deletes the current teach point.
PD_ALL (Teach data deletion)	Deletes the active teach data. If the active teach data is deleted, active teach data number becomes the top point in the first discovered teach data.　To activate other remaining teach data, the active teach data has to be altered.
PD_ALLDATA (Project deletion)	Deletes all teach data (project.)

(2) JUMP data delition

JUMP data deletion has two ways: the teach data and JUMP data deletions.　Each is performed to the active teach data.

JUMP data delition　:　pa_del_jmp

Designations	Instructions
Teach data deletion	Delets the active teach data.　Therefore, all JUMP data incidental to the active teach data are deleted.
JUMP data deletion	Designates JUMP condition number (JUMP data) incidental to the active teach data, then, deletes it.

6. 10. 3 Moving to the current point (teach point)

Before starting playback, it is needed to adjust the current point and the arm position. This is called the "current teach point shifting motion."
Current teach point shifting motions are as follows:

Current teach point shifting motions

Designations	Instructions
Axis shifting motion : **pa_axs_pnt**	Current teach point and arm position are adjusted through interpolation processing using current ideal target angle and angle attribute inside teach data. For PTP data (with NOA), this method cannot be employed to operate. (Angle data is not reliable as the data is automatically created at the upper point.)
RMRCshifting motion : **pa_mov_pnt**	Current teach point and arm position are adjusted through interpolation processing using the position/orientation calculated from current ideal target angle and angle attribute inside teach data.

RMRC shifting motion is controlled by RMRC. If the current position out of moving range or E1 axis angle is 0, RMRC control cannot be performed. First, move to RMRC control area, then, issue.

6. 10. 4 Playback motion (step operation) start

Four methods for a playback control (check-up operation) start are as follows:

Playback starting methods : pa_ply_pnt(,PLAYBACK,,)

Designations	Instructions
PB_FORES (Forward step operation)	Motion is created using teach point attributes (velocity, velocity pattern etc.) of the current teach point, from the current teach point to the next one. When this motion is completed, the current teach point is changed to the next one.
PB_BACKS (Reverse step operation)	Motion is created using teach point attributes (velocity, velocity pattern etc.) of the prior teach point from the current teach point to the prior one. When this motion starts, the current teach point is changed to the previous one.

PB_FORE
(Forward consecutive operation)
	Motion is created backwards from the current teach point. This motion continues until returning again to the top teach point after passing through at certain designated times. The current teach point is changed every time when the teach point is passed through while in motion.
	For example, if teach points are ①, ② and ③, the current point is ①, the designated time is once:
	①−②−③−①
	if the designated times are twice:
	①−②−③−①−②−③−①
	if the current teach point is ② and the designated times are twice:
	②−③−①−②−③−①
	(ATTENTION! The top ① point is passed through only once.)
	
	Teach data playback is always completed at the top teach point. For more, refer to “JUMP rule” in the section 8.8.

PB_BACK (Forward check-up operation)	Playback is performed with forward consecutive operation from the current teach point to the last teach point. If JUMP condition is established, not only JUMP performs, but also this operation is completed at the last teach point of each teach data.

6. 11　Playback Control

Playback controls according to teach points are as follows:

・Playback straight line interpolation control employing PTP straight line interpolation data

・Playback arc interpolation control employing PTP arc interpolation data

・Playback circle interpolation control employing PTP circle interpolation data

・Playback axis interpolation control employing PTP axis interpolation data

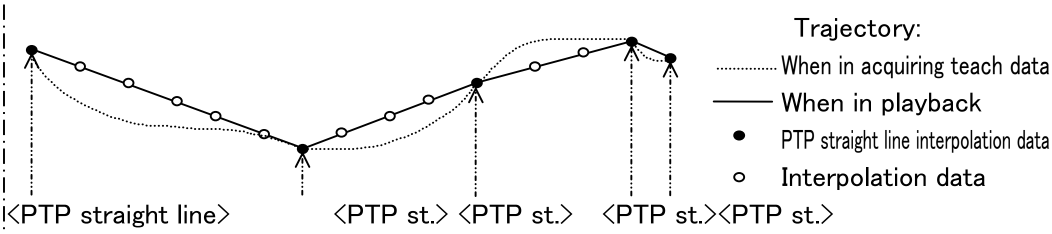
6. 11. 1 PTP straight line interpolation data and playback control

When teach data is acquired, if PTP straight line interpolation data is chosen, teach data is memorized as PTP straight line interpolation data.

Playback control of PTP straight line interpolation data is RMRC feedback control. Between two PTP straight line interpolation data, the tip is interpolated linearly.

Example: for Visual C++

```
<Teach data acquisition>
            :                                   Arm motion with RMRC control
pa_add_pnt(ARM0,PT_PTP);                        PTP data acquisition
            :                                   Arm motion with RMRC control
pa_add_pnt(ARM0,PT_PTP);                        PTP data acquisition
            :
 <Playback control>
            :
pa_chg_pnt(ARM0,PM_TOP,0);   Moves the teach pointer to the top teach data.
pa_mov_pnt(ARM0,WM_WAIT);    Moves to the current point.
pa_ply_pnt(ARM0,PB_FORE,WM_WAIT); Playback forward motion.
```



Example: for Visual BASIC

```
Dim ret As Long
    :
ret = pa_add_pnt(ARM0,PT_PTP)
    :
ret = pa_add_pnt(ARM0,PT_PTP)
    :
ret = pa_chg_pnt(ARM0,PM_TOP,0)
ret = pa_mov_pnt(ARM0,WM_WAIT)
ret = pa_ply_pnt(ARM0,PB_FORE,WM_WAIT)
```

6. 11. 2 PTP arc interpolation data & playback control

When in acquisition, if teach data type arc is designated, it is memorized as PTP arc data.

PTP arc data:

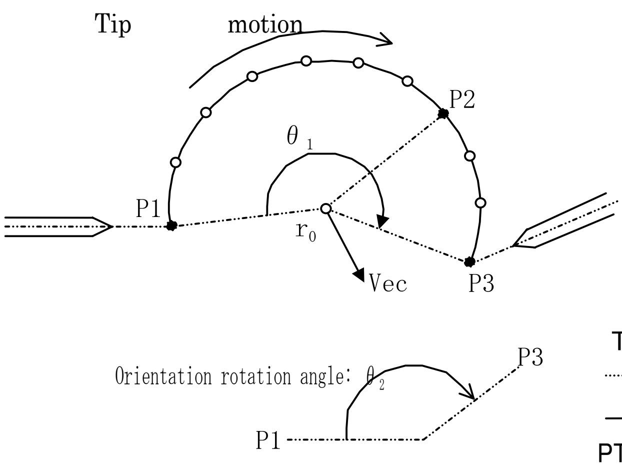
- PTP arc 1st point data :<P1>
- PTP arc 2nd point data:<P2>
- PTP arc 3rd point data:<P3>

These three constitute one block.

In playback control, the tip is interpolated to create the arc trajectory passing through three points. The motion direction is from <P1> to <P2>, then, <P3>. From <P1> to <P3>, this interval is interpolated equally for orientation.

Example: for Visual C++

```
＜Teach data acquisition＞
                    :                         Arm motion with RMRC control
  pa_add_pnt(ARM0,PT_ARC1);             PTP arc 1st data acquisition
                    :                         Arm motion with RMRC control
  pa_add_pnt(ARM0,PT_ARC2);             PTP arc 2nd data acquisition
                    :                         Arm motion with RMRC control
  pa_add_pnt(ARM0,PT_ARC3);             PTP arc 3rd data acquisition
                    :
＜Playback control＞
                    :
  pa_chg_pnt(ARM0,PM_TOP,0);        Moves the teach pointer to the top teach data.
  pa_mov_pnt(ARM0,WM_WAIT);             Moves to the current point
  pa_ply_pnt(ARM0,PB_FORE,WM_WAIT); Playback forward motion
```



Trajectory:
- ········· When in acquiring teach data
- —— When in playback
- ● PTP arc interpolation data
- ○ Interpolation data

Example: for Visual BASIC

```
Dim ret As Long
        :
ret = pa_add_pnt(ARM0,PT_ARC1)
ret = pa_add_pnt(ARM0,PT_ARC2)
ret = pa_add_pnt(ARM0,PT_ARC3)
                    :
ret = pa_chg_pnt(ARM0,PM_TOP,0)
ret = pa_mov_pnt(ARM0,WM_WAIT)
ret = pa_ply_pnt(ARM0,PB_FORE,WM_WAIT)
```

6. 11. 3 PTP circle interpolation data & playback control

When in acquisition, if circle is designated for teach data type, it is memorized as PTP circle data.

PTP arc data:

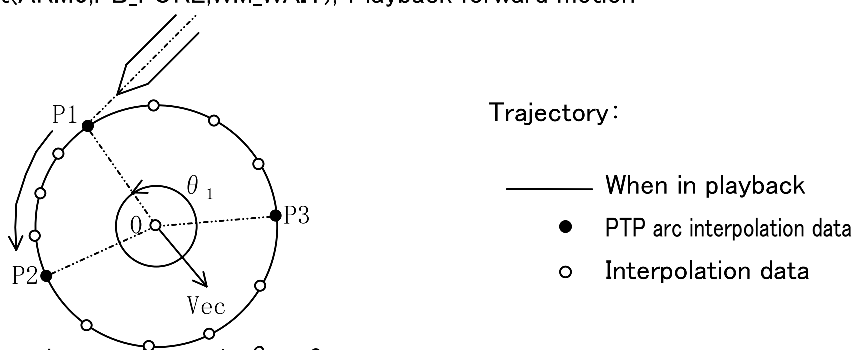
PTP circle 1st point data :<P1>
PTP circle 2nd point data:<P2>
PTP circle 3rd point data:<P3>

These three constitute one block.

In playback control, the tip is interpolated to create the circle trajectory passing through three points. The motion direction is from <P1> to <P2>, then, <P3>. Posture is fixed at <P1> orientation.

Example: for Visual C++

```
<Teach data acquisition>
                                                    Arm motion with RMRC control
pa_add_pnt(ARM0,PT_CIR1);              PTP circle 1st data acquisition
                     :                              Arm motion with RMRC control
pa_add_pnt(ARM0,PT_CIR2);              PTP circle 2nd data acquisition
                     :                              Arm motion with RMRC control
pa_add_pnt(ARM0,PT_CIR3);              PTP circle 3rd data acquisition
                     :
<Playback control>
pa_chg_pnt(ARM0,PM_TOP,0);          Moves the teach pointer to the top teach data.
pa_mov_pnt(ARM0,WM_WAIT);              Moves to the current point
pa_ply_pnt(ARM0,PB_FORE,WM_WAIT);  Playback forward motion
```



Orientation rotation angle: $\theta_2 = 0$
Linear motion/rotational angle: $\theta_1 = 2\pi$

Example: for Visual BASIC

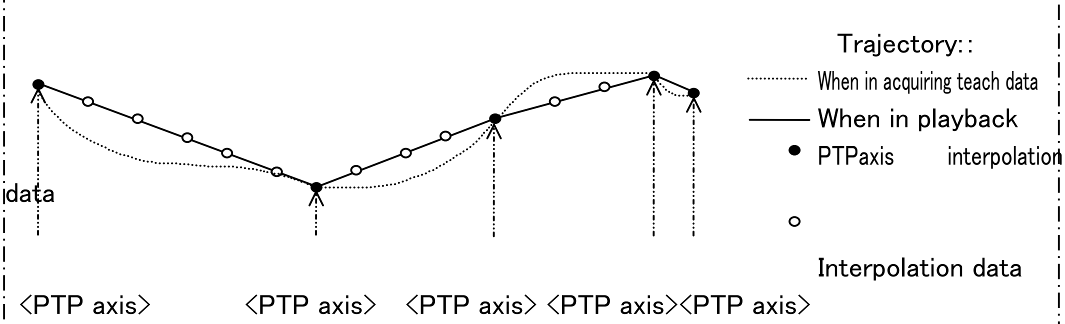
```
Dim ret As Long

ret = pa_add_pnt(ARM0,PT_CIR1)
ret = pa_add_pnt(ARM0,PT_CIR2)
ret = pa_add_pnt(ARM0,PT_CIR3)
     :
ret = pa_chg_pnt(ARM0,PM_TOP,0)
ret = pa_mov_pnt(ARM0,WM_WAIT)
ret = pa_ply_pnt(ARM0,PB_FORE,WM_WAIT)
```

6. 11. 4 PTP axis interpolation data & playback control

When teach data is acquired, if PTP axis interpolation data is chosen, teach data is memorized as PTP axis interpolation data. Playback control of PTP axis inerpolation data is axis angle feedback control. Between adjacent PTP axis interpolation data, each axis angle is interpolated.

Example: for Visual C++

```
＜Teach data acquisition＞
            :
  pa_add_pnt(ARM0,PT_AXS);        PTP axis inerpolation data acquisition
            :
  pa_add_pnt(ARM0,PT_AXS);        PTP axis inerpolation data acquisition
            :
＜Playback control＞
            :
  pa_chg_pnt(ARM0,PM_TOP,0);        Moves the teach pointer to the top teach data.
  pa_axs_pnt(ARM0,WM_WAIT);             Moves to the current point.
  pa_ply_pnt(ARM0,PB_FORE,WM_WAIT); Playback forward motion.
```



Example: for Visual BASIC

```
Dim ret As Long

ret = pa_add_pnt(ARM0,PT_AXS)
        :
ret = pa_add_pnt(ARM0,PT_AXS)
        :
        :
ret = pa_chg_pnt(ARM0,PM_TOP,0)
ret = pa_axs_pnt(ARM0,WM_WAIT)
ret = pa_ply_pnt(ARM0,PB_FORE,WM_WAIT)
```

NOTE:

As an example, if teach data consisting of PTP axis interpolation data for two points is acquired:

1st point target axis angle : T1[7]
2nd point target axis angle : T2[7]

When moving to the 1st point, if RMRC control is employed, the tip position/orientation matches the 1st point target tip position/orientation. But, The possibility for each axis angle to match is low. (This is the difficulty of the 7-axis manipulator control.)

To summarize, when arm arrived at 1st point, each axis angle cannot match T1[7]. Taking into account of such case, interpolation in axis angle feedback control calculates the target angle every sampling moment interpolating the current axis angle and the next target axis angle (T2[7]).

Interpolation processing with axis angle feedback control in the playback control, has a slight difference from the method explained in the section 3.3.

In the section 3.3, the maximum interpolation number is obtained as the result of dividing each axis angle deviation by each axis default velocity (θi) of 7 axes. Then, interpolation processing is performed.

Regarding the axis angle control in playback control, only one axis default velocity can be memorized as teach data. For this reason, all 7 axes are interpolated using one axis default velocity (default = 2π [rad/sec]).

6. 11. 5 Playback control with teach data and other types.

As described before, there are four teach data types.
The following explains t playback control type to be performed If these four data are put together to employ:

① If PTP straight line and PTP axis interpolation data are put together to employ:

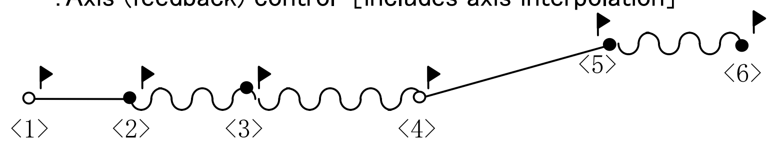
When PTP straight line and PTP axis interpolation data are adjacent, here is how to know which is RMRC feedback control or axis angle feedback control:

Teach data

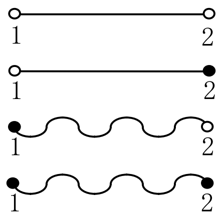
○:PTP straight line interpolation data
●:PTP axis interpolation data

Trajectory

───── :RMRC (feedback) control [includes position/orientation interpolation]
∿∿∿ :Axis (feedback) control [includes axis interpolation]



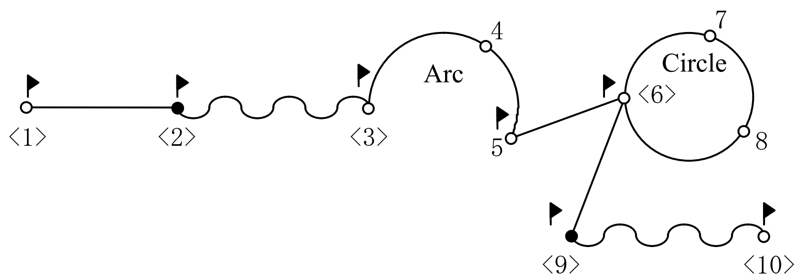
▶ :Data to stop arm motion with step transmission (forward step, reverse step).
Feedback control system depends on an early number data type as follows:



In this system, forward and reverse obtain the same result.

② If circle and arc are together to employ:

Here, how the arm stops if step transmission (pa_ply_pnt(ARM0, PB_FORES or PB_BACKS, WMWAIT) is performed when PTP circle and arc interpolation data are together to employ:



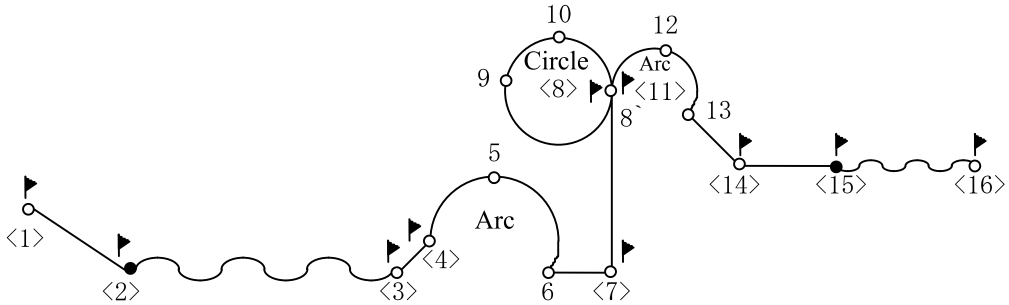
▶:Data to stop arm motion with step transmission

6. 11. 6 Differences between current point operation and playback control

Here are the differences when the current point is operated with pa_chg_pnt – without moving arm – and when the current point is operated with pa_ply_pnt – moving arm–.

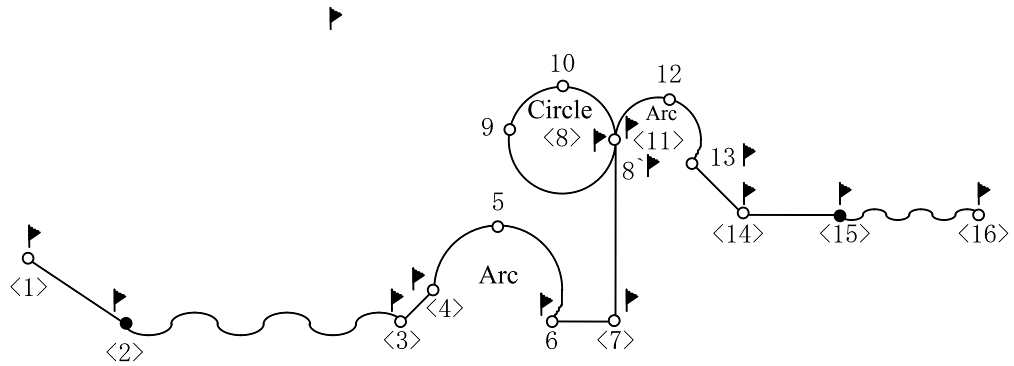
<u>If the current point is operated with ・pa_chg_pnt:</u>

As described before, the only number (closed with < >) being able to be the current point can be changed. To summarize, after changing the current point with pa_chg_pnt, motion control (pa_mov_pnt、pa_axs_pnt) is performed to the current point. Data to stop arm are the only ones where flags are located below.



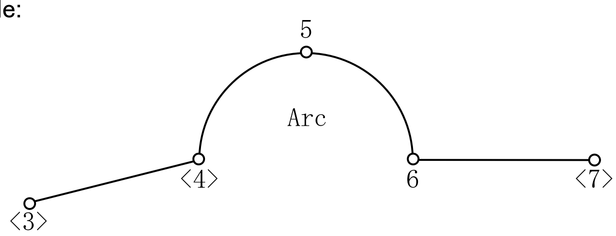
<u>If the current poimt is operated with forward and reverse step of ・pa_ply_pnt.</u>

Playback step control
　　pa_ply_pnt(ARM0, PB_FORES, WM_WAIT)　:forward
　　pa_ply_pnt(ARM0, PB_BACKS, WM_WAIT)　:reverse
Arm motion can be stopped only by data where flags are located.



Difference whether the circle and arc can be stopped at the last data or not.
With this difference the following happens:

For example:



The arc is stopped at teach data 3. Current point <3>
Issuing “pa_ply_pnt(ARM0, PB_FORES, WM_WAIT” three times. Arm is moved to teach data 7. Current point <7>

・After issuing “pa_chg_pnt(ARM0, PM_PRIV, 0)” (the current point is returned to the prior teach data.) or “pa_chg_pnt(ARM0, PM_JMP, 4)” (the current point is changed to the teach data 4), if arm is moved to the current point with “pa_mov_pnt、pa_axs_pnt”:

Arm is stopped at the teach data 4. (arc 1st point)

・If “pa_ply_pnt(ARM0, PB_BACKS, WM_WAIT)” (reverse step) is issued:

Arm is stopped at the teach data 6. (arc 3rd point)

Remark

For circle, the same result is obtained.

6. 11. 7 JUMP rule

When playback is performed, the method to make the arm move between two data not directly linked as teach data, is called "JUMP rule." JUMP rule can be broadly divided in two. "Tacit JUMP": the one not needing JUMP condition. "Conditional JUMP": the one needing JUMP condition.

① Tacit JUMP

"Tacit JUMP" interpolates an interval between the last and the top teach point only in forward motion and actuates the arm. (The last and the top teach point described here are located inside the same teach data "Key".) Teach data is never automatically changed by teach data "Key." This means: the end of playback performance always comes to the top teach point when in playback forward motion (Designated times are performed.)

For this case, the control method, motion velocity and velocity pattern employ the last teach data.

② Conditional JUMP

With JUMP condition inside teach data, teach data route is altered by force. This method interpolates teach data commanded from the current teach point, or interval between two teach points with ID designating Key. A playback route can be controlled by inputting DI on account of employing this conditional JUMP.

Remark

If "tacit JUMP" and conditional JUMP are employed together, the following set-back occurs:

Creating JUMP condition for the teach data "Key 2" (designated ID), inside the teach data "Key 1," if no JUMP condition is set inside the teach data "Kwy 2," motion is as follows:

Playback forward consecutive motion starts from teach data "Key1".
↓
JUMP to teach data "Key 2" (designated ID) with JUMP condition
↓ (Conditional JUMP processing)
Playback teach data "Key 2".
↓
Arrival to the last teach point of teach data "Key 2".
↓ (Tacit JUMP)
Playback from the top of teach data "Key 2".

As long as JUMP condition is not clearly designated, JUMP processing is not reversed from teach data "Key 2" to teach data "Key 1".

6. 12 Tip offset control

Method control to input offset value to the original playback trajectory when in RMRC control during playback control.

Tip offset control can be divided broadly in two as follows:

・Coordinate conversion matrix control

- Parallel motiom conversion matrix control
- Rotational motiom conversion matrix control
- Work coordinate system conversion matrix control

・Tip position offset control

- Mechanical interface coordinate system Absolute deviation offset control
- Mechanical interface coordinate system Relative deviation offset control
- Base coordinate system Absolute deviation offset control
- Base coordinate system Relative deviation offset control
- Trajectory coordinate system Absolute deviation offset control
- Trajectory coordinate system Relative deviation offset control

Memo

Trajectory coordinate system means the one on the playback tip trajectory.

6. 12. 1 Coordinate conversion matrix control

There are three coordinate conversions as follows:

(a) parallel motion: Add offset (△X, △Y and △Z) to teach data.
: Parallel motion conversion matrix

(b) Rotational motion: Add offset (△Yaw, △Pitch and △Roll) to teach data.
: Rotational motion conversion matrix

(c)Coordinate conversion: Replace data of teach data coordinate system on the work coordinate system.
: Work coordination conversion matrix

Memo

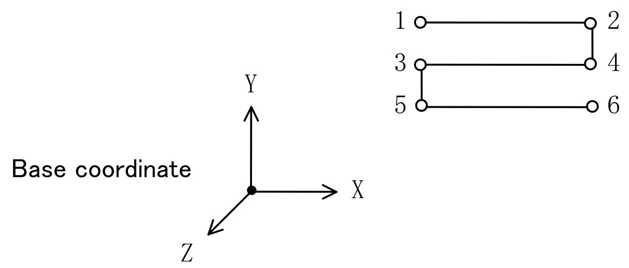
(a) and (b) are respectively explained here. If T-matrix including offset of both parallel and rotational motion is changed to conversion matrix, parallel and rotational motion can be performed simultaneously.

(a) Parallel motion conversion control

Parallel motion is performed through multiplying tip position/orientation (T-matrix) of playblack trajectory created from teach data by the conversion matrix including offset value (toward V, Y and Z) of the base coordinate system.

Program description:

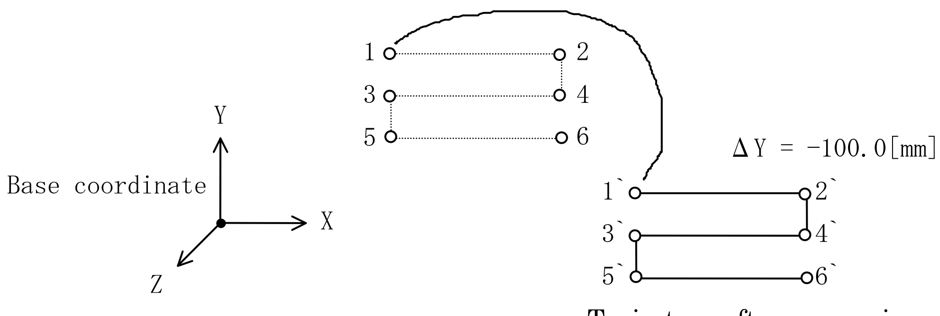
① Acquires playback teach data. : pa_add_pnt



② Sets parallel motion conversion matrix. : pa_set_mtx

Creates T-matrix adding offset (△X, △Y, △Z) toward X, Y and Z in the base coordinate system. Unit is [mm].

$$T = \begin{pmatrix} 1 & 0 & 0 & \triangle X \\ 0 & 1 & 0 & \triangle Y \\ 0 & 0 & 1 & \triangle Z \end{pmatrix}$$



Trajectory after conversion

③ Moves the current point to the top teach data. : pa_chg_pnt
pa_mov_pnt
(or pa_axs_pnt)

④ Starts playback control. : pa_ply_pnt

Example: for Visual C++

```
MATRIX          mat;
 int            i,j;

          :
pa_add_pnt(ARM0, PT_PTP);          PTP linear interpolation data acquisition
          :
pa_add_pnt(ARM0, PT_PTP);          PTP linear interpolation data acquisition

for(i=0;i<3;i++){
        for(j=0;j<3;j++){
                if(i==j)    mat[i][j] = 1.0;
                else        mat[i][j] = 0.0;
        }
}

 mat[0][3] =   250.0;                         △X＝ 250.0
 mat[1][3] = -100.0;                          △Y＝-100.0
 mat[2][3] =     0.0;                         △Z＝    0.0

pa_set_mtx(ARM0, mat);                        Conversion matrix setting
pa_chg_pnt(ARM0, PM_TOP, 0);                  Current point alternation
pa_mov_pnt(ARM0, WM_WAIT);         Moves to the current point.
pa_ply_pnt(ARM0, PB_FORE, WM_WAIT);
                              Playback control starts
            (Parallel motion conversion matrix control is performed.)
```

Example: for Visual BASIC

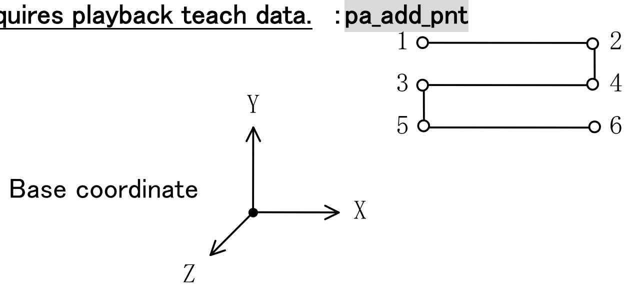
```
Dim ret As Long
Dim i As Integer
Dim j As Integer
Dim mat(3,2) As Single
            :
ret = pa_add_pnt(ARM0, PT_PTP)
            :
ret = pa_add_pnt(ARM0, PT_PTP)

For i=0 To 2 Step 1
        For j=0 To 2 Step 1
            If i = j Then
                        mat(i,j) = 1.0
            Else
                        mat(i,j) = 0.0
            End If
        Next j
Next i

mat(3,0) =   250.0
mat(3,1) = -100.0
mat(3,2) =      0.0

ret = pa_set_mtx(ARM0, mat(0,0))
ret = pa_chg_pnt(ARM0, PM_TOP, 0)
ret = pa_mov_pnt(ARM0, WM_WAIT)
ret = pa_ply_pnt(ARM0, PB_FORE, WM_WAIT)
```

(b)Rotational motion conversion matrix control

Rotational motion is performed through multiplying tip position/orientation (T−matrix) of playblack trajectory created from teach data by conversion matrix including rotation offset value (on V, Y and Z axis) of the base coordinate system.

Program description:

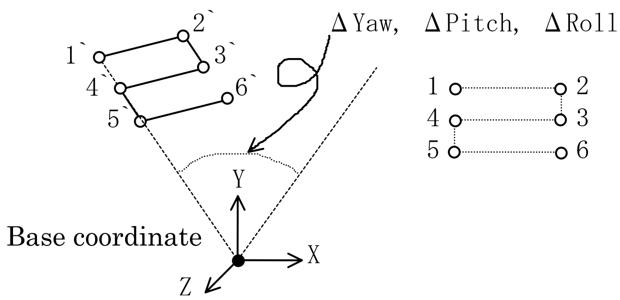
① Acquires playback teach data. : pa_add_pnt



② Sets rotational motion conversion matrix. : pa_set_mtx

Creates conversion matrix (T−matrix) adding rotation offset (△Yaw, △Pitch and △Roll) on X, Y and Z axis in the base coordinate system.

$$T = \begin{pmatrix} nx & ox & ax & 0 \\ ny & oy & ay & 0 \\ nz & oz & az & 0 \end{pmatrix}$$



③ Moves the current point to the top teach data. : pa_chg_pnt
pa_mov_pnt
(or pa_axs_pnt)

④ Starts playback control. : pa_ply_pnt

Example: for Visual C++

```
MATRIX     mat;
 int             i;
                 :
pa_add_pnt(ARM0, PT_PTP);        PTP linear interpolation data acquisition
                 :
pa_add_pnt(ARM0, PT_PTP);        PTP linear interpolation data acquisition

for(i=0;i<3;i++)     mat[i][3] = 0.0;
                 :
          T-matrix (noa section) creation
                 :
            pa_set_mtx(ARM0, mat);           Conversion matrix setting

pa_chg_pnt(ARM0, PM_TOP, 0);    Current point alternation
pa_mov_pnt(ARM0, WM_WAIT);       Moves to the current point.
pa_ply_pnt(ARM0, PB_FORE, WM_WAIT);
                Playback control satrts
              (Rotational motion conversion matrix control is performed.)
```

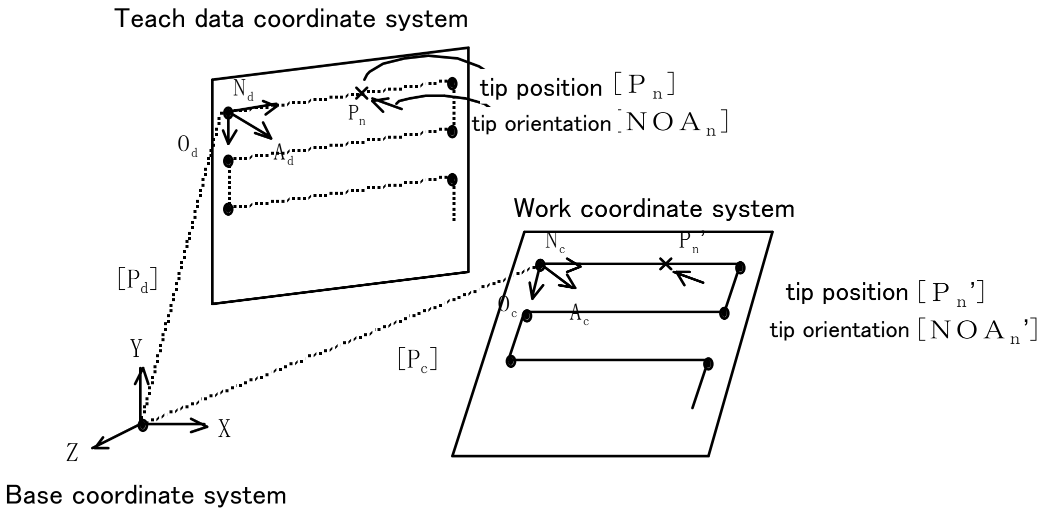
Example: for Visual BASIC

```
Dim mat(3,2) As Single
Dim i As Integer
Dim ret As Long
            :
ret = pa_add_pnt(ARM0, PT_PTP)
            :
ret = pa_add_pnt(ARM0, PT_PTP)

For i=0   to 2 Step 1
            mat(3,I) = 0.0
Next i

ret = pa_set_mtx(ARM0, mat(0,0))
ret = pa_chg_pnt(ARM0, PM_TOP, 0)
ret = pa_mov_pnt(ARM0, WM_WAIT)
ret = pa_ply_pnt(ARM0, PB_FORE, WM_WAIT)
```

(c)Coordinate conversion matrix control

Providing two matrixes: work coordinate and teach data coordinate matrix, the trajectory in the teach data coordinate system is converted to the one in the work coordinate system.

Teach data coordinate system $[N_d O_d A_d P_d]$: Teach data acquisition coordinate system
Work coordinate system $[N_c O_c A_c P_c]$: Actual work coordinate system



To convert the tip position/orientation [NOAP] of playback trajectory created from teach data, into the work coordinate position/orientation [NOAP'], the deviation in teach data coordinate is replaced to the one in the work coordinate.

A set value is indicated with absolute position matrix [P] and orientation matrix [NOA].
Only P is designated with a unit [mm]. As [NOA] is vector, it does not have a unit.
For a set value, the current set conversion matrix is indicated as a default value.
For resetting, a unit matrix has to be set for both absolute position matrix [P] and

$$[I] = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix}$$

orientation matrix [NOA]..

For a set [NOA] matrix, the following checks are performed:

- Each N, O and A vector have to be a unit vector.
- A vector has to be a cross product of N and O vector.
  (N, O and A have to be a vector crossing each other at the right angle.)

Program description:

① Acquires playback teach data. : pa_add_pnt

② Sets T-matrix (=mat1) of teach data coordination system and T-matrix (=mat0) of work coordination system.

: pa_set_mat

Creates T-matrix (=mat1) of teach data coordination system and T-matrix (=mat0) of work coordination system.

③ Moves the current point to the top teach data. : pa_chg_pnt
pa_mov_pnt
(or pa_axs_pnt)

④ Starts playback control. : pa_ply_pnt

Example: for Visual C++

```
MATRIX          mat0, mat1;
                       :
pa_add_pnt(ARM0, PT_PTP);      PTP linear interpolation data acquisition
                     :
pa_add_pnt(ARM0, PT_PTP);      PTP linear interpolation data acquisition
                     :
              (Work coordinate matrix creation      :mat0)
              (teach data coordinate matrix creation:mat1)
                       :
pa_set_mat(ARM0, mat0, mat1);   Conversion matrix setting

pa_chg_pnt(ARM0, PM_TOP, 0);   Current point alternation
pa_mov_pnt(ARM0, WM_WAIT);      Moves to the current point.
pa_ply_pnt(ARM0, PB_FORE, WM_WAIT);
                     Playback control starts
                     (Coordinate conversion matrix control is performed.)
```

Example: for Visual BASIC

```
Dim mat0(3,2) As Single
Dim mat1(3,2) As Single
Dim ret As Long
            :
ret = pa_add_pnt(ARM0, PT_PTP)
     :
ret = pa_add_pnt(ARM0, PT_PTP)
     :
ret = pa_set_mat(ARM0, mat0(0,0), mat1(0,0))

ret = pa_chg_pnt(ARM0, PM_TOP, 0)
ret = pa_mov_pnt(ARM0, WM_WAIT)
ret = pa_ply_pnt(ARM0, PB_FORE, WM_WAIT)
```

6. 12. 2 Tip position offset control

Method to control arm providing offset value in actual time in RMRC feedback control.
If brake-stop or feedback control is performed, offset cannot be added.

What is in RMRC feedback control:

- RMRC feedback control servo lock status
- When in playback control.(except PTP axis interpolation data)
- When in RMRC control motion to the current point.
- Waiting status for playback start

There are three coordinate systems able to input offset value. For each of them, absolute addition and relative addition are provided.

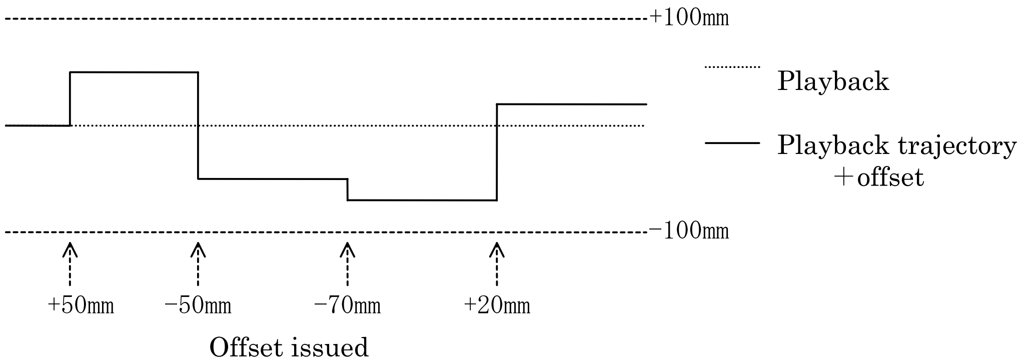
Mechanical interface coordinate system	Absolute deviation offset control
Mechanical interface coordinate system	Relative deviation offset control
Base coordinate system	Absolute deviation offset control
Base coordinate system	Relative deviation offset control
Trajectory coordinate system	Absolute deviation offset control
Trajectory coordinate system	Relative deviation offset control

Memo

Trajectory coordinate system means the one on the playback tip trajectory.
Further, more is explained later.

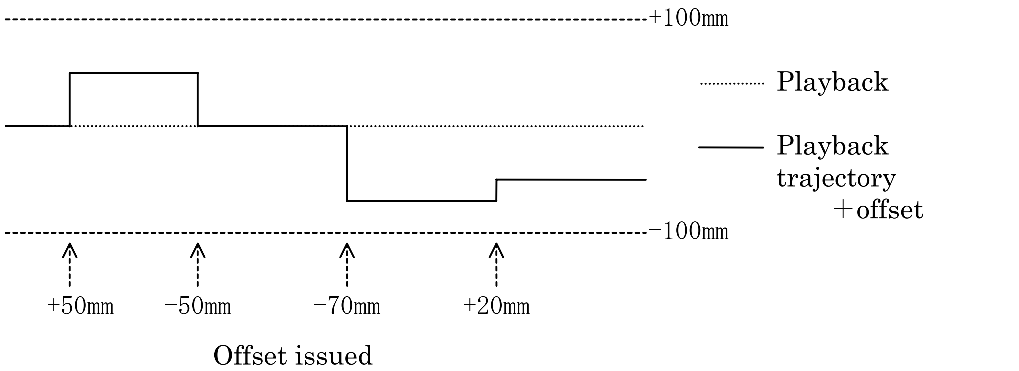
Absolute deviation

If offset is issued, offset value is added on the basis of playback trajectory.



Relative deviation

If offset is issued, offset value is added to the trajectory having previously added some offset value.



Offset Pool method:

Either absolute or relative deviation offset, offset value has a limit to be added, if needed, in every cycle. Therefore, the method adopted is: to set the offset limit value added in every cycle, creating offset pool, add the provided offset value little by little in several cycle.

For example, setting a limit value (5.0 mm) when in offset addition with absolute deviation offset control (the base coordinate system), offset value (toward X +100.0mm) is provided.

Adding offset (5.0mm toward X in every cycle), at the twentieth cycle, it reachs 100.0 mm toward X.

《On absolute and relative deviation offset control in the trajectory coordinate system》

Method to control adding offset value for playback trajectory coordinate system.
The playback trajectory coordinate system is changeable depending on data. Therefore, the method adopted here is the provided offset value, using trajectory coordinate, when in adding offset, converts to non changeable base coordinate, then, makes an addition to the base coordinate system.

How to create playback trajectory coordinate system:

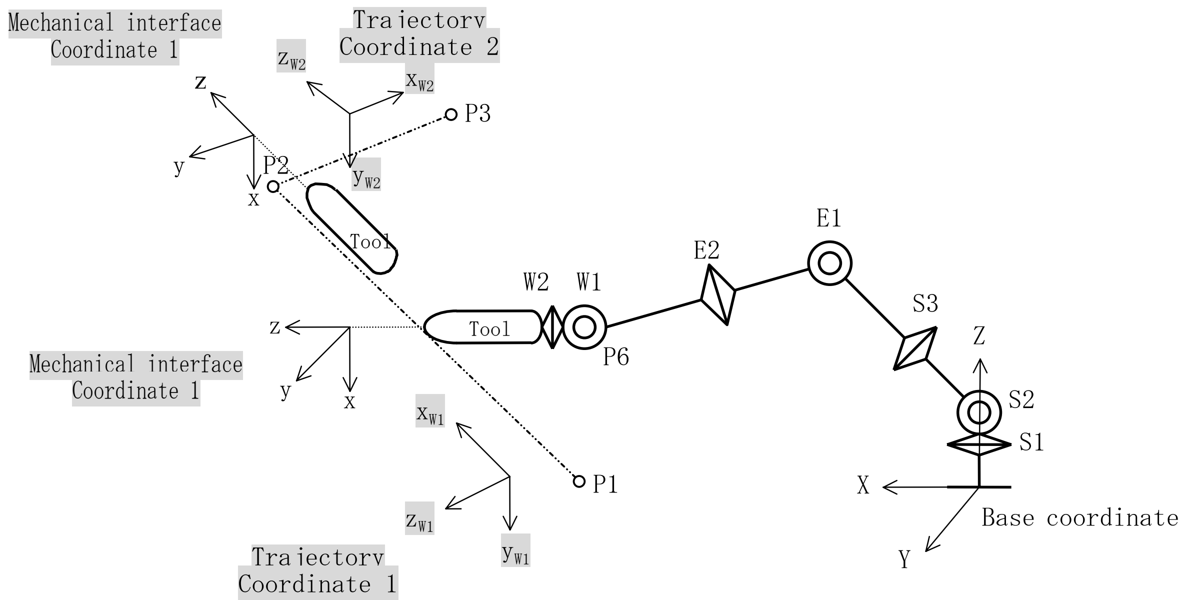
Three teach points of PTP linear interpolation data are defined as P1, P2 and P3

＜Trajectory coordinate system 1 (x_{w1}、y_{w1}、z_{w1}) from the 1st point P1 to the 2nd point P2＞

The direction created by linking linearly from the 1st point P1 to the 2nd point P2 is the direction of trajectory coordinate system 1 (x_{w1}、y_{w1}、z_{w1}). Solve the direction of trajectory coordinate y_{w1} through calculating the direction of mechanical interface coordinate 1 and vector product of x_{w1} direction. Finally, Solve trajectory coordinatez_{w1} from calculatedx_{w1} and y_{w1} direction.

＜Trajectory coordinate system 2 (x_{w2}、y_{w2}、z_{w2}) from the 2nd point P2 to the 3rd point P3＞

Likewise, the direction created by linking linearly from the 2nd point P2 to the 3rd point P3 is the direction of trajectory coordinate system 2 (x_{w2}、y_{w2}、z_{w2}). Solve the direction of trajectory coordinate y_{w2} through calculating the direction of mechanical interface coordinate 1 and vector product of x_{w2} direction. Finally, Solve trajectory coordinatez_{w2} from calculatedx_{w2} and y_{w2} direction.



Program description:

① Starts playback control. :pa_ply_pnt

The tip position offset control is available only for the teach data able to control RMRC feedback.

② Sets a limit value when in offset value addition. :pa_lmt_xyz

Sets offset limit value being added in every cycle, with a [mm] unit. The upper limit value is 1/100 (one hundredth) of linear limit velocity [mm/sec]. Its unit is [mm/10msec]. If this value is exceeded, the following warnings occur. The limit value is replaced with the upper one.

ERR_MIS_PARAM -1051 the designated parameter value exceeds the setting range.

③ Sets offset value and coordinate adding tip position offset. : pa_odr_xyz

With "trans.Enable" of TRNSMAT structure (TRANSMAT trans) of "pa_odr_xyz", sets the designated coordinate and mode (absolute and relative deviation).

MODE_xyz :Mechanical interface coordinate system Absolute deviation
(MODE_XYZ1 for Visual Basic)
Offset has to be set at "trans._xyz[3]".
MODEIxyz :Mechanical interface coordinate system Relative deviation
(MODE_XYZ2 for Visual Basic)
Offset has to be set at "trans.Ixyz[3]".
MODE_XYZ:Base coordinate system Absolute deviation
(MODE_XYZ3 for Visual Basic)
Offset has to be set at "trans._XYZ[3]"
MODEIXYZ:Base coordinate system Relative deviation
(MODE_XYZ4 for Visual Basic)
Offset has to be set at trans.IXYZ[3].
MODE_wave:Trajectory coordinate system Absolute deviation
(MODE_WAVE1 for Visual Basic)
Offset has to be set at trans._wave[3].
MODEIwave :Trajectory coordinate system Relative deviation
(MODE_WAVE2 for Visual Basic)
Offset has to be set at trans.Iwave[3].

For this example, with the base coordinate system absolute deviation offset control, offset 10 mm toward X and 25 mm toward Z are added.

for Visual C++
```
trans.Enable = MODE_XYZ;
trans._XYZ[0] = 100.0;
trans._XYZ[1] =     0.0;
trans._XYZ[2] =   25.0;
```

for Visual BASIC
```
trans.Enable = MODE_XYZ3
trans.xyz21(0) = 100.0
trans.xyz21(1) =     0.0
trans.xyz21(2) =   25.0
```

Example: for Visual C++

```
TRANSMAT   trans;
long            data;
                    :
pa_ply_pnt(ARM0, PB_FORE, WM_NOWAIT);Playback control starts

data = 5.0;                     Limit value when in offset addition = 5.0[mm]
pa_lmt_xyz(ARM0, data);         Limit value setting when in offset addition

trans.Enable = MODE_XYZ;    Base coordinate system absolute deviation selection
trans._XYZ[0] = 100.0;              Offset value toward X  = 10.0[mm]
trans._XYZ[1] =     0.0;            Offset value toward Y  =   0.0[mm]
trans._XYZ[2] =    25.0;            Offset value toward Z  =   5.0[mm]
pa_odr_xyz(ARM0, &trans);           Offset value setting
                    :
```

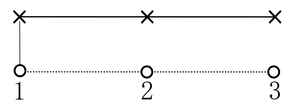
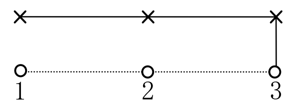
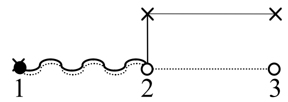
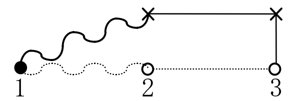
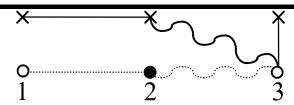
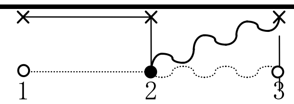
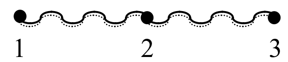
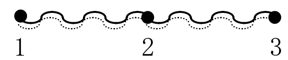
Example: for Visual BASIC

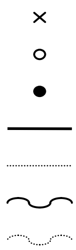
```
Dim trans As TRANSMAT
Dim dat As Long
Dim ret As Long
                    :
ret = pa_ply_pnt(ARM0, PB_FORE, WM_NOWAIT)

dat = 5.0
ret = pa_lmt_xyz(ARM0, dat)

trans.Enable = MODE_XYZ3
trans.xyz21(0) = 100.0
trans.xyz21(1) =     0.0
trans.xyz21(2) =    25.0
ret = pa_odr_xyz(ARM0, trans)
                    :
```

《Offset trajectory if PTP axis interpolation data is included in teach data》

As described before, offset control is available when in playback during RMRC feedback control. At brake-stop status, when in playback during axis feedback control, offset control is not available. Therefore, if PTP axis interpolation data is together with teach data, be aware: the trajectory after offset addition will be as follows:

If PTP axis interpolation data is included in teach data, between forward playback and reverse control, playback trajectory may be different after offset addition. With teach data including only PTP axis interpolation data, offset cannot be added.

	Forward playback	Reverse playback
Example 1		
Example 2		
Example 3		
Example 4		



× ･･･ Teach data after offset value addition
○ ･･･ Teach data (PTP linear interpolation data)
● ･･･ Teach data (PTP axis interpolation data)
･･ Playback trajectory + offset value (RMRC feedback control)
･･ Playback trajectory
･･ Playback trajectory + offset value (axis feedback control)
･･ Playback trajectory

6. 13　Cube Interference

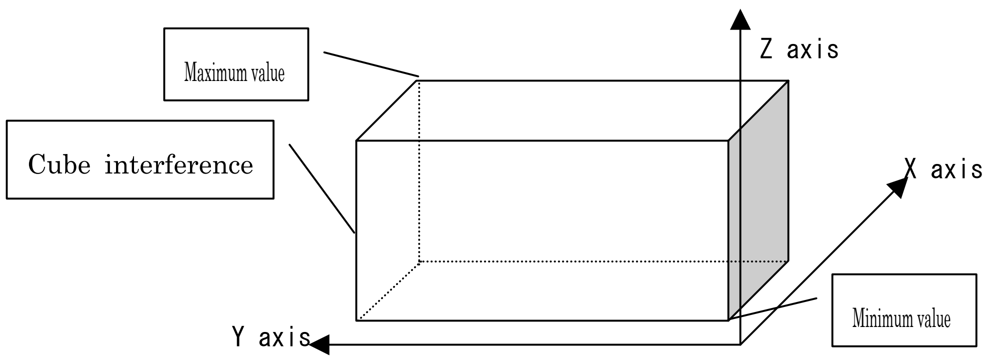
(1) Cube interference area

Cube interference area is the function to prevent interference from surrounding machines and tools.
24 (twenty four) cube interference area can be set at maximum.
Cube interference area is set parallel to the base coordinate system.
If the arm interferes with the cube, this arm happens to be automatically in a brake-stop status.　An error is indicated.

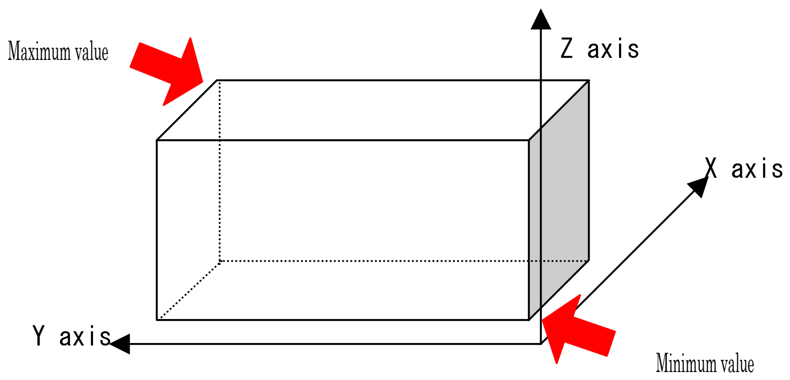
(2) Setting methods:

There are three ways to set cube interference area as follows:

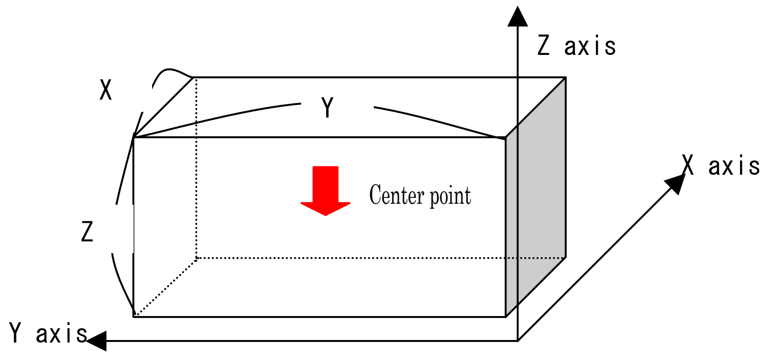
① Input numerically the maximum/minimum value of cube coordinate.



② Move the manipulator to the cube maximum/minimum value position with the axis operation.



③ After numerically inputting the cube three side length (axis length), move the manipulator to the center poimt.



6. 14 Parameter setting

In the motion control section, arm parameter information is as follows:
The details can be seen from the operation control section with “pa_get_prm”. But, It cannot be altered directly by a program. For alteration, use the operation support program (parameter setting).

Reference

This method can be referred to the operation support program (parameter setting) instructions.

WARNING <u>If the parameter is altered except the ● marked ones, control cannot be guaranteed.</u>

Arm parameter outline

	Designations	Types	Config.	Details
●*1	PUL	float	[0–6]	S1～W2 axis upper angle limit [rad]
●*1	PDL	float	[0–6]	S1～W2 axis lower angle limit [rad]
	VEL	float	[0–6]	S1～W2 axis velocity limit [rad/sec]
			[7]	Linear motion velocity limit [mm/sec]
			[8]	Rotational motion velocity limit [rad/sec]
●	DEV	float	[0–6]	S1～W2 axis standard motion velocity [rad/sec]
●			[7]	Standard Linear motion velocity [mm/sec]
●			[8]	Standard rotational motion velocity [rad/sec]
	LIM	float	[0–6]	Teach modeS1～W2 axis velocity limit [rad/sec]
			[7]	Teach mode Linear motion velocity limit [mm/sec]
			[8]	Teach mode Rotational motion velocity limit [rad/sec]
●	CEH	float	[0–6]	Teach mode S1～W2 axis fast motion velocity [rad/sec]
●			[7]	Teach mode fast linear motion velocity [mm/sec]
●			[8]	Teach mode fast rotational motion velocity [rad/sec]
●	CEM	float	[0–6]	Teach mode S1～W2 axis mid motion velocity [rad/sec]
●			[7]	Teach mode linear mid motion velocity [mm/sec]
●			[8]	Teach mode rotational mid motion velocity [rad/sec]
●	CEL	float	[0]	Teach mode S1～W2 axis slow motion velocity [rad/sec]
●			[7]	Teach mode linear slow motion velocity [mm/sec]
●			[8]	Teach mode rotational slow motion velocity [rad/sec]
	PG1	float	[0–2]	Robot coordinate RMRC control X, Y and Z direction gain
			[3–5]	Robot coordinate RMRC control X, Y and Z rotational direction gain
			[6]	Position control integral calculus gain
	PG2	float	[6]	S1～W2 axis control gain
	VG1	float	[0–2]	Tip coordinate RMRC control X, Y and Z direction gain (not used)
			[3–5]	Tip coordinate RMRC control X, Y and Z rotational direction gain (not used)
			[6]	Orientation control integral calculus gain
	TG1	float	[0–6]	Not used
	PCM	float	[0]	Angle control large size (S1, S2) motor angle deviation anomalous threshold value [rad]

		[1]	Angle control mid size (S3, E1) motor angle deviation anomalous threshold value [rad]
		[2]	Angle control small size (E2, W1, W2) motor angle deviation anomalous threshold value [rad]
		[3]	RMR control position deviation anomalous threshold value [mm]
		[4]	RMR control orientation deviation anomalous threshold value [mm]
		[5]	SC method linear/rotational velocity limit coefficient (threshold value creation)
		[6]	SC method axis velocity limit coefficient (threshold value creation)

: :

Arm parameter outline

	Designations	Types	Config.	Details
●	FCM	float	[0]	RMRC control start-up time [sec]
●			[1]	RMRC control shut-down time [sec]
●			[2]	Axis control start-up time [sec]
●			[3]	Axis control shut-down time [sec]
			[4]	Direct control parameter (deceleration ratio)
			[5]	Singularity caution W1 axis position
			[6]	Singularity caution W1 axis position
	ARL	float	[0-6]	Arm length (S1-S2) ～ (W2-Tool installment position) [mm]
	ARG	float	[0-6]	Arm gravity center (S1-S2) ～ (W2-Tool installment position) [mm]
	ARW	float	[0-6]	Arm weight (S1-S2)～(W2-TOOL)[[kg]
●	HOM	float	[0-6]	Home position S1～W2 angle [rad]
●	SAF	float	[0-6]	Safety position S1～W2 angle [rad]
●	ESC	float	[0-6]	Escape position S1～W2 angle [rad]
●	TOL	float	[0-2]	Tool length X, Y and Z direction [mm]
			[3-5]	Not used
●			[6]	Tool offset [mm]
	FVL	float	[0]	Position integral calculus element limit
			[1]	Orientation integral calculus element limit
			[2]	Taper rate when in singularity escape
			[3-6]	Not used
	DMY	long	[0-6]	Not used
	SPA	long	[0]	Servo driver type*2
			[1]	Arm controller numbers*3
			[2]	Arm axis numbers*4
			[3、4]	Not used
			[5]	RETRAC parameter valid flag *5
			[6]	RETRAC parameter adjustment mode flag*6

*1 Within ranges shown in axis charts below, upper and lower angle limit can be set.

6-axis arm	S1	S2	S3	E1	E2	W1	W2
Upper limit [deg]	177	124	Not used	158	255	165	255
Lower limit [deg]	−177	−64	Not used	−107	−255	−165	−255

7-axis arm	S1	S2	S3	E1	E2	W1	W2
Upper limit [deg]	177	94	174	137	255	165	255
Lower limit [deg]	−177	−94	−174	−137	−255	−165	−255

*2 Servo driver type :New type servo =0、Old type 7-axis servo = 7, 8-axis servo = 8

*3 Possible arm controller numbers : usually 2 controllers

*4 Arm axis numbers :6-axis arm = 6, 7-axis arm = 7 (except 6)

*5 RETRAC parameter valid/invalid:not used ＝0
(Only one arm can be used. When in valid, RETRAC initialization is processed.)

*6 RETRACadjustment mode :not used ＝0
(It is needed for motion to create ROB and TOL file.)

6. 15 Error Information

Error information is broadly divided in two, as follows:

・ **Errors recognized by a PA library and a driver of the operation control section.**

・**Errors recognized by the motion control section**

If motion control recognizes an error, control status might be converted.

More explanation, next page.

・PA library recognition errors;

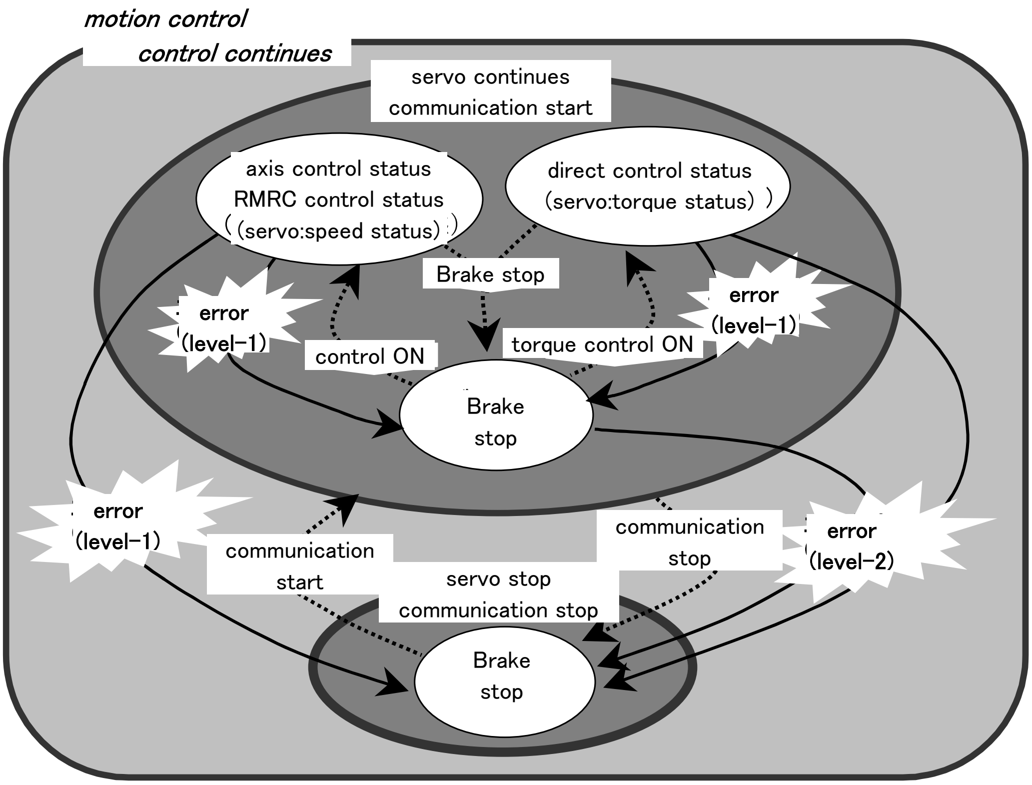
Error No.	Details
−1	The specified file does not exist
−2	File read failure
−3	File write failure
−4	Failed to Interrupt into 486
−5	pa_opn_arm() not executed
−6	Memory allocation failure
−7	Parameters are not allowed to be modified while control
−8	A specified degree of Teaching data is out of range
−20	Designated arm not exist
−21	Designated axis not exist
−22	Designated driver not exist
−23	Incorrect mode of playback motion
−24	Wrong Teaching point deletion type
−25	Wrong modification type for Teaching point attribution
−26	Wrong attribution of registered point velocity profile
−27	Wrong data type for Teaching point
−28	Wrong Teaching point operation type
−29	Incorrect mode of default velocity change
−30	Wrong control mode type for velocity
−31	Wrong control mode type for redundant axis
−32	Wrong operation type for redundant axis
−33	Wrong control mode type for target tip matrix
−34	Wrong direct control type
−35	Wrong digital input/output port designation
−36	Wrong digital input/output channel designation
−37	The error code is not defined
−38	Wrong digital input/output board designation
−39	Wrong digital input/output DI or DO designation
−40	Project is not loaded

・WinRT (driver) recognition errors;

Error No.	Details
−100	Error occurred in WinRTUnMapMemory
−101	Error occurred in WinRTUnMapMemory2
−200	Error occurred in WinRTOpenNamedDevice
−201	Error occurred in WinRTGetFullConfiguration
−300	Error occurred in WinRTMapMemory
−301	Error occurred in WinRTMapMemory2

6. 15. 1　Status conversion outline when error occurs

For control section recognition error or control status conversion by warning, depending on a controller (motion control/servo driver) occurring (recognizing) error, the difference is as follows:



<u>・warning information　　　　→Control status　continuing</u>

Among errors recognized by the motion control section, one identified as "warning," can be controlled.　The motion control might automatically change command value depending on the error, but, control continues.

<u>・Error information (level 1)　→Brake-stop (Communication status　continuing)</u>

Among errors recognized by the motion control section, one identified as "error (level 1)," cannot be controlled.　The motion control sets the command (brake-on) to the servo driver, its control status shifts to a brake-stop.　As the servo driver status is in control continuing communication, control commands can be issued at the remaining status.

<u>・Error information (level 2)　　　→Brake-stop (Communication-stop)</u>

With an error recognized by a servo driver, the servo driver status shifts to "waiting." The motion control status shifts to brake-stop (communication-stop.)　Before issuing control command, communication-start with a servo driver is needed.

Memo

Receiving communication-start command, the servo driver clears errors, then shifts to be in control.

(1)Warning information →Control Status continuing

Warnings occurring in arm motion controller, are as follows:

Control status is not converted.

Error No.	Details
−1000	You are not allowed to access the controller
−1001	Format do not match with command
−1002	Unavailable command under the current mode
−1003	Command invalid
−1004	The specified arm No. does not exist
−1005	Download New ROB File
−1006	Download New TOL File
−1010	S1 axis exceeding speed limit
−1011	S2 axis exceeding speed limit
−1012	S3 axis exceeding speed limit
−1013	E1 axis exceeding speed limit
−1014	E2 axis exceeding speed limit
−1015	W1 axis exceeding speed limit
−1016	W2 axis exceeding speed limit
−1018	Exceeding tip position velocity limit
−1019	Exceeding tip orientation velocity limit
−1020	S1 axis exceeding safety angle
−1021	S2 axis exceeding safety angle
−1022	S3 axis exceeding safety angle
−1023	E1 axis exceeding safety angle
−1024	E2 axis exceeding safety angle
−1025	W1 axis exceeding safety angle
−1026	W2 axis exceeding safety angle
−1030	S1 axis exceeding the motion limit of the target angle
−1031	S2 axis exceeding the motion limit of the target angle
−1032	S3 axis exceeding the motion limit of the target angle
−1033	E1 axis exceeding the motion limit of the target angle
−1034	E2 axis exceeding the motion limit of the target angle
−1035	W1 axis exceeding the motion limit of the target angle
−1036	W2 axis exceeding the motion limit of the target angle
−1038	NOA calculation cannot be executed
−1039	Generation not allowed for keeping Teaching data sequence
−1040	Memory allocation failure
−1041	Prior procedure needed to issue this command
−1042	Wrong designation for circle or arc
−1043	Next pointer not exist
−1044	Previous pointer not exists
−1045	End of Playback Data
−1046	Playback data not existed
−1047	Failed to find playback data
−1048	Accepted as replace command
−1049	Accident of pointer management
−1050	Target value is out of control area. (Arm length is not enough.)

Error No.	details
−1051	Designated parameter exceeded available setting range
−1060	Designated NOA is not appropriate
−1061	End of CP Data is Retrieved as Each Axis Attribution
−1062	Exceeding RMRC controllable range
−1063	Not Available while retrieving CP Data
−1064	Exceeded max No. of interpolation
−1065	Can not generate circle or arc
−1070	S1 axis exceeding angle limit in velocity control
−1071	S2 axis exceeding angle limit in velocity control
−1072	S3 axis exceeding angle limit in velocity control
−1073	E1 axis exceeding angle limit in velocity control
−1074	E2 axis exceeding angle limit in velocity control
−1075	W1 axis exceeding angle limit in velocity control
−1076	W2 axis exceeding angle limit in velocity control
−1080	Too large or too small designated value
−1081	Can not approached by each axis control
−1098	Continuous operation not allowed in teaching mode
−1099	Changed into teaching mode by external operation
−1100	Teach lock can not be turned on except in teaching mode
−1101	Teaching data for specified key not exist
−1103	Cannot change the key of Teaching data
−1200	Interfere range specified No. error
−1201	Having another cube attribution, side length can not be set to this cube
−1202	Having another cube attribution, upper limit teach can not be given to this cube
−1203	Having another cube attribution, lower limit teach can not be given to this cube
−1205	Having another cube attribution, center value teach can not be given to this cube
−1206	Unknown cube parameter settings
−1207	Having another cube attribution, can not set the information to this cube
−1249	Wrong designating number of key acquisition
−1250	The Teaching data specified by Key doesn't have the specified ID attribute
−1251	Designated teaching point doesn't have JUMP data
−1252	The Teaching data specified by Key doesn't have the number's JUMP data
−1253	The Teaching point specified by ID attribute doesn't have JUMP data
−1254	JUMP data set in teaching point attribute not found
−1255	Wrong parameter for retrieving and setting JUMP data
−1256	Wrong parameter for retrieving and setting JUMP data
−1300	Socket generation failure
−1311	Failed to bind socket and address
−1312	Listen failure
−1313	Accept failure
−1314	Socket sending failure
−1315	Not used
−1316	Too many connected clients
−1350	The motion velocity of the parameter is exceeding the velocity limit. Invalid parameter

（2）Error Information (Level 1) →Brake is active (Communication status continuing)

Errors occurring when in arm motion controller operation.
With an uncontrollable error, control status changes into a brake-stop status.

Error No.	Details
-2017	Exceeding RMRC controllable arm length during the motion
-2020	S1 axis exceeding axis limit angle
-2021	S2 axis exceeding axis limit angle
-2022	S3 axis exceeding axis limit angle
-2023	E1 axis exceeding axis limit angle
-2024	E2 axis exceeding axis limit angle
-2025	W1 axis exceeding axis limit angle
-2026	W2 axis exceeding axis limit angle
-2030	S1 axis exceeding angle limit in direct control
-2031	S2 axis exceeding angle limit in direct control
-2032	S3 axis exceeding angle limit in direct control
-2033	E1 axis exceeding angle limit in direct control
-2034	E2 axis exceeding angle limit in direct control
-2035	W1 axis exceeding angle limit in direct control
-2036	W2 axis exceeding angle limit in direct control
-2051	Can not turn into RMRC control from the current position
-2060	S1 resolver deviation error
-2061	S2 resolver deviation error
-2062	S3 resolver deviation error
-2063	E1 resolver deviation error
-2064	E2 resolver deviation error
-2065	W1 resolver deviation error
-2066	W2 resolver deviation error
-2070	Stopped automatically by exceeding checking time
-2071	Did not reach target value
-2080	S1 Axis Sync. Error (Exceeding deviation limit)
-2081	S2 Axis Sync. Error (Exceeding deviation limit)
-2082	S3 Axis Sync. Error (Exceeding deviation limit)
-2083	E1 Axis Sync. Error (Exceeding deviation limit)
-2084	E2 Axis Sync. Error (Exceeding deviation limit)
-2085	W1 Axis Sync. Error (Exceeding deviation limit)
-2086	W2 Axis Sync. Error (Exceeding deviation limit)
-2087	X axis synchronization error in RMRC control
-2088	Y axis synchronization error in RMRC control
-2089	Z axis synchronization error in RMRC control
-2090	Velocity deviation error
-2091	Tip orientation deviation error in RMRC control
-2100	Interfering to cube
-2200	Motion can not be continued or started at the arm singular point
-2201	Motion can not be continued or started at the arm singular point
-2202	Motion can not be continued or started at the arm singular point

(3) Error Information (Level 2) →Brake is active (Communication terminated)

Errors occurring in arm servo driver. Control status changes into a brake-stop status.

Error No.	Details
-3000	Control not started
-3001	Emergency stop has been pressed
-3002	Arc net communication error
-3003	S1 limit switch error
-3005	Servo driver type doesn't match designated parameter
-3070	**Communication integral servo (master) status error**
-3071	**Servo driver (S1) status error**
-3072	**Servo driver (S2) status error**
-3073	**Servo driver (S3) status error**
-3074	**Servo driver (E1) status error**
-3075	**Servo driver (E2) status error**
-3076	**Servo driver (W1) status error**
-3077	**Servo driver (W2) status error**
-3091	Error at issuing communication/control start command
-3092	Error at issuing communication/ control terminate command
-3093	Error at issuing initializing command
-4000	Mode management error

Anomalous servo status is shown when **occurring alarm** is not 00H.

Reference

Refer to each servo status.

Communication control (master) CPU status:

bit	Error details		Movement when in anomalous status
15			
14	Control Mode	1:Non control mode	
		0:Control mode	
13	Limit switch status	1:limit switch off	
		0:limit switch on	
12	Switch status during teaching	1:Switch on during teaching	
		0:Switch off during teaching	
11 | 4	Occurring alarm	0x00 Normal	
		0x01	
		0x02 Anomalous EEPROM	Do not convert to control mode (*1)
		0x03 Anomalous ARCNET initialization	
		0x04 Anomalous CPU	Converts to adjustment/ stop mode. (*1)
		0x05 Anomalous upper controller communication cycle	
		0x06 Anomalous power supply temperature	
		0x07 Anomalous 100V output	
		:	
		0x10 Anomalous other CPU	Converts to adjustment/ stop mode.
		0x11 Emergency stop switch on	
		0x12 Dead man switch off	
		0x13 Limit switch on	
		:	
3	Emergency stop switch status	1:Emergency stop switch off	
		0:Emergency stop switch on	
2	100V generating status	1:Generating 100V power	
		0:Stop generating 100V power	
1	power supply temperature status	1:Anomalous power supply temperature	
		0:Normal	
0	Dead man switch status	1:Dead man switch on	
		0:Dead man switch off	

(*1) If alarm at 0x02～0x07 occurs in communication control CPU, it is different from any other CPU anomaly. Servo CPU instantly stops arm motion with "brake on/servo off."

Servo driver (S1 ～ W2) status:

bit	bit	Error details	
15	Servo ON/OFF	1：Servo OFF（Brake ON）	
		0：Servo ON（Brake OFF）	
14	Control Mode	1：Non control mode	
		0：Control mode	
13			
12			
11 | 4	Occurring alarm	0x00 Normal	
		0x01 Anomalous shared memory	Do not convert to control mode
		0x02 Anomalous EEPROM	Do not convert to control mode
		0x03	
		0x04 Anomalous CPU	
		0x05 Anomalous communication CPU transmission cycle	
		0x06 Anomalous velocity deviation	
		0x07 Anomalous resolver deviation	Brake on/servo off
		0x08 Anomalous position limit exceeded	Brake on/servo off
		0x09 Anomalous motor torque	
		0x0A Anomalous IPM	
		0x0B Anomalous brake severance/short-circuit	
		0x0C Anomalous resolver (motor side) severance/short-circuit	
		0x0D Anomalous resolver (gear side) severance/short-circuit	
		0x0E Anomalous overcurrent	
		0x0F Anomalous overvelocity	
		0x10 Anomalous different CPU	
		0x11 Emergency stop switch on	Servo lock when in anomaly occurrence,
		0x12 Dead man switch off	After a certain time, brake-on.
		0x13 Limit switch on	After a certain time, servo-off.
		:	
		0xFF Anomalous communication cycle (*1)	
3			
2			
1	Forbidden status − side drive	1：Angle − side limit operation	forbidden − side drive
		0：Normal	
0	Forbidden status + side drive	1：Angle + side limit operation	forbidden + side drive
		0：Normal	

(*1) Anomalous communication cycle: servo CPU always provides CPU information in constant cycle to communication control CPU. If this information transmission stops for a certain time, communication control CPU recognizes its servo CPU as anomalous communication cycle.

(Example) For 0xC060

0x C 06 0

C : (Control mode) →Servo OFF + Non control mode
06 : (Current alarm) →Anomalous velocity deviation
0 : (Drive forbidden) →Normal

Chapter 7 Library Reference

Chapter 7 & 8 are for PA library reference.

Regarding a header file, two types below are explained to be included following an application development language.

- ・Visual C++ (Windows)
- ・Visual BASIC (Windows)

For function reference, it is explained as C programming language.

＜Header file for　Visual C++ (Windows)＞

・Data types with specific significance:

typedef　float　MATRIX[3][4]; 3×4 matrix indicating the tip position/orientation, etc.

$$\begin{pmatrix} nx & ox & ax & px \\ ny & oy & ay & py \\ nz & oz & az & pz \end{pmatrix}$$

typedef　float　NOAMAT[3][3];　3×3 matrix indicating the tip orientation,

$$\begin{pmatrix} nx & ox & ax \\ ny & oy & ay \\ nz & oz & az \end{pmatrix}$$

typedef　float　VECTOR[3];　Tip position vector, etc.

(px, py, pz)

・Data types when in processing end:

#define　WM_WAIT0　Returns from function after processing ends.
#define　WM_NOWAIT　1　Returns from function before processing ends.

PA library Data Structure（for Windows Visual C++)

・Axis data structure：　6-axis/7-axis angle storing structure:

```
typedef struct {
        float s1;        S1 axis value [rad]
        float s2;        S2 axis value [rad]
        float s3;        S3 axis value [rad]
        float e1;        E2 axis value [rad]
        float e2;        E3 axis value [rad]
        float w1;        W1 axis value [rad]
        float w2;        W2 axis value [rad]
}ANGLE, *ANGLEP;
```

・Arm Status Structure*：　Structure set by the motion controller:*

```
typedef struct {
        long     max;         Board controllable arm numbers   1or2
        long     arm;         Arm identification number 0or1
        long     axis;        Arm axis numbers
        long     typ;         Arm type
        long     drv;         Servo driver classification
        long     dio;         Extension DIO board   exist / not exist
        long     remote;      operation mode (valid / invalid)
        long     count;       Control counter value
        long     error;       Error code
        ANGLE    angle;       Current axis value
        MATRIX   noap;        Current tip orientation matrix
        float    ypr[3];      Current orientation
}ARMSTATUS, *ARMSTATUSP;
```

PA library Data Structure（for Windows Visual C++)

・Parameter Structure:

```
typedef struct{
        float    rezl;            Resolver resolution
        long     pul[7];          Position limiter(＋)
        long     pdl[7];          Position limiter(－)
        long     vel[7+2];        Velocity limiter
        long     dev[7+2];        Default velocity
        float    lim[7 + 2];
        float    ceh[7 + 2];
        float    cem[7 + 2];
        float    cel[7 + 2];
        float    pg1[7];          Position control gain1
        float    pg2[7];          Position control gain2
        float    vg1[7];          Velocity control gain
        float    tg1[7];          Force control gain
        float    pcm[7];          position control selection matrix
        float    fcm[7];          Force control selection matrix
        float    arl[7];          Arm length
        float    arg[7];          Axis gravity center position
        float    arw[7];          Axis weight
        float    hom[7];          Home position recovery target value
        float    saf[7];          Safety position recovery target value
        float    esc[7];          Escape position recovery target value
        float    tol[7];          Tool parameter
        float    fvl[7];
        long     dmy[7];
        long     spa[7];          Spare
}PARAM, *PARAMP;
```

・Digital I/O Sstructure:

```
typedef struct{
        unsigned char    io1;
        unsigned char    io2;
        unsigned char    io3;
        unsigned char    io4;
}DIOSTATUS, *DIOSTATUSP;
```

PA library Data Structure（for Windows Visual C++）

・Teach data structure:

```
typedef struct {
        float    agl[7];    S1 axis value
                            S2 axis value
                            S3 axis value
                            E1 axis value
                            E2 axis value
                            W1 axis value
                            W2 axis value
        float    vel[2];    Tip linear motion velocity[mm/sec]
                            Axis /Tip rotational motion velocity [rad/sec]
        long     atr[12];   Teach data type：PTP／PTP(NOAP)
                            Interpolation method：Axis/Straight line/Circle/Arc
                            Axis control arm stop accuracy[]
                            RMRC control arm stop accuracy []
                            Velocity interpolation pattern：Constant
                                    velocity/start up/shutdown/start up +
                                    shutdown
                            Start up time : Acceleration time designation[msec]
                            Shutdown time : Deceleration time designation [msec]
                            JUMP data number : Number specifying JUNP
                            condition
                            DO output
                            Waiting time : Motion start delay time[msec]
}PNTPNT, *PNTPNTP;


typedef struct {
        PLYPNT   pnt;
        char     cmt[32];           Comment
} PLAY, *PLAYP;


typedef struct {
        float    xyz[3];            Position : Arm XYZ coordinate [mm]
        float    noa[3][3];         Position  ：Arm NOA
} NOAP, *NOAPP;
```

PA library Data Structure　(for Windows Visual C++)

・JUMP Data Structure:

```
typedef struct {
        long     cnd[2];   JUMP conditional number
                           Spare
        long     xdi;      DI condition for Conditional appraisal
        long     tim;      Time out
        long     key;      JUMP destination teach data Key
        long     pid;      JUMP destination teach point ID
        long     cnt;
}JUDGE, *JUDGEP;


typedef struct {
        long     cid;
        JUDGE    jdg[8];
}JUMP, *JUMPP;



typedef struct {           . . . . Teach data structure
        PLAY     ply;
        NOAP     noa;
        JUMP     jmp;
}PNTDAT, *PNTDATP;
```

PA library Data Structure　(for Windows Visual C++)

・Sensor correction data structure:

```
typedef struct {
        long    Enable;     Designation bit
        float   _xyz[3];    Mechanical interface coordinate absolute
                            deviation correction value
        float   Ixyz[3];    Mechanical interface coordinate relative
                            deviation correction value
        float   _XYZ[3];    Base coordinate absolute deviation
                            correction value
        float   IXYZ[3];    Base coordinate relative deviation correction
                            value
        float   _wave[3];   Trajectory coordinate absolute deviation
                            correction value
        float   Iwave[3];   Trajectory coordinate relative deviation
                            correction value
} TRANSMAT, *TRANSMATP;
```

・Arm target value structure:

```
typedef struct {
        ANGLE       angle;   Target value
        MATRIX      noap;    Tip position/orientation matrix
        float       ypr[3];  Tip position
} ARMTARGET, *ARMTARGETP;
```

・Structure to send commands from the motion control to the servo driver:

```
typedef struct {
        long    sig;
        long    trq;
        long    vel;
} O8DRIVE;
```

・Structure to send commands from the servo driver to the motion control:

```
typedef struct {
        long    sts;
        long    agl;
        long    vel;
        long    trq;
} I8DRIVE;
```

PA library Data Structure　(for Windows Visual C++)

・CUBE information structure

```
typedef struct{
        long     ena;        Cube information Valid/Invalid
        long     mod;        Mode when in cube creation
        float    max[3];     Maximum value／Side length
        float    min[3];     Minimum value／Center
        char     cmt[32];    Comment
} CUBE, *CUBEP;
```

・Debug structure:

```
typedef struct {
        long     ldbg[16];
        float    fdbg[32];
} DEBG, *DEBGP;
```

PA library characteristic type definition（for Windows Visual C++）

・Data transmission format numbers:

```
#define   COM_FMT00   0
#define   COM_FMT01   1
#define   COM_FMT02   2
#define   COM_FMT03   3
#define   COM_FMT04   4
#define   COM_FMT05   5
#define   COM_FMT06   6
#define   COM_FMT07   7
#define   COM_FMT08   8
#define   COM_FMT09   9
#define   COM_FMT10   10
#define   COM_FMT11   11
```

・Arm classification：Control arm number selection:

```
typedef unsigned  long     ARM;
#define   ARM0    (ARM)0      Arm No. 0 selection
#define   ARM1    (ARM)1      Arm No. 1 selection
#define   ARM2    (ARM)2      Arm No. 2 selection
#define   ARM3    (ARM)3      Arm No. 3 selection
#define   ARM4    (ARM)4      Arm No. 4 selection
#define   ARM5    (ARM)5      Arm No. 5 selection
#define   ARM6    (ARM)6      Arm No. 6 selection
#define   ARM7    (ARM)7      Arm No. 7 selection
#define   ARM8    (ARM)8      Arm No. 8 selection
#define   ARM9    (ARM)9      Arm No. 9 selection
#define   ARM10   (ARM)10     Arm No. 10 selection
#define   ARM11   (ARM)11     Arm No. 11 election
#define   ARM12   (ARM)12     Arm No. 12 selection
#define   ARM13   (ARM)13     Arm No. 13 selection
#define   ARM14   (ARM)14     Arm No. 14 selection
#define   ARM15   (ARM)15     Arm No. 15 selection
```

PA library characteristic type definition（for Windows Visual C++）

・Axis classification：Control axis number selection:

```
typedef   unsigned  long      AXIS;
#define   S1        (AXIS)0x01          S1 axis designation
#define   S2        (AXIS)0x02          S2 axis designation
#define   S3        (AXIS)0x04          S3 axis designation
#define   E1        (AXIS)0x08          E2 axis designation
#define   E2        (AXIS)0x10          E3 axis designation
#define   W1        (AXIS)0x20          W1 axis designation
#define   W2        (AXIS)0x40          W2 axis designation

#define   AXISALL         (S1|S2|S3|E1|E2|W1|W2)
#define   ALLAXIS         (S1|S2|S3|E1|E2|W1|W2)
#define   LOCKAXIS_S1     (S2|S3|E1|E2|W1|W2)
#define   LOCKAXIS_S3     (S1|S2|E1|E2|W1|W2)
```

・Servo driver classification：Control servo driver number selection:

```
typedef   unsigned  long      DRIVER;
#define   DRV1      (DRIVER)0           Servo driver 1 (S1, S2)
#define   DRV2      (DRIVER)1           Servo driver 2 (S3, E1)
#define   DRV3      (DRIVER)2           Servo driver 3 (E2, W1)
#define   DRV4      (DRIVER)3           Servo driver 4 (W2)
```

PA library characteristic type definition (for Windows Visual C++)

・Playback motion classification:

```
typedef   unsigned long     PLAYBACK;
#define   PB_FORES          (PLAYBACK)0      Forward playback step motion
#define   PB_FOREB          (PLAYBACK)1      Not available
#define   PB_FORE           (PLAYBACK)2      Forward playback consecutive
                                              motion
#define   PB_BACK           (PLAYBACK)3      Reverse playback consecutive
                                              motion
```

・Teach data deletion operation classification:

```
typedef   unsigned long     PNTDEL;
#define   PD_CUR            (PNTDEL)0x7500   Current point teach data deletion
#define   PD_FORE           (PNTDEL)0x7501   Previous current point teach data
                                              deletion
#define   PD_ALL            (PNTDEL)0x7502   All active teach data deletion
#define   PD_ALLDATA        (PNTDEL)0        All teach data deletion
```

・Teach data attribution alteration classification:

```
typedef   unsigned long     PNTATTR;
#define   PA_CHGVEL         (PNTATTR)0x7300  Linear velocity alteration
#define   PA_CHGWAIT        (PNTATTR)0x7301  Wait time alteration
#define   PA_VELPTN         (PNTATTR)0x7302  Velocity interpolation
#define   PA_ROTVEL         (PNTATTR)0x7303  Rotational velocity alteration
#define   PA_AXSACC         (PNTATTR)0x7304  Each axis precision
#define   PA_RMRCACC        (PNTATTR)0x7305  Straight line precision
#define   PA_JUMPID         (PNTATTR)0x7306  JUMP conditional number
```

・Teach data type classification:

```
typedef   unsigned long     PNTTYPE;
#define   PT_CP     (PNTTYPE)0x710    Not available
#define   PT_PTP    (PNTTYPE)0x7101   Loading axis value for linear interpolation
#define   PT_BCP    (PNTTYPE)0x7102   Not available
#define   PT_BPTP   (PNTTYPE)0x7103   Linear interpolation axis value insertion
#define   PT_ARC1   (PNTTYPE)0x7104   Arc 1st point axis value loading
#define   PT_ARC2   (PNTTYPE)0x7105   Arc 2nd point axis value loading
#define   PT_ARC3   (PNTTYPE)0x7106   Arc 3rd point axis value loading
#define   PT_CIR1   (PNTTYPE)0x7107   Circle 1st point axis value loading
#define   PT_CIR2   (PNTTYPE)0x7108   Circle 2nd point axis value loading
#define   PT_CIR3   (PNTTYPE)0x7109   Circle 3rd point axis value loading
#define   PT_AXS    (PNTTYPE)0x710a   Loading axis value for axis interpolation
#define   PT_BAXS   (PNTTYPE)0x710b   Inserts axis value for axis interpolation
#define   PT_POS    (PNTTYPE)0x710c   Loading NOAP for linear interpolation
#define   PT_BPOP   (PNTTYPE)0x710d   Inserts NOAP for linear interpolation
#define   PT_ARC4   (PNTTYPE)0x710e   Arc 1st point NOAP loading
#define   PT_ARC5   (PNTTYPE)0x710f   Arc 2nd point NOAP loading
#define   PT_ARC6   (PNTTYPE)0x7110   Arc 3rd point axis value loading
#define   PT_CIR4   (PNTTYPE)0x7111   Circle 1st point NOAP loading
#define   PT_CIR5   (PNTTYPE)0x7112   Circle 2nd point NOAP loading
#define   PT_CIR6   (PNTTYPE)0x7113   Circle 3rd point NOAP loading
```

PA library characteristic type definition (for Windows Visual C++)

・Teach data pointer operation classification:

typedef	unsigned long	PNTMOVE;	
#define	PM_TOP	(PNTMOVE)0x7100	Moves pointer to top.
#define	PM_NEXT	(PNTMOVE)0x7101	Pointer forward, once.
#define	PM_PRIV	(PNTMOVE)0x7102	Pointer backward, once.
#define	PM_BTM	(PNTMOVE)0x7103	Moves pointer to bottom.
#define	PM_JMP	(PNTMOVE)0x7104	Moves pointer to designated number.
#define	PM_CIR	(PNTMOVE)0x7105	Circle teach point searched, moving pointer to teach point found first.
#define	PM_ARC	(PNTMOVE)0x7106	Arc teach point searched, moving pointer to teach point found first.

・Default velocity alteration classification:

typedef	unsigned long	VELTYPE;	
#define	VT_ONEVEL	(VELTYPE)0	Each axis default velocity alteration
#define	VT_XYZVEL	(VELTYPE)1	Tip position default velocity alteration
#define	VT_YPRVEL	(VELTYPE)2	Tip orientation default velocity alteration

・Velocity control mode classification:

typedef	unsigned long	VELMODE;	
#define	VM_XYZ	(VELMODE)0x200	Base coordinate linear velocity control
#define	VM_YPR	(VELMODE)0x201	Base coordinate rotational velocity control
#define	VM_xyz	(VELMODE)0x202	Mechanical interface coordinate linear velocity control
#define	VM_ypr	(VELMODE)0x203	Mechanical interface coordinate rotational velocity control
#define	VM_ONE	(VELMODE)0x204	Each axis velocity control
#define	VM_XYZYPR	(VELMODE)0x205	Base coordinate linear/rotational velocity control
#define	VM_xyzypr	(VELMODE)0x206	Mechanical interface coordinate linear/rotational velocity control

PA library characteristic type definition (for Windows Visual C++)

・Redundant axis control mode classification:

7-axis arm function

typedef	unsigned long	JOUMODE;	
#define	JM_SET	(JOUMODE)0x345	Redundant axis control parameter operation start
#define	JM_RESET	(JOUMODE)0x346	Redundant axis control parameter reset
#define	JM_VSET	(JOUMODE)0x347	Redundant axis velocity control mode
#define	JM_ON	(JOUMODE)0x348	Redundant axis control all axes restriction mode
#define	JM_OFF	(JOUMODE)0x349	Redundant axis control restriction release
#define	JM_S3ON	(JOUMODE)0x34a	Redundant axis control only S3 axis restriction mode
#define	JM_S3DIV	(JOUMODE)0x34b	Redundant axis control S3 axis interpolation restriction mode
#define	JM_S3HOLD	(JOUMODE)0x34c	Redundant axis control S3 axis fixation restriction mode

typedef	unsigned long	JOUTYPE;	
#define	JT_RIGHT	(JOUTYPE)1	Moves redundant axis restriction parameter to the right.
#define	JT_HOLD	(JOUTYPE)0	Holds redundant axis restriction parameter.
#define	JT_LEFT	(JOUTYPE)-1	Moves redundant axis restriction parameter to the left.

・Target tip matrix control mode classification:

typedef	unsigned long	MOVEMODE;	
#define	MM_XYZ	(MOVEMODE)0x5680	Tip position control
#define	MM_NOA	(MOVEMODE)0x5681	Tip orientation control
#define	MM_XYZNOA	(MOVEMODE)0x5682	Tip position/orientation control

PA library characteristic type definition (for Windows Visual C++)

・Direct control classification: (Optional function)

```
typedef   unsigned long   DIRECTMODE;
#define   DM_STOP         (DIRECTMODE)0   Direct control stop
#define   DM_START        (DIRECTMODE)1   Direct control start
#define   ARM_STANDING    1               Floor mounted
#define   ARM_HANGING     -1              Suspending from ceiling
```

・DIO port numbers:

```
typedef   unsigned long   DIOPORT;
#define   DP_PORT1        (DIOPORT)0      DIO 1 port selection
#define   DP_PORT2        (DIOPORT)1      DIO 2 port selection
#define   DP_PORT3        (DIOPORT)2      DIO 3 port selection
#define   DP_PORT4        (DIOPORT)3      DIO 4 port selection
#define   DPO_PORT1       (DIOPORT)4      DO 1 port selection
#define   DPO_PORT2       (DIOPORT)5      DO 2 port selection
#define   DPO_PORT3       (DIOPORT)6      DO 3 port selection
#define   DPO_PORT4       (DIOPORT)7      DO 4 port selection
#define   DPX_PORT1       (DIOPORT)8      DO 1 port selection
#define   DPX_PORT2       (DIOPORT)9      DO 2 port selection
#define   DPX_PORT3       (DIOPORT)10     DO 3 port selection
#define   DPX_PORT4       (DIOPORT)11     DO 4 port selection
```

Memo

DPO_XXXXX is used when acquiring contents set to be outputted by PA library.

DPX_XXXXX is used when acquiring current output value (related to information in PA library or playback data).

・DIO channel numbers:

```
typedef   unsigned long   DIOCH;
#define   DC_CH1  (DIOCH)0    Channel 1 selection
#define   DC_CH2  (DIOCH)1    Channel 2 selection
#define   DC_CH3  (DIOCH)2    Channel 3 selection
#define   DC_CH4  (DIOCH)3    Channel 4 selection
#define   DC_CH5  (DIOCH)4    Channel 5 selection
#define   DC_CH6  (DIOCH)5    Channel 6 selection
#define   DC_CH7  (DIOCH)6    Channel 7 selection
#define   DC_CH8  (DIOCH)7    Channel 8 selection
```

PA library characteristic type definition (for Windows Visual C++)

・Sensor correction coordinate classification:

```
typedef   unsigned long     TRANSMODE;
#define   MODE_xyz          (TRANSMODE)0x01     Adds absolute correction
                                                value in the mechanical
                                                interface coordinate
                                                system
#define   MODEIxyz          (TRANSMODE)0x02     Adds relative correction
                                                value in the mechanical
                                                interface coordinate
                                                system
#define   MODE_XYZ          (TRANSMODE)0x04     Adds absolute correction
                                                value in the base
                                                coordinate system
#define   MODEIXYZ          (TRANSMODE)0x08     Adds relative correction
                                                value in the base
                                                coordinate system
#define   MODE_wave         (TRANSMODE)0x10     Adds absolute correction
                                                value in the trajectory
                                                coordinate system
#define   MODEIwave         (TRANSMODE)0x20     Adds relative correction
                                                value in the trajectory
                                                coordinate system
```

・Teach point attribute designation:

```
typedef   unsigned long          PNTID;
#define   PA_SETID          (PNTID)0x7304
```

・Circle & arc teach point number designation:

```
typedef   unsigned long     PNTNO;
#define   PN_1              (PNTNO)1
#define   PN_2              (PNTNO)2
#define   PN_3              (PNTNO)3
```

・JUMP data valid/invalid (in teach data)

```
typedef unsigned long       JUMPONOFF;
#define JMP_ON        (JUMPONOFF)1        Valid
#define JMP_OFF       (JUMPONOFF)0        Invalid
```

・JUMP data valid/invalid (in JUMP data)

```
typedef unsigned long       JUMPENABLEDISABLE;
#define   JMPENABLE         (JUMPENABLEDISABLE)0x01000000   Valid
#define   JMPDISABLE        (JUMPENABLEDISABLE)0x00000000   Invalid
```

PA library characteristic type definition (for Windows Visual C++)

・JUMP Command

```
typedef unsigned long    JUMPORDER;
#define  NO_JUMP         (JUMPORDER)0x00010000  Unconditional JUMP
#define  DI_JUMP         (JUMPORDER)0x00020000  DI conditional JUMP
#define  DI_WAITJUMP     (JUMPORDER)0x00030000  DI conditional WAITJUMP
#define  DI_WAIT         (JUMPORDER)0x00040000  DI conditional WAIT
```

・JUMP Conditional Logic

```
typedef unsigned long    JUMPDILOGIC;
#define  LEVEL_ON        (JUMPDILOGIC)0x00000100
#define  LEVEL_OFF       (JUMPDILOGIC)0x00000200
#define  EDGE_ON         (JUMPDILOGIC)0x00000400
#define  EDGE_OFF        (JUMPDILOGIC)0x00000800
```

・JUMP ticket-oriented DI

```
typedef unsigned long    DIOKIND;
#define  DIO_INTERNAL    (DIOKIND)0x00000000    System
#define  DIO_EXTERNAL    (DIOKIND)0x00000001    User
```

・Teaching place when in CUBE creation:

```
typedef unsigned long    CUBEPNT;
#define MAXPNT           (CUBEPNT)1
#define MINPNT           (CUBEPNT)2
#define CENTERPNT        (CUBEPNT)3
```

・Mask setting:

```
typedef unsigned long    DIOMASK;
#define  DIMSK           (DIOMASK)0
#define  DOMSK           (DIOMASK)1
```

・RETRAC ON/OFF:

```
typedef unsigned long    RETRAC;
#define RETRACOFF      (RETRAC)0
#define RETRACON       (RETRAC)1
```

PA library characteristic type definition （for Windows Visual C++）

・CUBE information:

```
typedef unsigned long      CUBEINFO;
#define NOCUBE             (CUBEINFO)0x00000000
#define CUBEON             (CUBEINFO)0x00000001
#define CUBEMAX            (CUBEINFO)0x00000002
#define CUBEMIN            (CUBEINFO)0x00000004
#define CUBECENTER         (CUBEINFO)0x00000008
#define CUBESIDE           (CUBEINFO)0x00000010
```

・TEACH MODE

```
typedef unsigned long      TEACHMODE;
#define  TEACH_OFF         (TEACHMODE)0
#define  TEACH_LOW         (TEACHMODE)1
#define  TEACH_MID         (TEACHMODE)2
#define  TEACH_HIGH        (TEACHMODE)3
```

・TEACH LOCK

```
typedef unsigned long      TEACHLOCK;
#define LOCK_OFF       (TEACHLOCK)0
#define LOCK_ON        (TEACHLOCK)1
```

・Communication status with servo driver:

```
typedef unsigned long      COMSTATUS;
#define STP_STATUS         (COMSTATUS)0
#define MOV_STATUS         (COMSTATUS)1
#define SIM_STATUS         (COMSTATUS)2
```

・for RETRAC:

```
#define  MOD_ROBFILE     1
#define  MOD_TOLFILE     2
```

・for Dead man switch:

```
#define SET_DDM  3
```

＜ Header file for Visual BASIC (Windows)＞

・Data type when in processing end:_

Public Const WM_WAIT	As Long = 0	Returns from function after processing ends.
Public Const WM_NOWAIT	As Long = 1	Returns from function before processing ends.

PA library data structure (for Windows Visual BASIC)

・Axis data structure : 6-axis/7-axis angle storing structure

```
Type ANGLE
        S1   As Single          S1 axis value [rad]
        S2   As Single          S2 axis value [rad]
        S3   As Single          S3 axis value [rad]
        E1   As Single          E1 axis value [rad]
        E2   As Single          E2 axis value [rad]
        W1   As Single          W1 axis value [rad]
        W2   As Single          W2 axis value [rad]
End Type
```

・Arm status structure: Structure set by the motion controller

```
Type ARMSTATUS
   max          As Long        Board controllable arm numbers   1or2
   ARM          As Long        Arm identification number        0or1
   Axnum        As Long        Arm axis numbers
   typ          As Long        Arm type
   drv          As Long        Servo driver classification
   dio          As Long        Extension DIO board   exist / not exist
   remote       As Long        operation mode (valid / invalid)
   count        As Long        Control counter value
   error        As Long        Error code
   agl          As ANGLE       Current axis value
   NOAP(3, 2)   As Single      Current tip orientation matrix
   ypr(2)       As Single      Current orientation
End Type
```

PA library data structure (for Windows Visual BASIC)

・Parameter Structure:

```
Type PARAM
        rezl      As Single     Resolver resolution
        pul(6)    As Long       Position limiter (+)
        pdl(6)    As Long       Position limiter (-)
        vel(8)    As Long       Velocity limiter
        dev(8)    As Long       Default velocity
        lim(8)    As Single     Teach mode velocity limit
        ceh(8)    As Single     Teach mode fast motion velocity
        cem(8)    As Single     Teach mode medium motion velocity
        cel(8)    As Single     Teach mode slow motion velocity
        pg1(6)    As Long       Position control gain1
        pg2(6)    As Long       Position control gain2
        vg1(6)    As Long       Velocity control gain
        tg1(6)    As Long       Force control gain
        pcm(6)    As Long       position control selection matrix
        fcm(6)    As Long       Force control selection matrix
        arl(6)    As Long       Arm length
        arg(6)    As Long       Axis gravity center position
        arw(6)    As Long       Axis weight
        rfp(6)    As Long       Home position recovery target value
        rsp(6)    As Long       Escape position recovery target value
        rop(6)    As Long       Recovery target value for other points
        tol(6)    As Long       Tool parameter
        fvl(6)    As Single     Control parameter
        dmy(6)    As Long       Not available
        spa(6)    As Long       Spare
End Type
```

PA library data structure (for Windows Visual BASIC)

・Teach data structure:

```
Type PNTPNT
        agl(6)   As Single          S1 axis value
                                    S2 axis value
                                    S3 axis value
                                    E1 axis value
                                    E2 axis value
                                    W1 axis value
                                    W2 axis value
        vel(1)   As Single          Tip linear motion velocity
                                    Tip rotational motion velocity
        atr(11) As Long             Teach data type: PTP/PTP(NOAP)
                                    Interpolation method: Axis/Straight
                                                   line/Circle/Arc
                                    Axis control arm stop accuracy []
                                    RMRC control arm stop accuracy []
                                    Velocity interpolation pattern:
                                         Constant velocity/start
                                         up/shutdown/start up + shutdown
                                    Start up time: Acceleration time designation
                                              [msec]
                                    Shutdown time: Deceleration time
                                              designation [msec]
                                    JUMP data number:
                                         Number specifying JUNP condition
                                         DO output
                                    Waiting time : Motion start delay time [msec]
End Type


Type PLAY
        pnt       As PLYPNT
        cmt       As String * 32    Comment
End Type


Type NOAP
        xyz(2)      As Single       Position: Arm XYZ coordinate [mm]
        noa(2, 2)   As Single       Position  : Arm NOA
End Type
```

PA library data structure (for Windows Visual BASIC)

・JUMP Data Structure:

```
Type JUDGE
        cnd(1) As Long      JUMP conditional number Spare
        xdi As Long         DI condition for Conditional appraisal
        tim As Long         Time out
        key As Long         JUMP destination teach data Key
        pid As Long         JUMP destination teach point ID
        cnt As Long
End Type

Type JUMP
        cid As Long
        jdg(7) As JUDGE
End Type

Type PNTDATA
        ply     As      PLAY
        noa     As      NOAP
        jmp     As      JUMP
End Type
```

・Digital I/O structure:

```
Type DIOSTATUS
        Io1     As Byte         DIO (tool) 1 value
        Io2     As Byte         DIO (tool) 2 value
        Io3     As Byte         DIO (tool) 3 value
        Io4     As Byte         DIO (tool) 4 value
End Type
```

PA library data structure (for Windows Visual BASIC)

・Sensor correction data structure:

```
Type TRANSMAT
    Enable        As Long   Designation bit
    xyz11(2)      As Single Mechanical interface coordinate absolute deviation
                            correction value
    xyz12(2)      As Single Mechanical interface coordinate relative deviation
                            correction value
    xyz21(2)      As Single Base coordinate absolute deviation correction value
    xyz22(2)      As Single Base coordinate relative deviation correction value
    wave1(2)      As Single Trajectory coordinate absolute deviation correction
                            value
    wave2(2)      As Single Trajectory coordinate relative deviation correction
                  value
End Type
```

・Arm target value structure:

```
Type ARMTARGET
        agl           As ANGLE        Target angle
        noap(3, 2)    As Single       Target tip position/orientation
        ypr(2)        As Single       Target tip orientation
End Type
```

・Structure to send commands from the motion control to the servo driver:

```
Type O8DRIVE
        sig As Long
        trq As Long
        vel As Long
End Type
```

・Structure to send commands from the servo driver to the motion control:

```
Type I8DRIVE
        sts As Long
        agl As Long
        vel As Long
        trq As Long
End Type
```

PA library data structure (for Windows Visual BASIC)

・CUBE information structure:

```
Type CUBE
        ena      As Long            Cube information valid/invalid
        mod      As Long            Mode when in cube creation
        max(2)   As Single          Maximum value／Side length
        min(2)   As Single          Minimum value／Center
        cmt      As String * 32     Comment
End Type
```

・Debug structure:

```
Type DEBG
        ldbg(15)     As Long
        fdbg(31)     As Single
End Type
```

PA library characteristic type definition (for Windows Visual BASIC)

・Arm classification:Control arm number selection:

Public Const ARM0 As Long = 0	Arm No. 0 selection
Public Const ARM1 As Long = 1	Arm No. 1 selection
Public Const ARM2 As Long = 2	Arm No. 2 selection
Public Const ARM3 As Long = 3	Arm No. 3 selection
Public Const ARM4 As Long = 4	Arm No. 4 selection
Public Const ARM5 As Long = 5	Arm No. 5 selection
Public Const ARM6 As Long = 6	Arm No. 6 selection
Public Const ARM7 As Long = 7	Arm No. 7 selection
Public Const ARM8 As Long = 8	Arm No. 8 selection
Public Const ARM9 As Long = 9	Arm No. 9 selection
Public Const ARM10 As Long = 10	Arm No. 10 selection
Public Const ARM11 As Long = 11	Arm No. 11 selection
Public Const ARM12 As Long = 12	Arm No. 12 selection
Public Const ARM13 As Long = 13	Arm No. 13 selection
Public Const ARM14 As Long = 14	Arm No. 14 selection
Public Const ARM15 As Long = 15	Arm No. 15 selection

・Axis classification:Control axis number selection:

Public Const S1 As Long = &H1	S1 axis designation
Public Const S2 As Long = &H2	S2 axis designation
Public Const S3 As Long = &H4	S3 axis designation
Public Const E1 As Long = &H8	E2 axis designation
Public Const E2 As Long = &H10	E3 axis designation
Public Const W1 As Long = &H20	W1 axis designation
Public Const W2 As Long = &H40	W2 axis designation

Public Const AXISALL	As Long = S1 + S2 + S3 + E1 + E2 + W1 + W2
Public Const LOCKAXIS_S1	As Long = S2 + S3 + E1 + E2 + W1 + W2
Public Const LOCKAXIS_S3	As Long = S1 + S2 + E1 + E2 + W1 + W2

・Servo driver classification:Control servo driver number selection:

Public Const DRV1 As Long = 0	Servo driver 1 (S1, S2)
Public Const DRV2 As Long = 1	Servo driver 1 (S3, E1)
Public Const DRV3 As Long = 2	Servo driver 1 (E2, W1)
Public Const DRV4 As Long = 3	Servo driver 1 (W2)

PA library characteristic type definition（for Windows Visual BASIC）

・Playback motion classification:

Public Const PB_FORES	As Long = 0	Forward playback step motion
Public Const PB_BACKS	As Long = 1	Not available
Public Const PB_FORE	As Long = 2	Forward playback consecutive motion
Public Const PB_BACK	As Long = 3	Reverse playback consecutive motion

・Teach data deletion operation classification:

Public Const PD_CUR	As Long = &H7500	Current point teach data deletion
Public Const PD_FORE	As Long = &H7501	Previous current point teach data deletion
Public Const PD_ALL	As Long = &H7502	All active teach data deletion
Public Const PD_ALLDATA	As Long = &H7502	All teach data deletion

・Teach data attribution alteration classification:

Public Const PA_CHGVEL	As Long = &H7300	Linear velocity alteration when in playback
Public Const PA_CHGWAIT	As Long = &H7301	Wait time alteration when in playback
Public Const PA_VELPTN	As Long = &H7302	Velocity interpolation pattern alteration when in playback
Public Const PA_ROTVEL	As Long = &H7303	Rotational velocity alteration when in playback
Public Const PA_AXSACC	As Long = &H7304	Each axis precision
Public Const PA_RMRCACC	As Long = &H7305	Straight line precision
Public Const PA_JUMPID	As Long = &H7306	JUMP conditional number

PA library characteristic type definition (for Windows Visual BASIC)

・Teach data type classification:

Public Const PT_CP	As Long = &H7100	Not available
Public Const PT_PTP	As Long = &H7101	PTP linear interpolation data loading
Public Const PT_BCP	As Long = &H7102	Not available
Public Const PT_BPTP	As Long = &H7103	PTP linear interpolation data insertion
Public Const PT_ARC1	As Long = &H7104	Arc 1st point data loading
Public Const PT_ARC2	As Long = &H7105	Arc 2nd point data loading
Public Const PT_ARC3	As Long = &H7106	Arc 3rd point data loading
Public Const PT_CIR1	As Long = &H7107	Circle 1st point data loading
Public Const PT_CIR2	As Long = &H7108	Circle 2nd point data loading
Public Const PT_CIR3	As Long = &H7109	Circle 3rd point data loading
Public Const PT_AXS	As Long = &H710A	PTP axis interpolation data loading
Public Const PT_BAXS	As Long = &H710B	PTP axis interpolation data insertion
Public Const PT_POS	As Long = &H710C	Linear interpolation NOAP loading
Public Const PT_BPOS	As Long = &H710D	Linear interpolation NOAP insertion
Public Const PT_ARC4	As Long = &H710E	Arc 1st point NOAP loading
Public Const PT_ARC5	As Long = &H710F	Arc 2nd point NOAP loading
Public Const PT_ARC6	As Long = &H7110	Arc 3rd point NOAP loading
Public Const PT_CIR4	As Long = &H7111	Circle 1st point NOAP loading
Public Const PT_CIR5	As Long = &H7112	Circle 2nd point NOAP loading
Public Const PT_CIR6	As Long = &H7113	Circle 3rd point NOAP loading

・Teach data pointer operation classification:

Public Const PM_TOP	As Long = &H7100	Moves pointer to top.
Public Const PM_NEXT	As Long = &H7101	Pointer forward, once.
Public Const PM_PRIV	As Long = &H7102	Pointer backward, once.
Public Const PM_BTM	As Long = &H7103	Moves pointer to bottom.
Public Const PM_JMP	As Long = &H7104	Moves pointer to designated number.
Public Const PM_CIR	As Long = &H7105	Circle teach point searched, moving pointer to teach point found first.
Public Const PM_ARC	As Long = &H7106	Arc teach point searched, moving pointer to teach point found first.

PA library characteristic type definition（for Windows Visual BASIC）

・Default velocity alteration classification:

Public Const VT_ONEVEL As Long = &H0		Each default velocity alteration
Public Const VT_XYZVEL As Long = &H1		Tip position default velocity alteration
Public Const VT_YPRVEL As Long = &H2		Tip orientation default velocity alteration

・Velocity control mode classification:

Public Const VM_XYZ1	As Long = &H200	Base coordinate linear velocity control
Public Const VM_YPR1	As Long = &H201	Base coordinate rotational velocity control
Public Const VM_XYZ2	As Long = &H202	Mechanical interface coordinate linear velocity control
Public Const VM_YPR2	As Long = &H203	Mechanical interface coordinate rotational velocity control
Public Const VM_ONE	As Long = &H204	Each axis velocity control
Public Const VM_XYZYPR1	As Long = &H205	Base coordinate linear/rotational velocity control
Public Const VM_XYZYPR2	As Long = &H206	Mechanical interface coordinate linear/rotational velocity control

・Redundant axis control mode classification:　　*7-axis arm function*

Public Const JM_SET	As Long = &H345	Redundant axis control parameter operation start
Public Const JM_RESET	As Long = &H346	Redundant axis control parameter reset
Public Const JM_VSET	As Long = &H347	Redundant axis velocity control mode
Public Const JM_ON	As Long = &H348	Redundant axis control all axes restriction mode
Public Const JM_OFF	As Long = &H349	Redundant axis control restriction release
Public Const JM_S3ON	As Long = &H34A	Redundant axis control only S3 axis restriction mode
Public Const JM_S3DIV	As Long = &H34B	Redundant axis control S3 axis interpolation restriction mode
Public Const JM_S3HOLD	As Long = &H34C	Redundant axis control S3 axis fixation restriction mode
Public Const JT_RIGHT	As Long = 1	Moves redundant axis restriction parameter to the right.
Public Const JT_HOLD	As Long = 0	Holds redundant axis restriction parameter.
Public Const JT_LEFT	As Long=-1	Moves redundant axis restriction parameter to the left.

PA library characteristic type definition (for Windows Visual BASIC)

・Target tip matrix control mode classification:

Public Const MM_XYZ	As Long = &H5680	Tip position control
Public Const MM_NOA	As Long = &H5681	Tip orientation control
Public Const MM_XYZNOA	As Long = &H5682	Tip position/orientation control

・Direct control classification: (Optional function)

Public Const DM_STOP	As Long = 0	Direct control stop
Public Const DM_START	As Long = 1	Direct control start
Public Const ARM_STANDING	As Long = 1	Floor mounted
Public Const ARM_HANGING	As Long = -1	suspending from ceiling

・DIO port numbers:

Public Const DP_PORT1	As Long = 0	DIO 0 port selection
Public Const DP_PORT2	As Long = 1	DIO 1 port selection
Public Const DP_PORT3	As Long = 2	DIO 2 port selection
Public Const DP_PORT4	As Long = 3	DIO 3 port selection
Public Const DPO_PORT1	As Long = 4	DO 0 port selection
Public Const DPO_PORT2	As Long = 5	DO 1 port selection
Public Const DPO_PORT3	As Long = 6	DO 2 port selection
Public Const DPO_PORT4	As Long = 7	DO 3 port selection
Public Const DPX_PORT1	As Long = 8	DO 0 port selection
Public Const DPX_PORT2	As Long = 9	DO 1 port selection
Public Const DPX_PORT3	As Long = 10	DO 2 port selection
Public Const DPX_PORT4	As Long = 11	DO 3 port selection

Memo

DPO_XXXXX is used when acquiring contents set to be outputted by PA library.

DPX_XXXXX is used when acquiring current output value (related to information in PA library or playback data).

・DIO channel numbers:

Public Const DC_CH1	As Long = 0	Channel 1 selection
Public Const DC_CH2	As Long = 1	Channel 2 selection
Public Const DC_CH3	As Long = 2	Channel 3 selection
Public Const DC_CH4	As Long = 3	Channel 4 selection
Public Const DC_CH5	As Long = 4	Channel 5 selection
Public Const DC_CH6	As Long = 5	Channel 6 selection
Public Const DC_CH7	As Long = 6	Channel 7 selection
Public Const DC_CH8	As Long = 7	Channel 8 selection

PA library characteristic type definition (for Windows Visual BASIC)

・Sensor correction coordinate classification:

Public Const MODE_XYZ1 As Long = &H1
Adds absolute correction value in the mechanical interface coordinate system
Public Const MODE_XYZ2 As Long = &H2
Adds relative correction value in the mechanical interface coordinate system
Public Const MODE_XYZ3 As Long = &H4
Adds absolute correction value in the base coordinate system
Public Const MODE_XYZ4 As Long = &H8
Adds relative correction value in the base coordinate system
Public Const MODE_WAVE1 As Long = &H10
Adds absolute correction value in the trajectory coordinate system
Public Const MODE_WAVE2 As Long = &H20
Adds relative correction value in the trajectory coordinate system

・Teach point attribute designation:

Public Const PA_SETID As Long = &H7304

・Circle & arc teach point number designation:

Public Const PN_1 As Long = 1
Public Const PN_2 As Long = 2
Public Const PN_3 As Long = 3

・JUMP data valid/invalid (in teach data):

Public Const JMP_ON As Long = 1 Valid
Public Const JMP_OFF As Long = 0 Invalid

・JUMP data valid/invalid (in JUMP data):

Public Const JMPENABLE As Long = &H1000000
Public Const JMPDISABLE As Long = &H0

・JUMP command:

Public Const NO_JUMP As Long = &H10000
Public Const DI_JUMP As Long = &H20000
Public Const DI_WAITJUMP As Long = &H30000
Public Const DI_WAIT As Long = &H40000

PA library characteristic type definition（for Windows Visual BASIC）

・JUMP conditional logic:

```
Public Const LEVEL_ON       As Long = &H100
Public Const LEVEL_OFF      As Long = &H200
Public Const EDGE_ON        As Long = &H400
Public Const EDGE_OFF       As Long = &H800
```

・Objective DI:

```
Public Const DIO_INTERNAL   As Long = &H0
Public Const DIO_EXTERNAL   As Long = &H1
```

・Teaching place when in CUBE creation:

```
Public Const MAXPNT         As Long = 1
Public Const MINPNT         As Long = 2
Public Const CENTERPNT      As Long = 3
```

・DIorDO mask setting:

```
Public Const DIMSK          As Long = 0
Public Const DOMSK          As Long = 1
```

・RETRAC ON/OFF:

```
Public Const RETRACOFF      As Long = 0
Public Const RETRACON       As Long = 1
```

・CUBE data:

```
Public Const NOCUBE         As Long = &H0
Public Const CUBEON         As Long = &H1
Public Const CUBEMAX        As Long = &H2
Public Const CUBEMIN        As Long = &H4
Public Const CUBECENTER     As Long = &H8
Public Const CUBESIDE       As Long = &H10
```

PA library characteristic type definition（for Windows Visual BASIC）

・TEACHMODE:

```
Public Const TEACH_OFF      As Long = 0
Public Const TEACH_LOW      As Long = 1
Public Const TEACH_MID      As Long = 2
Public Const TEACH_HIGH     As Long = 3
```

・TEACHLOCK:

```
Public Const LOCK_OFF       As Long = 0
Public Const LOCK_ON        As Long = 1
```

・Communication status with servo driver:

```
Public Const STP_STATUS     As Long = 0
Public Const MOV_STATUS     As Long = 1
Public Const SIM_STATUS     As Long = 2
```

・fpr RETRAC:

```
Public Const MOD_ROBFILE    As Long = 1
Public Const MOD_TOLFILE    As Long = 2
```

・for Dead man switch:

```
Public Const SET_DDM        As Long = 3
```

ERROR LIST (in common)

Normal

ERR_OK	0	No error

(1)　*Operation control section (PA library) detection error:*

ERR_FILE	−1	Designated file not existing
ERR_READ	−2	File loading failure
ERR_WRITE	−3	File saving failure
ERR_INT	−4	Unsuccessful interruption into 486
ERR_OPEN	−5	pa_opn_arm() not executed
ERR_MALLOC	−6	Failed to allocate memory space
ERR_PRM	−7	Parameter alteration not allowed when in control
ERR_PNT	−8	A specified degree of Teaching data is out of range

・Parameter error:

ERR_ARM	−20	Designated arm not existing
ERR_AXIS	−21	Designated axis not existing
ERR_DRV	−22	Designated driver not existing
ERR_PB	−23	Incorrect playback motion mode
ERR_PD	−24	Incorrect teach point deletion mode
ERR_PA	−25	Incorrect teach point attribution mode
ERR_PTN	−26	Incorrect teach point velocity pattern attribution value
ERR_PT	−27	Incorrect teach point data type
ERR_PM	−28	Incorrect teach point operation type
ERR_VT	−29	Incorrect default velocity alteration type
ERR_VM	−30	Incorrect velocity control mode
ERR_JM	−31	Incorrect redundant axis control mode
ERR_JT	−32	Incorrect redundant axis operation mode
ERR_MM	−33	Incorrect target tip matrix control mode
ERR_DM	−34	Incorrect direct control mode
ERR_DP	−35	Incorrect digital input/output port designation
ERR_DC	−36	Incorrect digital input/output channel designation
ERR_MES	−37	Error code not defined
ERR_BOARD	−38	Error code not defined
ERR_DIO	−39	Incorrect digital input/output DIorDO designation
ERR_PRJ	−40	Project not loaded

・WinRT error:

ERR_UNMAPMEMORY	−100	Error occurred in WinRTUnMapMemory
ERR_UNMAPMEMORY2	−101	Error occurred in WinRTUnMapMemory2
ERR_OPENDEVICE	−200	Error occurred in WinRTOpenNamedDevice
ERR_CONFIG	−201	Error occurred in WinRTGetFullConfiguration
ERR_MAPMEMORY	−300	Error occurred in WinRTMapMemory
ERR_MAPMEMORY2	−301	Error occurred in WinRTMapMemory2

ERROR LIST (in common)

(2)Motion control section detection error:

・*Warning error:*

ERR_CANT_CPU	−1000	Access to motion controller not allowed.
ERR_NON_EVNT	−1001	Format does not match with command.
ERR_CANT_EVNT	−1002	Command not compatible with current mode
ERR_INVALD_EVNT	−1003	Invalid command
ERR_NON_ARM	−1004	Designated arm number not existing.
ERR_NON_ROB	−1005	Download new ROB file
ERR_NON_TOL	−1006	Download new TOL file
ERR_S1_VEL	−1010	S1 axis velocity exceeded
ERR_S2_VEL	−1011	S2 axis velocity exceeded
ERR_S3_VEL	−1012	S3 axis velocity exceeded
ERR_E1_VEL	−1013	E1 axis velocity exceeded
ERR_E2_VEL	−1014	E2 axis velocity exceeded
ERR_W1_VEL	−1015	W1 axis velocity exceeded
ERR_W2_VEL	−1016	W2 axis velocity exceeded
ERR_XYZ_VEL	−1018	Tip linear velocity exceeded
ERR_YPR_VEL	−1019	Tip rotational velocity exceeded
ERR_S1_SAGL	−1020	S1 axis safety angle exceeded
ERR_S2_SAGL	−1021	S2 axis safety angle exceeded
ERR_S3_SAGL	−1022	S3 axis safety angle exceeded
ERR_E1_SAGL	−1023	E1 axis safety angle exceeded
ERR_E2_SAGL	−1024	E2 axis safety angle exceeded
ERR_W1_SAGL	−1025	W1 axis safety angle exceeded
ERR_W2_SAGL	−1026	W2 axis safety angle exceeded
ERR_S1_TAGL	−1030	S1 axis target angle exceeded
ERR_S2_TAGL	−1031	S2 axis target angle exceeded
ERR_S3_TAGL	−1032	S3 axis target angle exceeded
ERR_E1_TAGL	−1033	E1 axis target angle exceeded
ERR_E2_TAGL	−1034	E2 axis target angle exceeded
ERR_W1_TAGL	−1035	W1 axis target angle exceeded
ERR_W2_TAGL	−1036	W2 axis target angle exceeded
ERR_NOA_CLC	−1038	Unable to calculate NOA　Ver.PCI
ERR_LNK_CTL	−1039	Unable to create teach point due to continuity restriction
ERR_MEM_FULL	−1040	Failed to allocate memory space
ERR_MIS_COMD	−1041	Prior procedure required before issuing this command
ERR_PB_CIR	−1042	Incorrect circle or arc designation
ERR_PB_NEXT	−1043	Next pointer not existing
ERR_PB_PRIV	−1044	Previous pointer not existing
ERR_PB_END	−1045	Playback data ended
ERR_PB_NULL	−1046	Playback data not existing
ERR_PB_REFER	−1047	Failed to find playback data
ERR_PB_REPLACE	−1048	Accepted as replace command

ERROR LIST (in common)

ERR_PB_PANIC	−1049	Pointer management accident
ERR_NOT_ENUGH	−1050	Target value is out of control area. (Arm length is not enough.)
ERR_MIS_PARAM	−1051	Designated parameter value exceeded the setting range
ERR_NOA_DAT	−1060	Designated NOA not appropriate
ERR_PNT_ATR	−1061	Not available
ERR_PTP_DAT	−1062	Exceeding RMRC motion range
ERR_CP_LOGGING	−1063	Not allowed to use while in CP data acquisition
ERR_FIFO_MAX	−1064	Exceeded the maximum interpolation number
ERR_FIFO_ARC	−1065	Unable to generate circle or arc
COVERS1	−1070	S1 axis velocity angle exceeded
COVERS2	−1071	S2 axis velocity angle exceeded
COVERS3	−1072	S3 axis velocity angle exceeded
COVERE1	−1073	E1 axis velocity angle exceeded
COVERE2	−1074	E2 axis velocity angle exceeded
COVERW1	−1075	W1 axis velocity angle exceeded
COVERW2	−1076	W2 axis velocity angle exceeded
ERR_MIS_VAL	−1080	Setting value is too large or too small
ERR_PNT_APP	−1081	Approach cannot be performed with axis control,
ERR_PLY_FOR	−1098	Consecutive motion not allowed while in teach mode.
ERR_PLY_MOD	−1099	Switched to teach mode by outer operation.
ERR_USE_TCH	−1100	Teach lock can be ON only in teach mode.
ERR_ACT_DAT	−1101	Designated Key teach data not existing
ERR_CHG_KEY	−1103	Unable to perform Key research for teach data
ERR_CUB_NUM	−1200	Interference area designation number error
ERR_CUB_LEN	−1201	Side length designation cannot be performed with this cube information. This cube has another attribution.
ERR_CUB_MAX	−1202	Upper value teaching cannot be performed with this cube information. This cube has another attribution.
ERR_CUB_MIN	−1203	Lower value teaching cannot be performed with this cube information. This cube has another attribution.
ERR_CUB_CTR	−1205	Center value teaching cannot be performed with this cube information. This cube has another attribution.
ERR_CUB_PRM	−1206	Unknown cube parameter setting
ERR_CUB_SET	−1207	Setting cannot be performed with this cube information. This cube has another attribution.

ERROR LIST (in common)

ERR_PLY_KEY	−1249	Wrong designated number when in Key acquisition
ERR_NON_KEY	−1250	There is no designated ID attribution in teach data designated by Key
ERR_NON_CID	−1251	Designated teach point has no JUMP data.
ERR_JMP_SET	−1252	Teach data designated by Key does not have its number JUMP information.
ERR_NON_IDN	−1253	Teach point designated by ID attribution has no JUMP information.
ERR_JMP_NUM	−1254	Unable to find JUMP information designated by teach point attribution.
ERR_JMP_ATR	−1255	Wrong designated parameter when in JUMP data acquisition/setting
ERR_KEY_ATR	−1256	Wrong designated parameter when in JUMP data acquisition/setting
ERR_SOC_TST	−1300	Socket generation failure
ERR_BND_TST	−1311	Failed to bind socket and address
ERR_LSN_TST	−1312	Listening failure
ERR_APT_TST	−1313	Accepting failure
ERR_SOC_SND	−1314	Socket generation failure
ERR_SOC_BLK	−1315	Not available
ERR_SOC_CLT	−1316	Too many clients connected
ERR_PRM_DEV	−1350	Parameter motion velocity is exceeding velocity limit value.　Parameter alteration is invalid.

ERROR LIST (in common)

・Operation continuity malfunction error:　－－＞　(Brake-stop status)

ERR_OVER900	-2017	Arm length exceeded RMRC motion limit length while in motion
ERR_S1_AGL	-2020	S1 axis angle exceeded
ERR_S2_AGL	-2021	S2 axis angle exceeded
ERR_S3_AGL	-2022	S3 axis angle exceeded
ERR_E1_AGL	-2023	E1 axis angle exceeded
ERR_E2_AGL	-2024	E2 axis angle exceeded
ERR_W1_AGL	-2025	W1 axis angle exceeded
ERR_W2_AGL	-2026	W2 axis angle exceeded
DOVERS1	-2030	S1 axis direct control angle exceeded
DOVERS2	-2031	S2 axis direct control angle exceeded
DOVERS3	-2032	S3 axis direct control angle exceeded
DOVERE1	-2033	E1 axis direct control angle exceeded
DOVERE2	-2034	E2 axis direct control angle exceeded
DOVERW1	-2035	W1 axis direct control angle exceeded
DOVERW2	-2036	W2 axis direct control angle exceeded
ERR_CANT_MOVE	-2051	RMRC control is not allowed at the current position.
ERR_S1_REZ	-2060	Anomalous S1 resolver deviation
ERR_S2_REZ	-2061	Anomalous S2 resolver deviation
ERR_S3_REZ	-2062	Anomalous S3 resolver deviation
ERR_E1_REZ	-2063	Anomalous E1 resolver deviation
ERR_E2_REZ	-2064	Anomalous E2 resolver deviation
ERR_W1_REZ	-2065	Anomalous W1 resolver deviation
ERR_W2_REZ	-2066	Anomalous W2 resolver deviation

Memo

Anomalous resolver deviation means when the resolver value inputted at the previous time and the present time one exceed the allowable range.　(Incorrect loading, provokes missing data.)

ERR_TIMEOUT	-2070	Automatically stopped on account of exceeding surveillance time.
ERR_SYNCOUT	-2071	Not reaching the target value

ERROR LIST (in common)

ERR_SYNC_S1	−2080	Anomalous S1 axis synchronization in axis control
ERR_SYNC_S2	−2081	Anomalous S2 axis synchronization in axis control
ERR_SYNC_S3	−2082	Anomalous S3 axis synchronization in axis control
ERR_SYNC_E1	−2083	Anomalous E1 axis synchronization in axis control
ERR_SYNC_E2	−2084	Anomalous E2 axis synchronization in axis control
ERR_SYNC_W1	−2085	Anomalous W1 axis synchronization in axis control
ERR_SYNC_W2	−2086	Anomalous W2 axis synchronization in axis control
ERR_RMRC_X	−2087	Anomalous X axis synchronization in RMRC control
ERR_RMRC_Y	−2088	Anomalous Y axis synchronization in RMRC control
ERR_RMRC_Z	−2089	Anomalous Z axis synchronization in RMRC control

Memo

Anomalous synchronization occurs when target and current value deviation exceed the allowable range. (Arm is not moving or rather delays motion.)

ERR_VELOCITY	−2090	Anomalous velocity deviation
ERR_RMRC_YPR	−2091	Anomalous tip orientation deviation in RMRC control
ERR_CUB_INN	−2100	Interfered with cube
ERR_ARM_ERR0	−2200	Motion start or continuation is not allowed at arm singularity
ERR_ARM_ERR1	−2201	Motion start or continuation is not allowed at arm singularity
ERR_ARM_ERR2	−2202	Motion start or continuation is not allowed at arm singularity

ERROR LIST (in common)

・Fatal error　－－＞　(Control stop status)

ERR_POWER_ON	−3000	control not started.

Memo

After fatal error occurred without issuing control start command, if other command is issued, this error occurs.

ERR_EM_CTL	−3001	Emergency stop is pushed.
ERR_ARC_SEND	−3002	Anomalous arc net communication
ERR_S1X_LIM	−3003	S1 axis limit switch is ON.
ERR_DRV_TYP	−3005	Servo driver type is different from parameter designation.
ERR_FORCE_ON	−3010	Not in force control
ERR_DDD_STA	−3070	Anomalous communication control servo (master) status.
ERR_D11_STA	−3071	Anomalous servo driver (S1) status
ERR_D12_STA	−3072	Anomalous servo driver (S2) status
ERR_D21_STA	−3073	Anomalous servo driver (S3) status
ERR_D22_STA	−3074	Anomalous servo driver (E1) status
ERR_D31_STA	−3075	Anomalous servo driver (E2) status
ERR_D32_STA	−3076	Anomalous servo driver (W1) status
ERR_D41_STA	−3077	Anomalous servo driver (W2) status

Memo

Anomalous servo driver is the case when servo driver detects any anomaly and turns into waiting status after being released from control.
For servo status, refer to next page.

ERR_S_SUSPD	−3091	Anomaly when issuing control (communication) start command
ERR_E_SUSPD	−3092	Anomaly when issuing control (communication) end command
ERR_I_SUSPD	−3093	Anomaly when issuing initialization command

Memo

Anomalous control command issuing means when issuing command to the servo driver, there is no response for a certain time.　(Servo driver is anomalous.)

ERR_MOD_CTL	−4000	Anomalous mode management

ERROR LIST (in common)

(3) Servo status driver detection error:

Reference

More information, refer to servo driver operation manual and (3) error information in the section 6.14.1.

DRV_MEM_ERR	1	Anomalous shared memory
EEP_ROM_ERR	2	Anomalous EEPROM
CPU_XXX_ERR	3	Anomalous CPU
ARC_NET_ERR	4	Anomalous communication cycle
VEL_SPN_ERR	5	Anomalous velocity deviation
REZ_SPN_ERR	6	Anomalous resolver deviation
VEL_LIM_ERR	7	Anomalous position limit
MTR_TRQ_ERR	8	Anomalous motor torque
IPM_XXX_ERR	9	Anomalous IPM
BRK_XXX_ERR	10	Severed brake line
REZ_001_ERR	11	Severed resolver line (gear side)
REZ_002_ERR	12	Severed resolver line (motor side)
OVR_TRQ_ERR	13	Over current
OVR_VEL_ERR	14	Over velocity
DMS_XXX_ERR	15	Anomalous dead man SW
CPU_NON_ERR	16	Other anomalous CPU

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--- Function on teach point operation & playback control ------------------------------

pa_axs_pnt	<8-23>	Axis motion control from the present position to the current point
pa_mov_pnt	<8-24>	Linear motion control from the present position to the current point
pa_ply_pnt	<8-25>	Playback control
pa_chg_pnt	<8-27>	Teach point pointer alteration ((current point alteration)
pa_add_pnt	<8-29>	Teach point addition
pa_del_pnt	<8-31>	Teach point deletion
pa_rpl_pnt	<8-32>	Teach point replacement
pa_set_pnt	<8-33>	Teach point attribution setting
pa_set_idn	<8-34>	ID_No. setting at teach point
pa_chg_dio	<8-35>	Teach point (PTP) DO attribution setting
pa_vel_pnt	<8-36>	Playback control velocity coefficient alteration
pa_swt_dio	<8-37>	Playback control teach point DO valid/invalid setting
pa_get_pnt	<8-38>	Current point teach point data loading
pa_get_cur	<8-40>	Current point teach point number loading
pa_get_num	<8-41>	Teach point all numbers loading
pa_get_idn	<8-42>	Current point ID_No. loading
pa_get_cpt	<8-43>	Current point circle/arc teach data loading
pa_get_pvl	<8-44>	Playback control velocity coefficient loading
pa_get_pdo	<8-45>	Playback control teach point DO valid/invalid loading
pa_lod_pnt	<8-46>	Loading teach data to controller
pa_sav_pnt	<8-47>	Saving teach data to man-machine controller
pa_set_dlc	<8-48>	Playback DO automatic stop/non stop setting
pa_get_dlc	<8-49>	Playback DO automatic stop/non stop loading

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---------------------------- (Additional function from Ver.3.0)------------

--- Velocity control function ---

---Tip absolute position/orientation, axis real-time control function ------------------------------

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--- Arm status information loading function ---------------------------------

---------------------- (Additional function from Ver.3.0)----------------------

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Chapter 8 PA Library

pa_ini_sys

Function

PA library initialization

Syntax

```
long    pa_ini_sys(void)
```

Explanation

This "pa_ini_sys" has to be called before using PA library.

Return value

ERR_OK　Normal termination

Others:　Anomalous termination (Refer to error table)

Reference

pa_ter_sys

Description example

```
#include  <pa.h>                 .. Library prototype declaration
#include  <paerr.h>              .. Error code

main()
{
        pa_ini_sys();
              :
              :
        pa_ter_sys();
}
```

Memo

pa.h　:Needs when the library is used.

paerr.h　:Needs on account error names are declared.

pa_ter_sys

Function

PA library is terminated.

Syntax

long　　pa_ter_sys(void)

Explanation

This “pa_ter_sys” has to be called after using PA library.

Return value

ERR_OK　Normal termination

Others:　Anomalous termination (Refer to error table)

Reference

pa_ini_sys

pa_opn_arm

Function

Open arm (control arm selection)

Syntax

ERR　pa_opn_arm(ARM armno)

armno　Arm number (No.)

Explanation

The arm designated by "armno" can be accessed.
When plural arms are controlled, arms are distinguished by "armno."

Return value

ERR_OK　Normal termination
Others:　Anomalous termination (Refer to error table)

Reference

pa_cls_arm

Description example

```
#include   <pa.h>            .. Library prototype declaration
#include   <paerr.h>         .. Error code

main()
{
        pa_ini_sys();
        pa_opn_arm(ARM1); .. Arm number selection     :
                :
        pa_cls_arm(ARM1);
        pa_ter_sys();
}
```

Memo

pa.h　:Needs when the library is used.
paerr.h　:Needs on account error names are declared.

All these descriptions are always needed to use the library.

pa_cls_arm

Function

Close arm

Syntax

long pa_cls_arm(ARM armno)

armno　Arm number (No.)

Explanation

The arm designated by "armno" cannot be accessed.

Return value

ERR_OK　Normal termination

Others:　Anomalous termination (Refer to error table)

Reference

pa_opn_arm

pa_sta_arm

Function

Motion controller operation start

Syntax

long pa_sta_arm(ARM armno)

armno　Arm number (No.)

Explanation

The controller designated by "armno" starts to communicate with servo driver.
The controller becomes ready to receive motion command.
This function has to be always performed except initialization.

Return value

ERR_OK　Normal termination
Others:　Anomalous termination (Refer to error table)

For return value, there is controller error other than "ERR_OK."

Reference

Refer to error table.

Reference

pa_ext_arm

Description example

```
#include   <pa.h>             .. Library prototype declaration
#include   <paerr.h>                   .. Error code

main()
{
            pa_ini_sys();
            pa_opn_arm(ARM1); .. Arm number selection
            pa_sta_arm(ARM1);
                              :
                   Arm motion function
                              :
            pa_ext_arm(ARM1);
            pa_cls_arm(ARM1);
            pa_ter_sys();
}
```

Memo

pa.h　:Needs when the library is used.
paerr.h　:Needs on account error names are declared

All these descriptions are always needed to use the library.
This sentence is omitted in following description examples.

pa__ext__arm

Function

Motion controller operation exit

Syntax

long pa_ext_arm(ARM armno)

armno Arm number (No.)

Explanation

The controller designated by "armno" terminates to communicate with servo driver
The controller becomes not ready to receive control command.

Return value

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference

pa_sta_arm

pa_sta_sim

Function

Starts arm motion with simulation mode.

Syntax

long pa_sta_sim(ARM armno)

armno Arm number (No.)

Explanation

The controller designated by “armno” starts inner servo driver simulation and controls it.

This library is used in place of “pa_sta_arm.” Program can be debugged without moving arm.

Return value

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

Reference

pa_ext_sim

Description example

```
#include <pa.h>            .. Library prototype declaration
#include <paerr.h>                   .. Error code

main()
{
        pa_ini_sys();
        pa_opn_arm(ARM1);.. Arm number 1 selection
        pa_sta_sim(ARM1);   .. Uses “pa_sta_arm” when the actual machine is
                                   operated.
                :
            Arm motion function
                :
        pa_ext_sim(ARM1);   .. Uses “pa_ext_arm” when the actual machine is
                                   operated.

        pa_cls_arm(ARM1);
        pa_ter_sys();
}
```

Memo

Control can be terminated with “pa_ext_arm,” also, when in simulation (pa_sta_sim).

pa__ext__sim

Function

Simulation mode is terminated.

Syntax

long pa_ext_sim(ARM armno)

armno Arm number (No.)

Explanation

The controller designated by “armno” terminates inner servo driver simulation and ends control.

Return value

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

Reference

pa_sta_sim

pa__stp__arm

Function

The brake stops arm motion.

Syntax

long pa_stp_arm(ARM armno, long func)

armno Arm number (No.)

func Designation whether to wait or not until motion is completed.

Explanation

The controller designated by “armno” stops servo and performs brake-stop to arm.

This function creates motion by “func” as follows:

- Designates WM_WAIT : does not return unless motion stops completely.
- Designates WM_NOWAIT : returns without confirming a stop.

However, “pa_stp_arm” is performed instantly.

Return value

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

Description example

```
        :                       .. Arm in motion
if (stop key is pushed)
        pa_stp_arm(ARM1,WM_WAIT);
        :                       .. Arm brake-stop
```

pa_sus_arm

Function

Stops the arm motion temporarily.

Syntax

long pa_sus_arm(ARM armno, long func)

armno Arm number (No.)
func Designation whether to wait or not until motion is completed.

Explanation

The arm designated by “armno” becomes servo-lock status if it is in motion. Maintaining as it was before temporary-stop, continues the status kept by “par_rsm_arm.”

This function creates motion by “func” as follows:

・Designates WM_WAIT : does not return unless temporarily, motion stops completely.
・Designates WM_NOWAIT : returns without confirming a temporary stop.

However, “pa_sus_arm” is executed instantly.

Return value

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference

pa_rsm_arm

Description example

```
                    :                     .. Arm in motion
if (temporary stop-key is pushed)
        pa_sus_arm(ARM1, WM_WAIT);
                    :                     .. While in arm servo lock
if (resuming key is pushed)
        pa_rsm_arm(ARM1, WM_WAIT);
                                          .. Arm servo lock released
                                                   (Resuming arm motion)
```

pa_rsm_arm

Function

Releases arm temporary stop.

Syntax

long pa_rsm_arm(ARM armno, long func)

armno Arm number (No.)

func Designation whether to wait or not until motion is completed.

Explanation

If the arm designated by “armno” is in temporary stop, it is released resuming prior motion.

This function creates motion by “func” as follows:

・Designates WM_WAIT :does not return unless temporarily, motion stops completely.

・Designates WM_NOWAIT:returns without confirming temporary-stop-release. However, “pa_rsm_arm” is executed instantly.

Return value

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

Reference

pa_sus_arm

pa_exe_axs

Function

Performs each axis motion.

Syntax

```
long pa_exe_axs(ARM armno, AXIS axis, ANGLEP angle, long func)
```

armno	Arm number (No.)
axis	designates by "enum AXIS": motion axis designation. Plural axes can be selected. (Example: S1 | S2 | S3)
angle	Motion angle: is designated by pointer type "ANGLEP" to structure ANGLE
func	Designation whether to wait or not until motion is completed.

Explanation

The axis designated by "axis" creates motion at default angle velocity to the angle designated by "angle".

This function creates motion by "func" as follows:

- Designates WM_WAIT : does not return unless motion stops completely.
- Designates WM_NOWAIT : returns without confirming motion completion.

Remark

When the designated axis target angle exceeds its axis motion range, its target angle is altered to motion range allowing maximum value. Automatic target value alteration is reported to users with the warning: "target angle exceeded."

Angle velocity default value employs default velocity.

Reference

For alteration, arm parameter has to be changed. Arm parameter alteration method can be referred to parameter setting manual or "pa_set_vel."

Return value

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

Reference

pa_set_vel

Description example

```
            :
ANGLE   ang;

ang.s1=1.57;
ang.s2=1.57;
ang.w2=1.57;
pa_exe_axs(ARM1, S1|S2|W2, &ang, WM_WAIT);
                    .. Moves S1, S2 and W2 axis at the distance of 1.57 [rad]
          :
```

pa__exe__hom

Function

Controls each axis to home position.

Syntax

long pa_exe_hom(ARM armno, long func)

armno　Arm number (No.)
func　Designation whether to wait or not until motion is completed.

Explanation

Moves to the home position setting in the arm parameter.
Home position default angle for all axes is 0 [deg].

Reference

Home position default angle correction method can be referred to parameter setting manual or "pa_set_hom."

This function creates motion by "func" as follows:
・Designates WM_WAIT　:does not return unless motion is completed.
・Designates WM_NOWAIT:returns without confirming motion completion.

Return value

ERR_OK　Normal termination
Others:　Anomalous termination (Refer to error table)

Reference

pa_set_hom　Alters home position.
pa_def_hom　Replaces home position with current value.

pa_exe_esc

Function

Controls each axis to "escape" position.

Syntax

long pa_exe_esc(ARM armno, long func)

armno Arm number (No.)
func Designation whether to wait or not until motion is completed.

Explanation

Moves to the "escape" position setting in parameter.
Escape position default angles are:

S2 : 45[deg]
E1 : 90[deg]
W1 : 45[deg]
Others : 0[deg]

Reference

Escape position default angle correction method can be referred to parameter setting or "pa_set_esc."

This function creates motion by "func" as follows:

- Designates WM_WAIT : does not return unless motion is completed.
- Designates WM_NOWAIT : returns without confirming motion completion.

Return value

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference

pa_set_esc Alters escape position.
pa_def_esc Replaces escape position with current value.

pa__exe__saf

Function

Controls each axis to "safety position."

Syntax

long pa_exe_saf(ARM armno, long func)

armno Arm number (No.)

func Designation whether to wait or not until motion is completed.

Explanation

Moves to "safety" position setting in parameter.

Safety position default angles are:

S2 : 45[deg]

E1 : 90[deg]

W1 : −45[deg]

Others : 0[deg]

Reference

Escape position default angle correction method can be referred to parameter setting or "pa_set_saf."

This function creates motion by "func" as follows:

・Designates WM_WAIT : does not return unless motion is completed.

・Designates WM_NOWAIT : returns without confirming motion completion.

Return value

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

Reference

pa_set_saf Alters safety position.

pa_def_saf Replaces safety position with current value.

pa_mov_XYZ

Function

RMRC　base coordinate　position deviation control

Syntax

long pa_mov_XYZ(ARM armno, float X, float Y, float Z, long func)

armno	Arm number (No.)
X	Base coordinate　toward X　position deviation [mm]
Y	Base coordinate　toward Y　position deviation [mm]
Z	Base coordinate　toward Z　position deviation [mm]
func	Designation whether to wait or not until motion is completed.

Explanation

With base coordinate axis as standard, the tip position moves at exact distance created from designated position deviation toward X, Y and Z.　Tip orientation does not change.

Tip motion trajectory is linear.　Velocity is interpolated creating modified sin curve profile for start-up/shutdown.

This function creates motion by "func" as follows:

・Designates WM_WAIT　：does not return unless motion is completed.

・Designates WM_NOWAIT：returns without confirming motion completion.

PA-10 RMRC control: method to interpolate arm tip trajectory and orientation setting position and orientation as the target value.

In PA-10 RMRC control, uncontrollable areas exist.

This is defined as a singularity.　It is the point where E1 axis becomes 0 [deg] (930 [mm] length from S2 rotation origin to W1 rotation origin).　Singularity check is performed when the target value is created in RMRV control.

Reference

For more, refer to programming manual in chapter 3.

Remark

When the tip target position calculated from designated deviation, exceeds arm motion range, warning occurs: "target value arm length exceeds 925 [mm] (automatically cut target value)."

If arm motion continues and exceeds motion range, the operation is automatically switched to temporary-stop status.　Immediately, the servo-lock performs.

When LENGTH value is beyond 925 [mm] before being in motion, this motion is not performed as the motion range exceeds.

Two motion range types: LENGTH 925 [mm] available for RMRC control and axis angle limit.　If exceeding either limit, arm motion is not performed.

Return value

ERR_OK　Normal termination

Others:　Anomalous termination (Refer to error table)

pa_mov_YPR

Function

RMRC Base coordinate　orientation deviation control

Syntax

long pa_mov_YPR(ARM armno, float Y, float P, float R, long func)

armno	Arm number (No.)
Y	Base coordinate　rotation on X axis　orientation deviation [rad]
P	Base coordinate　rotation on Y axis　orientation deviation [rad]
R	Base coordinate　rotation on Z axis　orientation deviation [rad]
func	Designation whether to wait or not until motion is completed.

Explanation

With base coordinate axis as standard, the tip orientation (direction) rotates at exact distance created from designated deviation: Yaw, Pitch and Roll.　Tip position does not change.
Tip rotational velocity is interpolated creating modified sin curve profile for start-up/shutdown.

This function creates motion by "func" as follows:
・Designates WM_WAIT　:does not return unless motion is completed.
・Designates WM_NOWAIT:returns without confirming motion completion.

PA-10 RMRC control: method to interpolate arm tip trajectory and orientation setting position and orientation as the target value.
In PA-10 RMRC control, uncontrollable areas exist.
This is defined as a singularity.　It is the point where E1 axis becomes 0 [deg] (930 [mm] length from S2 rotation origin to W1 rotation origin).

Reference

For more, refer to programming manual in chapter 3.

Remark

No warning occurs even if the tip target orientation calculated by the designated deviation exceeds arm motion range.
If arm motion continues and exceeds motion range, the operation is automatically switched to temporary-stop status.　Immediately, the servo-lock performs.

When LENGTH value is beyond 925 [mm] before being in motion, this motion is not performed as the motion range exceeds.
Two motion range types: LENGTH 925 [mm] available for RMRC control and axis angle limit.　If exceeding either limit, arm motion is not performed.

Return value

ERR_OK　Normal termination
Others:　Anomalous termination (Refer to error table)

pa_mov_xyz (for Visual BASIC, pa_mov_XYZ0)

Function

RMRC mechanical interface coordinate position deviation control

Syntax

long pa_mov_xyz(ARM armno, float x, float y, float z, long func)

armno	Arm number (No.).
x	Mechanical interface coordinate toward X position deviation [mm]
y	Mechanical interface coordinate toward Y position deviation [mm]
z	Mechanical interface coordinate toward Z position deviation [mm]
func	Designation whether to wait or not until motion is completed.

Explanation

With base coordinate axis as standard, the tip position moves at the only distance created from designated position deviation toward X, Y and Z. Tip orientation does not change.
Tip motion trajectory is linear. Velocity is interpolated creating trapezoidal profile.

This function creates motion by “func” as follows:
- ・Designates WM_WAIT :does not return unless motion is completed.
- ・Designates WM_NOWAIT:returns without confirming motion completion.

PA-10 RMRC control: method to interpolate arm tip trajectory and orientation setting position and orientation as the target value.
In PA-10 RMRC control, uncontrollable areas exist.
This is defined as a singularity. It is the point where E1 axis becomes 0 [deg] (930 [mm] length from S2 rotation origin to W1 rotation origin). Singularity check is performed when the target value is created in RMRV control.

Reference

For more, refer to programming manual in chapter 3.

Remark

When the tip target position calculated from designated deviation, exceeds arm motion range, warning occurs: “target value arm length exceeds 925 [mm] (automatically cut target value).”
If arm motion continues and exceeds motion range, the operation is automatically switched to temporary-stop status. Immediately, the servo-lock performs.

When LENGTH value is beyond 925 [mm] before being in motion, this motion is not performed as the motion range exceeds.
Two motion range types: LENGTH 925 [mm] available for RMRC control and axis angle limit. If exceeding either limit, arm motion is not performed.

Return value

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

pa_mov_ypr (for Visual BASIC, pa_mov_YPR0)

Function

RMRC mechanical interface coordinate orientation deviation control

Syntax

long pa_mov_ypr(ARM armno, float y, float p, float r, long func)

armno Arm number (No.).
y Mechanical interface coordinate rotation on X axis position deviation [rad]
p Mechanical interface coordinate rotation on Y axis position deviation [rad]
r Mechanical interface coordinate rotation on Z axis position deviation [rad]
func Designation whether to wait or not until motion is completed.

Explanation

The tip orientation moves with RMRC control at the distance created from orientation deviation designated at y, p and r in the mechanical interface coordinate.

This function creates motion by "func" as follows:
・Designates WM_WAIT :does not return unless motion is completed.
・Designates WM_NOWAIT:returns without confirming motion completion.

PA-10 RMRC control: method to interpolate arm tip trajectory and orientation setting position and orientation as the target value.
In PA-10 RMRC control, uncontrollable areas exist.
This is defined as a singularity. It is the point where E1 axis becomes 0 [deg] (930 [mm] length from S2 rotation origin to W1 rotation origin).

Reference

For more, refer to programming manual in chapter 3.

Remark

No warning occurs even if the tip target orientation calculated by the designated deviation exceeds arm motion range.
If arm motion continues and exceeds motion range, the operation is automatically switched to temporary-stop status. Immediately, the servo-lock performs.

When LENGTH value is beyond 925 [mm] before being in motion, this motion is not performed as the motion range exceeds.
Two motion range types: LENGTH 925 [mm] available for RMRC control and axis angle limit. If exceeding either limit, arm motion is not performed.

Return value

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

pa_mov_mat

Function

Tip position/orientation target absolute position designation control

Syntax

long pa_mov_mat(ARM armno, MOVEMODE mmod, MATRIX mat,
ANGLEP angle, long func)

armno	Arm number (No.).
mmod	Absolute target matrix classification ? 絶先目標行列種別???????
mat	Absolute tip position/orientation target matrix
angle	Each axis value for redundant axis restriction control [rad]
func	Designation whether to wait or not until motion is completed.

Explanation

Moves to the target provided by "mat" for the arm designated by "armno".
Three motion target designation methods: absolute position, absolute orientation and absolute position/orientation. These can be designated by "mmod".
Trajectory to the designated target value is interpolated linearly.

MOVEMODE mmod classification:

- ・MM_XYZ : By "mat", position is altered without changing absolute position target matrix tip orientation.
- ・MM_NOA : By "mat", orientation is moved without changing absolute orientation target matrix tip position.
- ・MM_XYZNOA : By "mat", absolute position orientation matrix tip position/orientation is moved.

MATRIX mat:

$$\begin{pmatrix} nx & ox & ax & px \\ ny & oy & ay & py \\ nz & oz & az & pz \end{pmatrix} \quad \text{matrix:} \quad \text{mat[3][4]}$$

ANGLEP angle

Also, in this control, redundant axis control mode (the mode selected by "pa_mod_jou") to control elbow position is available and restricted by each axis value provided by "angle." For 6-axis or 7-axis arm, when redundant axis control mode is OFF (no restriction), "angle" is invalid. However, a variable has to be set 0.

This function creates motion by "func" as follows:

- ・Designates WM_WAIT : does not return unless motion is completed.
- ・Designates WM_NOWAIT : returns without confirming motion completion.

PA-10 RMRC control: method to interpolate arm tip trajectory and orientation setting position and orientation as the target value.
In PA-10 RMRC control, uncontrollable areas exist.
This is defined as a singularity. It is the point where E1 axis becomes 0 [deg] (930 [mm] length from S2 rotation origin to W1 rotation origin).

Reference

For more, refer to programming manual.

Return value

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

Description example

```
            :
MATRIX  mat;
 ANGLE          an;

mat[0][0] = 0.0;
          :
mat[2][3]= 850.0;

an.s1 = 0.0;
an.s2 = 0.0;
an.s3 = 60.0/180.0*M_PI;   ..60[deg]
    :
an.w2 = 0.0;
pa_mov_mat(ARM1, MM_XYZNOA, mat, &an, WM_WAIT);
     :
```

Moves with RMRC interpolation from the current point to the tip position/orientation indicated by “mat”.

pa__axs__pnt

Function

Moves from the present point to the current point.

Syntax

long pa_axs_pnt(ARM armno, long func)

armno Arm number (No.).
func Designation whether to wait or not until motion is completed.

Explanation

Moves the arm with axis interpolation from the present point to the current point.

＜Differences between pa_axs_pnt and pa_mov_pnt＞

- Whatever a current point data type is, “pa_axs_pnt” moves with axis control.
- For “pa_mov_pnt,” when the current point data type is PTP data, moves with linear interpolation (RMRC) control. When type is CP data, moves with axis interpolation (axis angle control.)

When the present and current point position/orientation are completely different, it is advisable to use axis interpolation. From any position/orientation (home orientation, etc.) it can reach the current point.

Explanation for “func” is the same as “pa_mov_pnt”.

Return value

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference

pa_mov_pnt Moves linearly to the current point.

Description example

```
          :
pa_chg_pnt(ARM1, PM_TOP, 0);        .. Moves teach point pointer to the top.
pa_axs_pnt(ARM1, WM_WAIT);          .. Moves to the current (top) teach point with
                                               axis interpolation.
```

pa_mov_pnt

Function

Moves from the present point to the current point.

Syntax

long pa_mov_pnt(ARM armno, long func)

armno Arm number (No.).
func Designation whether to wait or not until motion is completed.

Explanation

Moves the arm from the present point to the current point interpolating linearly tip trajectory and tip orientation.

This function creates motion by "func" as follows:
・Designates WM_WAIT : does not return unless motion is completed.
・Designates WM_NOWAIT : returns without confirming motion completion.

For this method, RMRC control is employed, the arm tip position trajectory from the present position to the current one is linearly interpolated and orientation is also interpolated.

For 7-axis arm:

Even if the tip position/orientation trajectory is the same, plural axis values exist then. So that redundant axis control has to be set.

・If redundant axis operation control mode is selected, current point teach data axis value restricts motion.
・If redundant axis operation control mode not restricted is selected, motion is not restricted by current point teach data axis value.

Either redundant axis control modes, the tip trajectories are the same. But, each axis value is different.

Redundant axis control mode is available in all RMRC controls until it is reset.

Reference

For more, refer to programming manual in chapter 3.

Return value

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference

pa_chg_pnt	Current point alteration
pa_axs_pnt	Each axis moves to the current point.
pa_ply_pnt	Playback control
pa_mod_jou	Restricted axis control mode

Description example

```
pa_mod_jou(ARM1, JM_ON); .. Redundant axis control mode "All axes restriction"
                                     selection
pa_chg_pnt(ARM1, PM_TOP, 0);         .. Moves the teach point pointer to the top
pa_mov_pnt(ARM1, WM_WAIT);           .. Moves to the current (top) teach point with
                                     axis interpolation.
```

pa__ply__pnt

Function

Performs playback control.

Syntax

long pa_ply_pnt(ARM armno, PLAYBACK pbmod, long number, long func)

armno Arm number (No.).

pbmod Motion direction and motion method are designated by "enum PLAYBACK."

func Designation whether to wait or not until motion is completed.

Explanation

Performs playback motion designated by "pbmod".

PB_FORES : Performs playback with step toward.
If data is PTP, motion continues to the next.

PB_BACKS : Performs playback with step reverse.
If data is PTP, motion continues to the next.

PB_FORE : Starts to consecutively playback forward for teach data from the current point. Playback is performed as many as designated by the number. If the number is designated −1, playback is infinitely performed.

This function creates motion by "func" as follows:

- Designates WM_WAIT : does not return unless motion is completed.
- Designates WM_NOWAIT : returns without confirming motion completion.

Playback motion is available when teach data is being loaded or when teaching is performed. However, this can be used only when the current point and the arm position are placed together. If not, move the arm to the current point.

Playback control: method to interpolate the tip position/orientation calculated from teach data axis value and control it.

7-axis arm function

For 7-axis arm, Even if the tip position/orientation trajectory is the same, plural axis values exist. So that redundant axis operation has to be set.

Before performing playback control:

- If redundant axis operation control mode is selected, teach point data axis value restricts motion.
- If redundant axis operation control mode: "JM_OFF" is selected, motion is not restricted by teach point data axis value.

Default is JM_OFF.

With any redundant axis control mode, the tip trajectory is the same. But, each axis value is different.

Redundant axis control mode is available in all RMRC controls until it is reset.

Reference

For more, refer to programming manual.

Return value

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

Reference

pa_mov_pnt	Moves linearly to the arm current point.
pa_axs_pnt	Each axis moves to the arm current point.
pa_mod_jou	Performs redundant axis operation control.

Description example

```
                :
pa_mod_jou(ARM1, JM_ON); .. Redundant axis control mode "all axes restriction"
                            selection
                :
pa_chg_pnt(ARM1, PM_TOP, 0);     .. Moves the teach point pointer to the top
pa_mov_pnt(ARM1, WM_WAIT);       .. Moves to the current (top) teach point with
                                    axis interpolation.
pa_ply_pnt(ARM1, PB_FORE, -1, WM_WAIT);    .. Playback control starts from the
                                              current point (top) to infinity.
```

pa__chg__pnt

Function

Alters the current point of teach point.

Syntax

long　pa_chg_pnt(ARM armno, PNTMOVE pmov, long jpt)

armno　Arm number (No.).
pmov　Designates teach point pointer forwarding place with "enum PNTMOVE."
jpt　Pointer shifting designation number
pmov =　Available when in "PM_JMP."

Explanation

Changes teach point pointer to the teach point position designated by "pmov".
Teach point pointed out by teach point pointer is called current point.

PM_TOP　: Moves the teach point pointer to the top.

PM_NEXT　: Moves the teach point pointer to the next teach point.

Memo

This function is available when teach data is being loaded or when teaching is performed. If the current point is at the last teach point, nothing is performed.

PM_PRIV　: Moves the teach point pointer to the previous teach point.

Memo

This function is available when teach data is being loaded or when teaching is performed. If the current point is at the top teach point, nothing is performed.

PM_BTM　: Moves the teach point pointer to the last teach point.

Memo

This function is available when teach data is being loaded or when teaching is performed. If the current point is at the last teach point, nothing is performed.

PM_JMP　: Moves the teach point pointer to the teach point. With designated number "jpt".

PM_CIR　: Researches the circle teach point forward from the current point and moves the teach point pointer to the teach point found in the first place.

PM_ARC　: Researches the arc teach point forward from the current point and moves the teach point pointer to the teach point found in the first place.

When the current point (the 2ndpoint) is the circle first point, if "PM_NEXT" is designated, the current point become the 5th point. To summarize, the points able to be the current point are point attribution: PTP and circle 1st point and arc 1st point.

Return value

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

Reference

pa_sav_pnt

Memo

Teach point pointer:

When operation function on teach point is performed, the teach point has to be indicated for the operation target. The one indicating this teach point is the teach point pointer.

The teach point pointed out by teach point pointer is called the current point (current teach point).

After pointer shifting operation, if intending to restart playback, the current point and present arm position have to be placed together.

When teach data is loaded, the current point is the top teach point.

Teach point operation is total only for teach data operation. It has nothing to do with actuating arm itself.

Reference

For more, refer to programming manual 3

pa__add__pnt

Function

Adds the current position to the teach point.

Syntax

long　　pa_add_pnt(ARM armno, PNTTYPE ptyp)

armno　 Arm number (No.).
ptyp　Teach point addition position and data type designated by "enum PNTTYPE".

Adds the current value as teach point with the method designating by "ptyp".

- **PT_PTP** : Adds PTP linear interpolation data after the current point.
  The current point becomes the added teach point.

- **PT_BPTP** : Adds PTP linear interpolation data before the current point.
  The current point becomes the added teach point.

- **PT_ARC1** : Adds the arc 1st point.
  The current point becomes the added teach point.

- **PT_ARC2** : Adds the arc 2nd point.
  The current point has to be the arc 1st point.
  The current point becomes the added teach point.

- **PT_ARC3** : Adds the arc 3rd point.
  The current point has to be the arc 2nd point.
  The current point becomes the added teach point.

- **PT_CIR1** : Adds the circle 1st point.
  The current point becomes the added teach point.

- **PT_CIR2** : Adds the circle 2nd point.
  The current point has to be the circle 1st point.
  The current point becomes the added teach point.

- **PT_CIR3** : Adds the circle 3rd point
  The current point has to be the circle 2nd point.
  The current point becomes the added teach point.

- **PT_AXS** : Adds PTP axis interpolation data retaining axis recovery attribution after the current point.
  The current point becomes the added teach point.

- **PT_BAXS** : Inserts PTP axis interpolation data retaining axis recovery attribution before the current point.
  The current point becomes the inserted teach point.

・**PT_POS** : Adds PTP linear interpolation NOAP data after the current point.
The current point becomes the added teach point.

・**PT_BPOS** : inserts PTP linear interpolation NOAP data before the current point.
The current point becomes the added teach point.

・**PT_ARC4** : Adds the arc 1st point with NOAP data.
The current point becomes the added teach point.

・**PT_ARC5** : Adds the arc 2nd point with NOAP data.
The current point has to be the arc 1st point.
The current point becomes the added teach point.

・**PT_ARC6** : Adds the arc 3rd point with NOAP data.
The current point has to be the arc 2nd point.
The current point becomes the added teach point.

・**PT_CIR4** : Adds the circle 1st point with NOAP data.
The current point becomes the added teach point.

・**PT_CIR5** : Adds the circle 2nd point with NOAP data.
The current point has to be the circle 1st point.
The current point becomes the added teach point.

・**PT_CIR6** : Adds the circle 3rd point with NOAP data.
The current point has to be the circle 2nd point.
The current point becomes the added teach point.

Return value
ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference

pa_chg_pnt	Current point alteration
pa_del_pnt	Teach data deletion

Description example

```
            :
pa_chg_pnt(ARM1, PM_JMP, 5); .. Moves the teach point pointer to the
                                5th teach point.
pa_add_pnt(ARM1, PT_PTP);     .. loads PTP linear interpolation data
                                teach point to the 6th teach point.
            :
```

pa__del__pnt

Function

Deletes the teach point.

Syntax

long pa_del_pnt(ARM armno, PNTDEL pdel)

armno Arm number (No.).
pdel Designates teach point to be deleted, with "enum PNTDEL".

Explanation

Deletes teach point designated by "pdel".

・ **PD_CUR** : Deletes teach point of current point.
If current point is deleted, teach point pointer moves back to the prior teach point after deletion.

On account current point is changeable, when intending to restart playback, the arm has to be moved to the current point position to get coordination.

・**PD_ALL** : Deletes all teach points of current teach Key.

・**PD_ALLDATA** : Deletes all teach data points.

Command cannot be accepted while in playback.

Return value

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference

pa_chg_pnt Current point alteration
pa_add_pnt Teach point addition

pa_rpl_pnt

Function

Replaces the present axis value with teach point data of current point.

Syntax

long pa_rpl_pnt(ARM armno)

armno Arm number (No.).

Explanation

Replaces the present axis value with teach point data of current point.

Remark

This function is available when teach data is being loaded or when teaching is performed.

There is no function to recover replaced data.

This replacement function is available when the current point is PTP data.

When intending to change only the position of certain completed teach data, if this replacement and current point alteration functions are combined well, alteration can be easily performed.

Return value

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

Reference

pa_chg_pnt Current point alteration

Description example

```
        :
pa_chg_pnt(ARM1, PM_JMP, 3);      .. Moves the teach point pointer to the 3rd
                                         teach point.

pa_rpl_pnt(ARM1);                 .. Replace the 3rd teach point with the
                                         current point.
```

pa__set__pnt

Function

Sets the teach point attribution.

Syntax

long pa_set_pnt(ARM armno, PNTATTR pattr, long* ldat, float fdat)

armno Arm number (No.).
pattr Designates attribution altered, with “enum PNTATTR”.
ldat Attribution altered
fdat Attribution altered

Explanation

Attribution designated by current point: “armno” has to be set in “ldat” or “fdat”.

・PA_CHGVEL : Alters playback linear velocity.
“fdat” dimension: [mm/sec]
・PA_CHGWAIT : Alters playback waiting time. “ldat[0]” dimension: [msec]
・PA_VELPTN : Alters teach data velocity interpolation pattern.
ldat[0] shows velocity pattern.
ldat[1] shows start up time [*10mSec]
ldat[2] shows start up time [*10mSec]
・PA_ROTVEL : Alters playback rotational velocity.
“fdat” dimension: [rad/sec]
・PA_AXSACC : Alters each axis accuracy. “fdat” dimension: [deg]
・PA_RMRCACC : Alters straight line accuracy. “fdat” dimension: [mm]
・PA_JUMPID : Alters JUMP numbers. Setting at ldat[0].

Reference

For teach data format, refer to programming manual.

Return value

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Description example

```
long     i,ldat[3];

for(i=0;i<3;i++)     ldat[i]=0;
  :
pa_chg_pnt(ARM1, PM_JMP, 3);.. Moves the teach point pointer to the 3rd teach
                                                                        point.

pa_set_pnt(ARM1, PA_CHGVEL, ldat, 1.2f);    .. Changes 3rd teach point velocity to
                                                                  1.2[mm/sec].
```

pa_set_idn

Function

Sets teach point ID data attribution.

Syntax

long pa_set_idn(ARM armno, PNTID pa, long dat)

armno Arm number (No.).
pa Alteration attribution designation
dat Attribution value

Explanation

This “pa” designates teach point attribution intended to change. Now, the attribution supported by this library is only one.

Macro definition
PA_SETID : Sets ID number.

This ID number is set to be designated by “dat”.

Return value

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference

pa_get_idn Teach point ID number acquisition

Description example

```
        :
pa_set_idn(ARM0,PA_SETID,0x1234);   .. ID No. setting
```

pa_chg_dio

Function

Sets teach point (PTP) DO data attribution.

Syntax

long pa_chg_dio(ARM armno, DIOSTATUSP dp)

armno　Arm number (No.).
dp　Pointer to the DO data attribution structure “DIOSTATUS”.

Explanation

Sets each designated port data attribution as current point DO data attribution. (Port 1 cannot be set on account of the system activation.)
Setting cannot be performed while in playback control.

Return value

ERR_OK　Normal termination
Others:　Anomalous termination (Refer to error table)

Description example

```
DIOSTATUS dos;
        :
dos.io1 = 0x01;                  .. PORT1 CH1 ON
dos.io2 = 0x80;                  .. PORT2 CH8 ON
dos.io3 = 0x40;                  .. PORT3 CH7 ON
        :
pa_chg_dio(ARM1,&dos);      .. Sets current point teach data DIO information.
```

Remark

DO information format inside teach data is long.　Beware when putting this format into “DIOSTATUS” type.

Example:　For adding PORT1_CH1 ON, PORT2_CH3 ON and PORT3_CH8 ON to current point DO information.

```
        :
PNTDAT pnt;
UBYTE*   ubp;
DIOSTATUS dos;
        :
pa_get_pnt(ARM0,&pnt);        .. Current point DO information loading
ubp = (UBYTE*)&pnt.ply.pnt.atr[6];     .. Setting with DIOSTATUS type.
dos.io1 = *(ubp+2);
dos.io2 = *(ubp+1);                  (ATTENTION!   To each port address.)
dos.io3 = *ubp;
dos.io1 |= 0x01;                ..Adds DIO information.
dos.io2 |= 0x04;
dos.io3 |= 0x80;
pa_chg_dio(ARM0,&dos);        .. Setting to current point DIO information
```

pa__vel__pnt

Function

Alters all teach data interpolation velocity in playback control.

Syntax

long pa_vel_pnt(ARM armno, float vgain)

armno Arm number (No.).
vgain Interpolation velocity alteration gain

Explanation

Alters arm playback interpolation velocity designated by “armno”.
Velocity of all data with PTP interpolation is corrected.

PTP interpolation velocity in playback control is the shifting time calculating from shifting value created from tip linear motion velocity: Vxyz and tip rotational motion velocity: Vypr.

$$\Delta Txyz = \Delta XYZ / Vxyz$$
$$\Delta Typr = \Delta YPR / Vypr$$

Larger one is selected.
Selected velocity (Vxyz or Vypr) is altered by “vgain”.
If “$\Delta Txyz > \Delta Typr$”,
Vxyz = Vxyz*vgain
Velocity is interpolated on the basis of “Vxyz”.

Return value

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference

pa_get_pvl Playback velocity coefficient information acquisition

pa_swt_dio

Function

Sets teach point DO data valid/invalid.

Syntax

long pa_swt_dio(ARM armno, long sw)

armno Arm number (No.).
sw Valid/invalid parameter

Explanation

When parameter (sw) is 0, DO attribution inside teach data becomes invalid and is not output even during playback control.
If parameter (sw) is not 0, output is exactly performed following teach data DO attribution in playback control.
Default is 1
This can be changed while in playback control.

Return value

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference

pa_ply_pnt performs playback control.
pa_get_pdo DO data valid/invalid acquisition while in playback.

pa__get__pnt

Function

Acquires teach point attribution of current point.

Syntax

long pa_get_pnt(ARM armno, PNTDATP tea)

armno Arm number (No.).
tea Download area for teach point attribution of current point.

Explanation

Acquires current point teach data.

tea.ply.pnt.agl[0] ～tea.ply.pnt.agl[6]	S1 axis angle [rad]～W2 axis [rad]
tea.ply.pnt.vel[0]	Linear velocity [mm/sec]
tea.ply.pnt.vel[1]	Rotational velocity [rad/sec]
tea.ply.pnt.atr[0]	Teach point type(PTP/PTP(NOAP))
tea.ply.pnt.atr[1]	Interpolation method (straight line/circle/arc)
tea.ply.pnt.atr[2]	Velocity type (Acceleration & Deceleration/ Acceleration/ Deceleration/Straight line)
tea.ply.pnt.atr[3]	Waiting time [*10mSec]
tea.ply.pnt.atr[4]	Serial number (not available for users)
tea.ply.pnt.atr[5]	ID number
tea.ply.pnt.atr[6]	DO information
tea.ply.pnt.atr[7]	Accuracy Upper 16 bit: RMRC accuracy (0-25.5[mm]) Lower 16 bit: axis accuracy (0-25.5[deg])
tea.ply.pnt.atr[8]	JUMP conditional number
tea.ply.pnt.atr[9]	Acceleration time [*0.01mSec]
tea.ply.pnt.atr[10]	Deceleration time [*0.01mSec]
tea.ply.pnt.atr[11]	Spare
tea.ply.cmt[32]	Maximum 32 letters comment
tea.noa.xyz[0]～tea.noa.xyz[3]	Arm X, Y and Z coordinate [mm]
tea.noa.noa[0]～tea.noa.noa[3]	Arm orientation
tea.jmp.cid	Number specifying JUMP condition
tea.jmp.jdg[0].cnd[0]	JUMP condition
tea.jmp.jdg[0].cnd[1]	Not available
tea.jmp.jdg[0].xdi	DI information
tea.jmp.jdg[0].tim	Time-out [mSec]
tea.jmp.jdg[0].key	Teach data Key
tea.jmp.jdg[0].pid	Teach point ID
tea.jmp.jdg[0].cnt	Inside information
:	
tea.jmp.jdg[7].cnd[0]	JUMP condition
tea.jmp.jdg[7].cnd[1]	Not available
tea.jmp.jdg[7].xdi	DI information
tea.jmp.jdg[7].tim	Time-out [mSec]
tea.jmp.jdg[7].key	Teach data Key

tea.jmp.jdg[7].pid	Teach point ID
tea.jmp.jdg[7].cnt	Inside information

JUMP condition can be set 8 (eight).

Reference

For interpolation pattern, refer to programming manual.

Return value

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

Reference

pa_get_cur	Acquires teach point number of current point.
pa_get_num	Acquires total numbers of teach point.
pa_get_idn	Acquires teach point ID number.

pa__get__cur

Function

Acquires current point teach point number.

Syntax

long　pa_get_cur(ARM armno, long* cur)

armno　Arm number (No.).
cur　Current point teach point number.

Explanation

Acquires teach point number from teach point attributions of current point.

Return value

ERR_OK　Normal termination
Others:　Anomalous termination (Refer to error table)

Reference

pa_get_pnt　Acquires current point teach point attribution.
pa_get_num　Acquires teach point total numbers.

pa_get_num

Function

Acquires teach point total numbers.

Syntax

long pa_get_num(ARM armno, long* num)

armno	Arm number (No.).
num	Teach point total numbers

Explanation

Acquires teach point total numbers.

Return value

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

Reference

pa_get_pnt	Acquires current point teach point attribution.
pa_get_cur	Acquires current point teach point number.

pa__get__idn

Function

Acquires teach point ID data attribution.

Syntax

```
long     pa_get_idn(ARM armno, long* idn)
```

armno   Arm number (No.).
idn   attribution value

Explanation

Acquires current point ID data attribution.

Return value

ERR_OK   Normal termination
Others: Anomalous termination (Refer to error table)

Reference

pa_set_idn   Teach point ID number setting

Description example

```
long     id;
         :
pa_get_idn(ARM0,&id);          .. Current point ID number acquisition
```

pa_get_cpt

Function

1st, 2nd and 3rd point information are acquired when current point is circle/arc.

Syntax

long pa_get_cpt(ARM armno, PNTNO pno, PNTDATP pntdat)

armno Arm number (No.).
pno Circle/arc Identification number designation.
pntdat Pointer for teach data structure “PNTDAT”.

Explanation

Teach data to obtain by “pa_get_pnt” is only the current point data. Therefore, if intending to acquire 2nd/3rd data for circle/arc, use this function.

Return value

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference

pa_get_pnt Acquires current point teach point attribution.

pa__get__pvl

Function

Acquires playback velocity coefficient information.

Syntax

long pa_get_pvl(ARM armno, float* div)

armno Arm number (No.).
div Playback velocity coefficient

Explanation

Acquires current setting playback velocity coefficient information.
For Playback velocity coefficient, default = 1. This default can be changed by "pa_vel_pnt".

Return value

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference

pa_vel_pnt Playback velocity coefficient information setting

pa__get__pdo

Function

Acquires DO information valid/invalid inside teach data when in playback control.

Syntax

```
long    pa_get_pdo(ARM armno, long* stat)
```

armno　Arm number (No.).
stat　DO valid/invalid flag

Explanation

stat = 1 : Playback data DO information valid.
stat = 0 : Playback data DO information invalid.

Return value

ERR_OK　Normal termination
Others:　Anomalous termination (Refer to error table)

Reference

pa_swt_dio　　Teach data DO information valid/invalid setting when in playback control.

pa_lod_pnt

Function

Loads teach point to controller.

Syntax

long　pa_lod_pnt(ARM armno, STRING file)

armno　Arm number (No.).
file　Teach point data file name

Explanation

Loads data designated by "file" to the arm designated by "armno".

Return value

ERR_OK　Normal termination
Others:　Anomalous termination (Refer to error table)

Reference

pa_sav_pnt　Teach data saving

pa_sav_pnt

Function

Loads teach points from the controller.　Saves them in hard disk of man-machine controller.

Syntax

long　pa_sav_pnt(ARM armno, STRING file)

armno　Arm number (No.).
file　Teach data storing file name

Explanation

Uploads teach data from the arm controller designated by "armno".　Saves it with the designated file name in the hard disk of man-machine controller.

Return value

ERR_OK　Normal termination
Others:　Anomalous termination (Refer to error table)

Reference

pa_lod_pnt　Teach data loading

pa__set__dlc

Function

Sets either to stop automatically or not synchronizing DO information with arm motion in playback control.

Syntax

long pa_set_dlc(ARM armno, long data)

armno Arm number (No.).
data DO automatic stop valid/invalid parameter

Explanation

When teach point DO information is outputted during playback control, if the arm is temporarily stopped (paused) or in brake-stop, set either to stop or not to output DO information.

When parameter (data) is 0, if the arm is stopped, DO information output is also stopped.
When parameter (data) is 1, even if the arm is stopped, DO information output continues.

Return value

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference

pa_get_dlc

pa__get__dlc

Function

Acquires determination whether to automatically stop or not synchronizing DO information with arm motion in playback control.

Syntax

long　pa_get_dlc(ARM armno, long* stat)

armno　Arm number (No.).
stat　DO automatic stop valid/invalid flag

Explanation

stat = 0 : Teach data DO information automatic stop invalid.
stat = 1 : Teach data DO information automatic stop valid.

Return value

ERR_OK　Normal termination
Others:　Anomalous termination (Refer to error table)

Reference

pa_set_dlc

pa_ply_set

Function

Acquires teach data Key with number designation.

Syntax

```
long     pa_ply_set(ARM armno, long number, long* key);
```

armno Arm number (No.).
number Teach data number
key Teach data Key number pointer

Explanation

Acquires teach data Key with number designation.

Return value

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference

pa_jmp_set Acquires JUMP data with Key and number designation

Description example:

```
long     key;
         :
pa_ply_set(ARM0,0,&key);      .... Acquires teach data Key with number
                                   designation.
```

pa_act_pnt

Function

Active teach data switching

Syntax

long pa_act_pnt(ARM armno, long key)

armno Arm number (No.).
key Teach data Key number

Explanation

Switches currently active teach data to designated Key.

Return value

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference

pa_chg_key Switching currently active teach data to Key.

Description example:

```
        :
pa_act_pnt(ARM0,3);        .... Alters from Key No.3 data into active teach data.
        :
```

pa_jmp_set

Function

JUMP data acquisition with number designation

Syntax

```
long      pa_jmp_set(ARM armno, long key, long num, JUMPP jmp);
```

armno Arm number (No.).
key Teach data Key number
num Data number
jmp JUMP data

Explanation

Acquires JUMP data by teach data Key and number designation

Return value

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference

pa_set_jmp JUMP data setting
pa_get_jmp JUMP data acquisition

Description example:

```
JUMP    jmp;
          :
pa_jmp_set(ARM0,2,0,&jmp);       .... JUMP data acquisition by Key2 and number
                                      designation
```

pa_get_jmp

Function

JUMP data acquisition.

Syntax

```
long	pa_get_jmp(ARM armno, long key, long id, JUMPP jmp);
```

armno	Arm number (No.).
key	Teach data Key number
id	Teach point ID number
jmp	JUMP data pointer

Explanation

Acquires JUMP data.

Return value

ERR_OK　Normal termination

Others:　Anomalous termination (Refer to error table)

Reference

pa_set_jmp　　JUMP data setting

Description example:

```
JUMP	jmp;
	:
pa_get_jmp(ARM0,2,0,&jmp);		.... This is defined in Key=2 and ID=0.
						JUMP data acquisition
```

pa__set__jmp

Function

JUMP data setting

Syntax

long pa_set_jmp(ARM armno, long key, long id, JUMPP jmp);

armno Arm number (No.)
key Teach data Key number
id Teach data ID number
jmp JUMP data

Explanation

Sets JUMP data.

Return value

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference

pa_get_jmp JUMP data acquisition

pa_ena_jmp

Function

JUMP data valid/invalid setting.

Syntax

```
long        pa_ena_jmp(ARM armno, long stat);
```

armno Arm number (No.).

stat 0： invalid

1： valid

Explanation

Sets JUMP data valid/invalid.

Return value

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

Reference

pa_get_ena JUMP data valid/invalid status acquisition

Description example:

```
                :
        pa_ena_jmp(ARM0,1);                     .... JUMP data is valid
                :
```

pa_ply_mod

Function

Teach mode setting

Syntax

long　　pa_ply_mod(ARM armno, long mod);

armno　Arm number (No.).

mod　　0：Teach mode released
　　　　1：Low
　　　　2：Medium
　　　　3：High

Explanation

Sets teach mode.

Macro definitions employed in “mod” are as follows:

Macro definition：

TEACH_OFF	Teach mode released
TEACH_LOW	Teach mode：Low
TEACH_MID	Teach mode：Medium
TEACH_HIGH	Teach mode：High

Return value

ERR_OK　Normal termination

Others:　Anomalous termination (Refer to error table)

Reference

pa_get_pmd　　Teach mode acquisition

Description example:

```
        :
pa_ply_mod(ARM0,TEACH_LOW);          .... Teach mode ON（low velocity）
        :
```

pa_chg_key

Function

Alters currently active teach data Key.

Syntax

```
long     pa_chg_key(ARM armno, long key);
```

armno Arm number (No.).

key Teach data Key number pointer

Explanation

Alters currently active teach data Key.

Return value

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

Reference

pa_act_pnt	Alters active teach data.
pa_get_key	Acquires currently active teach data Key.

Description example:

```
long     key;
         :
pa_get_key(ARM0,&key);          .... Alters currently active teach data Key.

if(key==1)                      .... When active teach data Key is 1
         pa_chg_key(ARM0,2);    .... Alters currently active teach data Key to
                                     2.
         :
```

pa_get_key

Function

Acquires active teach data Key.

Syntax

```
long    pa_get_key(ARM armno, long* key);
```

armno Arm number (No.).

key Teach data Key number pointer

Explanation

Acquires active teach data Key.

Return value

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

Reference

pa_chg_key	Alters currently active teach data Key.
pa_act_pnt	Alters active teach data.

pa_mon_pnt

Function

Acquires current teach point data (for monitor.)

Syntax

```
long    pa_mon_pnt(ARM armno, PNTDATP pntdat);
```

armno Arm number (No.).

pntdat Pointer to teach point data structure.

Explanation

Acquires current teach point data (for monitor.)

Return value

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

Reference

pa_get_pnt Acquires current teach point data.

pa_set_cmt

Function

Teach data comment setting

Syntax

```
long        pa_set_cmt(ARM armno, char* cmt);
```

armno Arm number (No.).

cmt Comment

Explanation

Designates comment at teach point (maximum 32 letters.)

Return value

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

Description example:

```
            :
pa_set_cmt(ARM0,"Diverging point");   .... Sets comment at current point.
            :
```

pa_jmp_cmt

Function

Moves current teach point by comment designation.

Syntax

long pa_jmp_cmt(ARM armno, long key, char* cmt);

armno Arm number (No.).
key Teach data Key number designation
cmt Comment designation

Explanation

Moves current teach point by comment designation.

Return value

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference

pa_chg_pnt

Description example:

```
        :
pa_jmp_cmt(ARM0,1,"Diverging point");     ....Moves current point to teach point
                                              with comment designated by Key 1.
        :
```

pa__get__ena

Function

JUMP data valid/invalid acquisition.

Syntax

long　pa_get_ena(ARM armno, long* stat);

armno　Arm number (No.).
stat　0: valid
　　　1：ｉnvalid

Explanation

Acquires JUMP data valid/invalid.

Return value

ERR_OK　Normal termination
Others:　Anomalous termination (Refer to error table)

Reference

pa_ena_jmp　JUMP data valid/invalid setting

pa＿get＿pmd

Function

Teach mode acquisition

Syntax

long　pa_get_pmd(ARM armno, long* mod);

armno　Arm number (No.).
mod　0：Teach mode released
　1：Low
　2：Medium
　3：High

Explanation

Acquires teach mode.

Macro definitions employed in “mod” are as follows:

Macro definition：

TEACH_OFF	Teach mode released
TEACH_LOW	Teach mode：Low
TEACH_MID	Teach mode：Medium
TEACH_HIGH	Teach mode：High

Return value

ERR_OK　Normal termination
Others:　Anomalous termination (Refer to error table)

Reference

pa_ply_mod　Teach mode setting

pa_del_jmp

Function

JUMP data deletion

Syntax

```
long      pa_del_jmp(ARM armno, long key, long jnm);
```

armno Arm number (No.).
key Key number
jnm JUMP number

Explanation

Deletes JUMP data.

Return value

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference

pa_set_jmp JUMP data setting

Description example:

```
long      key;
          :
pa_get_key(ARM0,&key);            .... Active Key acquisition
pa_jmp_cmt(ARM0,key,0);           .... JUMP data deletion
          :
```

pa_sav_ptj

Function

Teach and JUMP data saving.

Syntax

long pa_sav_ptj(ARM armno, char* name);

armno Arm number (No.).
name File name

Explanation

Saves active teach data and its JUMP data.

Return value

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference

pa_lod_ptj	Teach data and JUMP data loading
pa_lod_prj	Project loading
pa_sav_prj	Project saving
pa_lod_pnt	Teach data loading
pa_sav_pnt	Teach data saving

Description example:

```
        :
pa_sav_ptj(ARM0,"c:¥¥data.csv");          .... Teach and JUMP data saving.
        :
```

pa_lod_ptj

Function

Teach and JUMP data loading.

Syntax

```
long     pa_lod_ptj(ARM armno, char* name);
```

armno Arm number (No.).
name File name

Explanation

Loads active teach data and its JUMP data.

Return value

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference

pa_sav_ptj	Teach data and JUMP data loading
pa_lod_prj	Project loading
pa_sav_prj	Project saving
pa_lod_pnt	Teach data loading
pa_sav_pnt	Teach data saving

Description example:

```
        :
pa_lod_ptj(ARM0,"c:¥¥data.csv");     .... Teach and JUMP data loading
        :
```

pa__get__prj

Function

Project name acquisition

Syntax

long pa_get_prj(ARM armno, char* name);

armno Arm number (No.).
name Project name

Explanation

Acquires project name.

Return value

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference

pa_set_prj Project name setting

pa__set__prj

Function

Project name setting

Syntax

long pa_set_prj(ARM armno, char* name);

armno Arm number (No.).
name Project name

Explanation

Sets project name with maximum 128 letters.

Return value

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference

pa_get_ptj Project name acquisition

Description example:

```
        :
pa_set_prj(ARM0,"Test project");     .... Project name setting
        :
```

pa_sav_prj

Function

Project saving

Syntax

long　　pa_sav_prj(ARM armno, char* fdname);

armno　Arm number (No.).
name　Storing folder name

Explanation

Saves project.

Return value

ERR_OK　Normal termination
Others:　Anomalous termination (Refer to error table)

Reference

pa_sav_ptj	Teach data and JUMP data loading
pa_lod_ptj	Teach data and JUMP data loading
pa_lod_prj	Project loading
pa_lod_pnt	Teach data loading
pa_sav_pnt	Teach data saving

Description example:

```
        :
pa_sav_prj(ARM0,"c:¥¥data");        .... Project saving
        :
```

pa_lod_prj

Function

Project loading

Syntax

long pa_lod_prj(ARM armno, char* fdname);

armno Arm number (No.).
name Storing folder name

Explanation

Loads project.

Return value

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference

pa_sav_ptj	Teach data and JUMP data saving
pa_lod_ptj	Teach data and JUMP data loading
pa_sav_prj	Project saving
pa_lod_pnt	Teach data loading
pa_sav_pnt	Teach data saving

Description example:

```
        :
pa_lod_prj(ARM0,"c:¥¥data");        .... Project loading
        :
```

pa＿set＿cub

Function

CUBE designation

Syntax

```
long        pa_set_cub(ARM armno, long num, float xyz[], float ypr[]);
```

armno Arm number (No.).
num CUBE number (0-23)
xyz[] Maximum value [mm]
ypr[] Minimum value [mm]

Explanation

Designates CUBE.

Return value

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference

pa_get_cub CUBE information teaching
pa_cub_len CUBE side length designation

Description example:

```
float       xyz[3];
float       ypr[3];

            :
xyz[0]=100.0;
xyz[1]=100.0;
xyz[2]=100.0;
ypr[0]=0.0;
ypr[1]=0.0;
ypr[2]=0.0;
pa_set_cub(ARM0, 0, xyz, ypr);          .... 0 (zero) CUBE designation
            :
```

pa_get_cub

Function

CUBE teaching designation

Syntax

```
long      pa_get_cub(ARM armno, long num, long mod);
```

armno　Arm number (No.).
num　CUBE number (0-23)
mod　1 : Maximum value
　　　2 : Minimum value
　　　3 : Center

Explanation

Designates CUBE teaching.

Macro definitions employed in "mod" are as follows:
Macro definition:
MAXPNT :　Maximum value
MINPNT : Minimum value
CENTERPNT :　Center

Return value

ERR_OK　Normal termination
Others:　Anomalous termination (Refer to error table)

Reference

pa_set_cub　CUBE information designation
pa_cub_len　CUBE side length designation

Description example:

```
          :
pa_get_cub(ARM0, 0, MAXPNT);        .... 0 (zero) CUBE designation
          :
```

pa_cub_len

Function

CUBE side length designation

Syntax

```
long     pa_cub_len(ARM armno, long num, float xyz[]);
```

armno Arm number (No.).

num CUBE number (0–23)

xyz Each side length [mm]

Explanation

CUBE side length designation

Return value

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

Reference

pa_set_cub CUBE information designation

pa_get_cub CUBE information teaching

pa＿cub＿cmt

Function

Names CUBE.

Syntax

long　　pa_cub_cmt(ARM armno, long num, char* name);

armno　Arm number (No.).
num　　CUBE number (0–23)
name　　CUBE name

Explanation

Names CUBE.(maximum 32 letters)

Return value

ERR_OK　Normal termination
Others:　Anomalous termination (Refer to error table)

pa__del__cub

Function

CUBE deletion

Syntax

```
long        pa_del_cub(ARM armno, long num);
```

armno Arm number (No.).

num CUBE number (0–23)

Explanation

CUBE deletion

Return value

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

pa_ena_cub

Function

CUBE valid/invalid

Syntax

```
long    pa_ena_cub(ARM armno, long num, long mod);
```

armno Arm number (No.).

num CUBE number (0–23)

mod 1 : valid

0 : invalid

Explanation

Sets CUBE valid/invalid

By designating num as −1, all CUBE information can be set to be invalid at a time.

Valid designation is impossible.

Return value

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

pa__inf__cub

Function

CUBE information reference

Syntax

long pa_inf_cub(ARM armno, long num, CUBEP cub);

armno Arm number (No.).
num CUBE number (0–23)
cub CUBE information

Explanation

Refers to CUBE information.

cub..ena	CUBE information valid/invalid
cub..mod	Designation method when in CUBE information creation
NOCUBE :	CUBE information not exists
CUBEON :	Maximum value/minimum value designation
CUBEMAX :	Maximum value teaching
CUBEMIN :	Minimum value teaching
CUBECENTER :	Center teaching
CUBESIDE :	Side length designation
cub.max[3]	Maximum value or side length
cub.min[3]	Minimum value or center
cub.cmt[32]	Comment

Combination of cub.mod are as follows:

CUBEON	Maximum value/minimum value designation
CUBEMAX/CUBEMIN	Maximum value/minimum value teaching
CUBECENTER/CUBESIDE	Side length/center teaching

This combination is not correct. CUBE information is not established.

Return value

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference

pa_set_cub	CUBE information designation
pa_get_cub	CUBE information teaching
pa_cub_len	CUBE side length designation

pa_mod_vel

Function:

Sets velocity mode.

Syntax:

long pa_mod_vel(ARM armno, VELMODE vmod, AXIS axis)

armno Arm number (No.)
vmod Designates velocity mode by "enum VELMODE".
axis Designates motion axis. Plural valid axes can be designated only when axis velocity mode is designated. Velocity can be also. (ex) S1 | S3

Explanation:

Sets in velocity mode designated by "vmod".
If velocity mode is set, the arm moves with velocity set value.
Setting or alteration for velocity set value is performed by "pa_odr_vel".

VM_XYZ : Linear velocity mode in base coordinate
(for Visual BASIC: VM_XYZ1)
VM_YPR : Rotational velocity mode in base coordinate
(for Visual BASIC: VM_YPR1)
VM_xyz : Linear velocity mode in mechanical interface coordinate
(for Visual BASIC: VM_XYZ2)
VM_ypr : Rotational velocity mode in mechanical interface coordinate
(for Visual BASIC: VM_YPR2)
VM_ONE : Axis velocity mode
Makes the axis designated by "axis" move with the designated velocity.
VM_XYZYPR : Linear/rotational velocity mode in base coordinate
(for Visual BASIC: VM_XYZYPR1)
VM_xyzypr : Linear/rotational velocity mode in mechanical interface coordinate
(for Visual BASIC: VM_XYZYPR2)

Remark

Uncontrollable areas exist in any control except in axis velocity control.
This is defined as a singularity. It is the point where E1 axis becomes 0 [deg] (930 [mm] length from S2 rotation origin to W1 rotation origin).

Reference

For more, refer to programming manual in chapter 3.

Remark

When the tip target position calculated from designated velocity, exceeds arm motion range, warning occurs: "target value arm length exceeds 925 [mm] (automatically cut target value)."

If arm motion continues and exceeds motion range, the operation is automatically switched to temporary-stop status. Immediately, the servo-lock performs.
When LENGTH value is beyond 925 [mm] before being in motion, this designation is ignored on account of being out of motion range.

For axis velocity control likewise, each axis angle exceeds each axis angle limit at designated velocity, the following warnings occur:

−1070	S1 axis	velocity control	angle exceeded
−1071	S2 axis	velocity control	angle exceeded
−1072	S3 axis	velocity control	angle exceeded
−1073	E1 axis	velocity control	angle exceeded
−1074	E2 axis	velocity control	angle exceeded
−1075	W1 axis	velocity control	angle exceeded
−1076	W2 axis	velocity control	angle exceeded

There are two motion ranges: LENGTH 925 [mm] available for RMRC control and axis angle limit. If exceeding either limit, arm motion cannot be performed to the direction exceeding the motion range. Velocity command to this direction is ignored. But, velocity command to the movable direction can be provided.

Return value:

ERR_OK　Normal termination
Others:　Anomalous termination (Refer to error table)

Reference:

pa_odr_vel　　　Velocity setting in velocity mode

pa_odr_vel

Function:

Sets velocity for velocity mode.

Syntax:

long pa_odr_vel(ARM armno, float spd[])

armno Arm number (No.)

spd[] Velocity setting (Its significance is different depending on velocity mode.)

Explanation:

Sets velocity for velocity control mode.

for Base coordinate linear velocity mode &
Mechanical interface coordinate linear velocity mode

spd[0]: Displacement/velocity toward x [mm/sec]
spd[1]: Displacement/velocity toward y [mm/sec]
spd[2]: Displacement/velocity toward z [mm/sec]

for Base coordinate rotational velocity mode &
Mechanical interface coordinate rotational velocity mode

spd[0]: Angular velocity on x axis [rad/sec]
spd[1]: Angular velocity on y axis [rad/sec]
spd[2]: Angular velocity on z axis [rad/sec]

for Axis velocity mode

spd[0]: S1 axis motion angular velocity [rad/sec]
spd[1]: S2 axis motion angular velocity [rad/sec]
spd[2]: S3 axis motion angular velocity [rad/sec]
spd[3]: E1 axis motion angular velocity [rad/sec]
spd[4]: E2 axis motion angular velocity [rad/sec]
spd[5]: W1 axis motion angular velocity [rad/sec]
spd[6]: W2 axis motion angular velocity [rad/sec]

for Base coordinate linear/rotational velocity mode &
Mechanical interface coordinate linear/rotational velocity mode

spd[0]: Displacement/velocity toward x [mm/sec]
spd[1]: Displacement/velocity toward y [mm/sec]
spd[2]: Displacement/velocity toward z [mm/sec]
spd[3]: Angular velocity on x axis [rad/sec]
spd[4]: Angular velocity on y axis [rad/sec]
spd[5]: Angular velocity on z axis [rad/sec]

Remark

Sets velocity command value with seven float type configurations. After entering velocity control mode, velocity command ("pa_odr_vel" or "pa_chk_cnt") has to be issued every time-out (maximum value: 1000 msec) setting by "pa_set_tim". If command is not issued within time-out, it is recognized as controller anomaly. The arm automatically stops velocity control and sets in brake-stop status.

Return value:
- ERR_OK Normal termination
- Others: Anomalous termination (Refer to error table)

Reference:

pa_mod_vel	Velocity mode setting
pa_chk_cnt	Synchronization processing
pa_set_tim	Time-out setting

Description example:

```
float spd[7];
            :
 pa_set_tim(ARM1, 20);                    ･･･Time-out setting
                                                            (200msec)
pa_mod_vel(ARM1, VM_XYZ, 0);               … Velocity mode setting
                         :
Hereafter, "pa_odr_vel" or "pa_chk_cnt" has to be issued, at least once, within
200msec.
                         :
spd[0] = -50.0;                            … X
pd[1] =   40.0;                            … Y
spd[2] = 100.0;                            … Z
pa_odr_vel(ARM1, spd);                     … Velocity alteration
            :
spd[0] = 0.0;                              … X
spd[1] = 0.0;                              … Y
spd[2] = 0.0;                              … Z
pa_odr_vel(ARM1,   spd);                   … Velocity clear
           :
 pa_sus_arm(ARM1, WM_NOWAIT);               ･･･ Velocity control termination
```

Memo

AXIS is invalid except VM_ONE.

pa_mod_dpd

Function:

Sets target tip position/orientation direct real-time control mode.

Syntax:

long pa_mod_dpd(ARM armno);

armno　Arm number (No.)

Explanation:

Sets directly target tip position/orientation.
This mode creates motion, taking target value provided by "pa_odr_dpd" as absolute value.
Even though motion to absolute target value can be performed employing "pa_mov_mat", there is a difference whether interpolation is performed or not.

Trajectory from current position to target value provided by "pa_odr_dpd" is not interpolated. Therefore, when this mode is employed, velocity/trajectory interpolation has to be performed by users.

Remark

If entering real-time control mode, command library (pa_odr_dpd) has to be issued at least once within 1000msec all the time. If command is not issued within 1000 msec, it is recognized as man-machine controller anomaly. The arm automatically terminates real-time control mode and sets in brake-stop status.
For time-out setting, use "pa_set_tim".

Return value:

ERR_OK　Normal termination
Others:　Anomalous termination (Refer to error table)

Reference:

pa_odr_dpd	RMRC real-time control
pa_chk_cnt	Synchronization processing
pa_set_tim	Time-out setting

Description example:

```
MATRIX  mat;
ANGLE   an;
        :
pa_mov_mat(ARM1, MM_XYZNOA, mat, &an, WM_WAIT);
        :
pa_set_tim(ARM1, 20);           ･･･ Time-out setting(200msec)
pa_mod_jou(ARM1, JM_ON);        ･･･ Redundant axis control mode setting (all
                                        axes restricted)
pa_mod_dpd(ARM1);               ･･･ Control mode selection by tip matrix
        :
Hereafter, "pa_odr_dpd" or "pa_chk_pnt" has to be issued, at least once, within
200msec.
        Renewing "mat".
pa_odr_dpd(ARM1, mat, &an); ･･･ Tip matrix and restriction data axis value setting
                                        ( Refer to "pa_odr_dpd")
        Renewing "mat".
pa_odr_dpd(ARM1, mat, &an);
                :
pa_sus_arm(ARM1 , WM_NOWAIT);   ･･･ Real-time control termination
```

pa_odr_dpd

Function:

Sets target tip position/orientation data in real time.

Syntax:

long pa_odr_dpd(ARM armno, MATRIX mat, ANGLEP angle);

armno	Arm number (No.)
mat	Absolute target position/orientation matrix
angle	Each axis value for redundant axis restriction control

Explanation:

Sets target value when in target position/orientation direct mode.

For “mat”, designates absolute position/orientation every control cycle (10ms). Motion controller performs RMRC feedback control without trajectory interpolation for position/orientation provided by “mat”.
To summarize, arm control trajectory is controlled by the value set in PA library. Therefore, a difference between current position/orientation and setting “mat” has to be one cycle deviation (velocity divided by control cycle.)

In this control, likewise, redundant axis control mode (mode selected by “pa_mod_jou”) to control elbow position is valid and restricted by each axis value provided by “angle”.
If redundant axis control mode is “no restriction” or “S3 axis fixed”, “angle” is invalid.
If redundant axis control mode is “S3 interpolation”, “MATRIX mat” likewise, S3 axis angle every control cycle is also set in “angle”.

Remark

If entering real-time control mode, command library (pa_odr_dpd) has to be issued at least once within 1000msec all the time. If command is not issued within 1000 msec, it is recognized as man-machine controller anomaly. The arm automatically terminates real-time control mode and sets in brake-stop status.
For time-out setting, use “pa_set_tim”.

Return value:

ERR_OK　Normal termination
Others:　Anomalous termination (Refer to error table)

Reference:

pa_mod_dpd	RMRC real-time control mode setting
pa_mod_axs	Each axis real-time control mode setting
pa_odr_axs	Each axis real-time control
pa_chk_cnt	Synchronization processing
pa_set_tim	Time-out setting

pa_mod_axs

Function:

Sets target angle direct control (real-time) mode.

Syntax:

long pa_mod_axs(ARM armno);

armno　Arm number (No.)

Explanation:

Sets directly target angle.
This mode creates motion, taking target value provided by "pa_odr_axs" as absolute value.
Even though motion to target angle value can be performed employing "pa_exe_axs", there is a difference whether interpolation is performed or not.

Angle from current position to target value provided by "pa_odr_axs" is not interpolated. Therefore, when this mode is employed, velocity/angle interpolation has to be performed by users.

Remark

If entering real-time control mode, command library (pa_odr_axs) has to be issued at least once within 1000msec all the time. If command is not issued within 1000 msec, it is recognized as man-machine controller anomaly. The arm automatically terminates real-time control mode and sets in brake-stop status.
For time-out setting, use "pa_set_tim".

Return value:

ERR_OK　Normal termination
Others:　Anomalous termination (Refer to error table)

Reference:

pa_odr_axs　　Each axis real-time control

Description example:

```
ANGLE   angle;

pa_get_agl(ARM1, &angle);
        :
pa_odr_axs(ARM1, &angle);       … Each axis value (current value) setting
pa_set_tim(ARM1, 20);           ･･･ Time-out setting (200msec)
pa_mod_axs(ARM1);  … Control mode selection by axis real-time control
        :
Hereafter, "pa_odr_axs" or "pa_chk_pnt" has to be issued, at least once, within 200msec.
        :
angle.s3 += 0.5*M_PI/180.0;             … Each axis renewal
pa_odr_axs(ARM1, &angle);               … Each axis value setting
        :                               … Each axis renewal
pa_odr_axs(ARM1, &angle);               … Each axis value setting
        :
pa_sus_arm(ARM1, WM_NOWAIT);            ･･･ Real-time control termination
```

pa_odr_axs

Function:

Sets target axis data in real time.

Syntax:

long pa_odr_axs(ARM armno, ANGLEP angle);

armno Arm number (No.)
angle Each axis target value for each axis real-time control

Explanation:

Sets target axis value in real time.
For "angle", designates each axis value every control cycle (10ms).
Motion controller performs axis feedback control without axis interpolation for each axis provided by "angle".
To summarize, arm axis is controlled by the value set in PA library. Therefore, the difference between current angle and setting "angle" has to be one cycle deviation (velocity divided by control cycle.)

Remark

If entering real-time control mode, command library (pa_odr_axs) has to be issued at least once within 1000msec all the time. If command is not issued within 1000 msec, it is recognized as man-machine controller anomaly. The arm automatically terminates real-time control mode and sets in brake-stop status.
For time-out setting, use "pa_set_tim".

Return value:

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference:

pa_mod_axs Each axis real-time control setting
pa_odr_dpd RMRC real-time control

pa_mod_dir

Function:

Direct control (servo lock) ON/OFF

Syntax:

long pa_mod_dir(ARM armno, DIRECTMODE dmod);

armno Arm number (No.)

dmod Designates servo lock by "enum DIRECTMODE".

Explanation:

Before changing to weight compensation control or simplified weight compensation control, the arm has to be in servo-lock status.

Its servo-lock status ON/OFF switching is performed.

DM_START : Servo-lock ON

DM_STOP : Servo-lock OFF

Remark

If entering weight compensation control, (to be concrete, issuing pa_wet_ded), synchronization processing library (pa_chk_cnt) has to be issued, at least once, within 1000msec. If command is not issued within 1000 msec, it is recognized as man-machine controller anomaly. The arm automatically terminates real-time control mode and sets in brake-stop status.

For time-out setting, use "pa_set_tim".

Return value:

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

Reference:

pa_chk_cnt Synchronization processing

pa_set_tim Time-out setting

pa__wet__ded

Function:

Weight compensation control

Syntax:

long pa_wet_ded(ARM armno, AXIS axis);

armno Arm number (No.)
axis Weight compensation axis designation

Explanation:

Weight compensation control is performed with axis angle, adjacent arm link weight and gravity center position.

Macro definitions		Designated axes
LOCKAXIS_S3	:	S1|S2|E1|E2|W1|W2
LOCKAXIS_S1	:	S2|S3|E1|E2|W1|W2

As macro definitions shown above, there are only two weight compensation controls. Axes able to operate simultaneously are six. Either S1 or S3 axis is always in servo-lock status. (If different setting except the ones above are adopted, "LOCKAXIS_S3 " is automatically set on the motion control calculator side.)

This function can be performed only when in arm direct control.

Return value:

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference:

pa_mod_dir Direct control status ON/OFF

Description example:

```
AXIS axis;
        :
axis = LOCKAXIS_S1;
        :
pa_set_tim(ARM0,20);              ･･･ Time-out setting
                                      (200msec)
pa_mod_dir(ARM0,DM_START);        ... Direct control start
pa_wet_ded(ARM0,axis);            ... S1 servo-lock selection
        :
        :
```

Hereafter, "pa_odr_dpd" or "pa_chk_pnt" has to be issued, at least once, within 200msec.

```
         :                   "mat" renewal
pa_sus_arm(ARM0, WM_NOWAIT);  ･･･ Weight compensation control termination
```

pa_drt_ded

Function:

Sets arm installation position. (floor mounted/suspending from ceiling)

Syntax:

long pa_drt_ded(ARM armno, long vec);

armno	Arm number (No.)
vec	Arm installation position designation

Explanation:

Before performing weight compensation control, designate the arm status either floor mounted or suspending from ceiling. On account of arm being already initialized as floor mounted status, only when the arm is suspended from the ceiling, this library has to be performed.

Macro definition employed in "vec" as follows:

Macro definitions	Designation
ARM_STANDING	Floor mounted status
ARM_HANGING	Status suspended from ceiling

Arm installation positions when in weight compensation control are only two macro definitions as described above. Other definitions cannot be employed.

Return value:

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

Reference:

pa_wet_ded	Direct control status ON/OFF
pa_get_drt	Direct control installation position acquisition

pa__chk__cnt

Function:

Synchronization processing in weight compensation control (velocity, redundant axis velocity and real-time control)

Syntax:

long pa_chk_cnt(ARM armno)

armno Arm number (No.)

Explanation:

Synchronization processing between man-machine controller and motion controller is performed in weight compensation control.

If entering weight compensation control, this PA library has to be issued at least once within 1000msec all the time. If command is not issued within 1000 msec, it is recognized as man-machine controller anomaly. The arm automatically terminates real-time control mode and sets in brake-stop status.

For time-out setting, use "pa_set_tim".

Return value:

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

Reference:

pa_wet_ded	Weight compensation control start
pa_set_tim	Time-out setting in synchronization processing

Description example:

```
AXIS axis;
          :
axis = LOCKAXIS_S1;
          :
pa_set_tim(ARM0,20);              ･･･ Time-out setting
                                                    (200msec)
pa_mod_dir(ARM0,DM_START);        ･･･ Direct control start
pa_wet_ded(ARM0,axis);            ･･･ S1 axis servo-lock selection
          :
```

Hereafter, "pa_odr_dpd" or "pa_chk_pnt" has to be issued, at least once, within 200msec.

```
while(1){
          :
   pa_chk_cnt(ARM1);              ･･･ Synchronization processing
   Sleep(100);
          :
          :        <Actuates arm manually.>
}
pa_mod_dir(ARM1, DM_STOP);        ･･･ Direct control  termination
                    :
```

pa_set_tim

Function:

Time-out setting in synchronization processing

Syntax:

long pa_set_tim(ARM armno, long tim);

armno Arm number (No.)

tim Time-out

Explanation:

Sets synchronization processing time-out in weight compensation, velocity and redundant axis control

Default (when power is ON) is 1000ms.

Setting range is 10～1000ms.

Unit is［*10ms］.

(ex) tim = 1 : 10ms

tim ＞ 100 : error

Return value:

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

Reference:

pa_wet_ded	Weight compensation control
pa_chk_cnt	Synchronization processing
pa_get_tim	Time-out acquisition

pa_get_tim

Function:

Time-out acquisition in synchronization processing

Syntax:

long pa_get_tim(ARM armno, long* tim);

armno Arm number (No.)
tim Time-out

Explanation:

Acquires synchronization processing time-out in weight compensation, velocity and redundant axis control. Unit is[*10ms].

Return value:

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference:

pa_chk_cnt Synchronization processing
pa_set_tim Time-out setting

pa__get__drt

Function:

Arm installation position acquisition in direct control (floor mounted/suspending from ceiling)

Syntax:

long pa_get_drt(ARM armno, long* stat);

armno Arm number (No.)

stat Arm installation position parameter

Explanation:

Before performing weight compensation control, acquire arm status either mounted on the floor or suspended from the ceiling.

Parameter（stat） is 1: floor mounted

Parameter（stat） is −1: suspending from ceiling

Return value:

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

Reference:

pa_drt_ded Arm installation direction setting in direct control

pa_set_hom

Function:

Alters home position

Syntax:

long pa_set_hom(ARM armno, ANGLEP angle);

armno Arm number (No.)
angle Designates each axis angle. Unit: [rad]

Explanation:

Alters home position set in arm parameter.
Returns to default value when power supply is off.
Home position default angle is 0[deg] for all axes.
For home position default angle correction method, refer to parameter setting.)

Return value:

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference:

pa_def_hom Defines current value as home position
pa_exe_hom Arm control to home position

Description example:

```
                :
ANGLE   angle;

angle.s1 = 1.3;
angle.s2 = 1.5;
                :
angle.w2 = 0.0;
pa_set_hom(ARM1, &angle);
                :
```

pa__set__esc

Function:

Alters escape position.

Syntax:

long pa_set_esc(ARM armno, ANGLEP angle);

armno Arm number (No.)

angle Designates each axis angle. Unit: [rad]

Explanation:

Alters escape position set in arm parameter.

Returns to default value when power supply is off.

Escape position default angles are:

S2: 45 [deg]

E1: 90 [deg]

W1: 45 [deg]

Others: 0[deg]

Reference

For escape position default angle correction method, refer to parameter setting.

Return value:

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

Reference:

pa_def_esc Defines current value as escape position

pa_exe_esc Arm control to escape position

pa__set__saf

Function:

Alters safety position.

Syntax:

long pa_set_saf(ARM armno, ANGLEP angle)

armno	Arm number (No.)
angle	Designates each axis angle. Unit: [rad]

Explanation:

Alters safety position set in arm parameter.
Returns to default value when power supply is off.
Safety position default angles are:

S2: 45 [deg]
E1: 90 [deg]
W1: −45 [deg]
Others: 0[deg]

Reference

For safety position default angle correction method, refer to parameter setting.

Return value:

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference:

pa_def_saf	Defines current value as safety position.
pa_exe_saf	Arm control to safety position

pa_def_hom

Function:

Memorizes each axis angle of current value as home position.

Syntax:

```
long pa_def_hom(ARM armno);
```

armno Arm number (No.)

Explanation:

Memorizes each axis angle of current value as home position.
Returns to default value when power supply is off.
Home position default angle is 0 [deg] for all axes.

Reference

For home position default angle correction method, refer to parameter setting.

Return value:

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference:

pa_set_hom	Home position alteration
pa_exe_hom	Arm control to escape position

Description example:

```
            :
pa_def_hom(ARM1); ... Defines current value as home position.
            :
```

pa__def__esc

Function:

Memorizes each axis angle of current value as escape position.

Syntax:

```
long pa_def_esc(ARM armno);
```

armno Arm number (No.)

Explanation:

Memorizes each axis angle of current value as escape position.
Returns to default value when power supply is off.
Escape position default angles are:

S2: 45 [deg]
E1: 90 [deg]
W1: 45 [deg]
Others: 0[deg]

Reference

For escape position default angle correction method, refer to parameter setting.

Return value:

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference:

pa_set_esc	Escape position alteration
pa_exe_esc	Arm control to escape position

pa_def_saf

Function:

Memorizes each axis angle of current value as safety position.

Syntax:

long pa_def_saf(ARM armno)

armno　Arm number (No.)

Explanation:

Memorizes each axis angle of current value as safety position.
Returns to default value when power supply is off.
Safety position default angles are:

S2: 45 [deg]
E1: 90 [deg]
W1: -45 [deg]
Others: 0[deg]

Reference

For safety position default angle correction method, refer to parameter setting.

Return value:

ERR_OK　Normal termination
Others:　Anomalous termination (Refer to error table)

Reference:

pa_set_saf	Safety position alteration
pa_exe_saf	Arm control to safety position

pa_set_mtx

Function:

Conversion matrix setting in three dimension space coordinate while in playback control

Syntax:

```
long pa_set_mtx(ARM armno, MATRIX mat1)
```

armno Arm number (No.)
mat1 Coordinate conversion matrix

Explanation:

Sets coordinate conversion matrix "mat1" for the arm designated by "armno".
Arm trajectory control is corrected by conversion matrix in playback control. Coordinate conversion matrix default value is unit matrix I.

$$I = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{pmatrix}$$

Reference

For more, refer to programming manual, chapter 3.

Return value:

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Description example:

```
        :
MATRIX  mat1;

        :
pa_set_mtx(ARM1, mat1);          ... Sets coordinate conversion matrix.
        :
```

pa_set_mat

Function:

Playback trajectory coordinate conversion

Syntax:

long pa_set_mat(ARM armno, MATRIX mat0, MATRIX mat1);

armno Arm number (No.)
mat0 Work coordinate matrix
mat1 Teach data coordinate matrix

Explanation:

Places playback teach data from teach data coordinate to work coordinate system.
Creating standard coordinate matrix (:mat1) from teach data, provides work coordinate matrix (:mat0) to place deviation in its coordinate system.

Reference

For work coordinate matrix/teach coordinate matrix creation method, refer to programming manual, chapter 3.

"pa_set_mtx" is unit matrix [I] created from one of this function: "mat1".

This function cannot be performed while in playback control.

Return value:

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference:

pa_set_mtx

Description example:

```
MATRIX  mat0,mat1;
              :
(Work coordinate matrix creation：mat0)
(Teach data coordinate matrix creation：mat1)
              :
pa_set_mat(ARM0,mat0,mat1);   … Sets coordinate conversion matrix
              :
```

pa_odr_xyz

Function:

Sets tip position offset.

Syntax:

```
long        pa_odr_xyz(ARM armno, TRANSMATP trans);
```

armno Arm number (No.)

trans Designates either coordinate system with absolute deviation or with relative deviation. Pointer to trajectory offset data structure: TRANSMAT.

Explanation:

Sets tip position offset with mode and coordinate designated by "trans->Enable". Coordinates and modes of "trans->Enable" are as follows:

MODE_xyz : Mechanical interface coordinate, absolute deviation
Offset is set as trans->_xyz[0]-[2].
(for Visual BASIC: MODE_XYZ1)

MODEIxyz : Mechanical interface coordinate, relative deviation
Offset is set as trans->Ixyz[0]-[2].
(for Visual BASIC: MODE_XYZ2)

MODE_XYZ : Base coordinate, absolute deviation
Offset is set as trans->_XYZ[0]-[2].
(for Visual BASIC: MODE_XYZ3)

MODEIXYZ : Base coordinate, relative deviation
Offset is set as trans->IXYZ[0]-[2].
(for Visual BASIC: MODE_XYZ4)

MODE_wave: Trajectory coordinate, absolute deviation
Offset is set as trans->_wave[0]-[2].
(for Visual BASIC: MODE_WAVE1)

MODEIwave: Trajectory coordinate, relative deviation
Offset is set as trans->Iwave[0]-[2].
(for Visual BASIC: MODE_WAVE2)

With this function, offset value can be changed in real-time during playback control. This makes it possible to detect playback trajectory deviation with sensor, etc. and correct it.

Return value:

ERR_OK Normal termination

Others: Anomalous termination (Refer to error charts)

Reference:

pa_get_sns Trajectory offset acquisition during playback control

Description example:

```
        TRANSMAT tm;
        float      data;
                 :
        pa_ply_pnt(ARM0,PB_FORE,-1,WM_WAIT);   ... Playback start
                 :
         data = 0.5f;                    ...  Limit value when in offset addition = 0.5[mm]
        pa_lmt_xyz(ARM0, data);          ...   Limit value setting when in offset addition

tm.Enable = MODE_xyz;  ...   mechanical interface coordinate absolute deviation selection
        tm._xyz[0] = 2.0;                ...  Offset value toward x = 2.0[mm]
        tm._xyz[1] = 0.0;                ...  Offset value toward y = 0.0[mm]
        tm._xyz[2] = 0.0;                ...   Offset value toward z = 0.0[mm]
        pa_odr_xyz(ARM0,&tm);   ...   Adds offset value to mechanical interface coordinate
                              :
```

pa_lmt_xyz

Function:

Sets limit value (value added every cycle) when in tip position offset addition

Syntax:

long pa_lmt_xyz(ARM armno, float data);

armno Arm number (No.)
data Limit value when in offset addition. Unit: [mm]

Explanation:

In offset control, when tip position offset is provided by "pa_odr_xyz", offset value first enters the offset pool. This offset value is added with very small fixed quantity every cycle until offset value fills out the pool in several cycles,
Sets a very small fixed quantity every cycle (here is called limit value.)

Return value:

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference:

pa_get_lmt Tip position offset limit value acquisition

pa__get__mat

Function:

Acquires coordinate conversion matrix when in playback.

Syntax:

long pa_get_mat(ARM armno, MATRIX mat0, MATRIX mat1);

armno Arm number (No.)
mat0 Work coordinate matrix
mat1 Teach data coordinate matrix

Explanation:

Acquires teach data coordinate matrix and work coordinate matrix currently set by "pa_set_mat" or "pa_set_mtx".

As work coordinate matrix is the only one set by "pa_set_mtx", "mat1" ought to be a unit matrix.

MATRIX mat0, mat1:

$$\begin{pmatrix} nx & ox & ax & px \\ ny & oy & ay & py \\ nz & oz & az & pz \end{pmatrix}$$ Matrix mat0[3][4], mat1[3][4]

Return value:

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference:

pa_set_mat	Playback trajectory coordinate conversion
pa_set_mtx	Conversion matrix setting in three dimension space coordinate when in playback control

pa_get_sns

Function:

Acquires trajectory offset when in playback.

Syntax:

long pa_get_sns(ARM armno, TRANSMATP sns);

armno Arm number (No.)

sns Pointer to currently provided trajectory offset structure TRANSMAT

Explanation:

Trajectory offset is stored in TRANSMAT type: sns.

sns._xyz[] : Mechanical interface coordinate, absolute deviation offset value (x,y,z)
(for Visual BASIC: sns.xyz11)
sns.Ixyz[] : Mechanical interface coordinate, relative deviation offset value (x,y,z)
(for Visual BASIC: sns.xyz12)
sns._XYZ[] : Base coordinate, absolute deviation offset value (X,Y,Z)
(for Visual BASIC: sns.xyz21)
sns.IXYZ[] : Base coordinate, relative deviation offset value (X,Y,Z)
(for Visual BASIC: sns.xyz22)
sns._wave[]: Trajectory coordinate, absolute deviation offset value (xw,yw,zw)
(for Visual BASIC: sns.wave1)
sns.Iwave[]: Trajectory coordinate, relative deviation offset value (xw,yw,zw)
(for Visual BASIC: sns.wave2)

Remark

For absolute deviation, offset value currently set by "pa_odr_xyz" is set.
For relative deviation, integration value of offset value set by "pa_odr_xyz" is set.

Return value:

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

Reference:

pa_odr_xyz Tip position offset setting

pa_get_lmt

Function:

Acquires limit value (value added every cycle) when in tip position offset addition.

Syntax:

```
long    pa_get_lmt(ARM armno, float* dat);
```

armno Arm number (No.)
dat Limit value when in offset addition. Unit: [mm]

Explanation:

Acquires very small quantity offset value (limit value) added every cycle in tip offset control.

Return value:

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference:

pa_lmt_xyz Limit value setting when in offset addition

pa_mod_jou

7-axis arm function

Function:

Redundant axis control mode

Syntax:

long pa_mod_jou(ARM armno, JOUMODE jmod);

armno Arm number (No.)
jmod Designates redundant axis control mode by "enum JOUMODE".

Explanation:

Sets redundant axis control mode

For 7-axis arm, like PA-10, even if tip position and orientation trajectory are the same, plural axis values exist. Redundant axis operation has to be set.

IN all RMRC control, if intending to control elbow position, following redundant axis control modes are provided:

JM_OFF : Redundant axis control restriction release
Redundant axis control is reset in RMRC control.

JM_ON : Redundant axis control all axes restriction mode
Each axis value, when in motion, is restricted by teach point or each axis value of designated data in RMRC control.

JM_S3ON : Redundant axis control only S3axis restricted mode
Each axis value of S3 axis when in motion is restricted by teach point or each axis value of designated data in RMRC control.

JM_S3DIV : Redundant axis control S3 axis interpolation restriction mode
Each axis value of S3 axis when in motion is restricted by teach point or each axis value of designated data in RMRC control.

JM_S3HOLD : Redundant axis control S3 axis fixation restriction mode
Each axis value of S3 axis when in motion is fixed by teach point or each axis value of designated data in RMRC control.

In any method, tip trajectory is the same. But, each axis value is different.

Reference

For more, refer to programming manual, chapter 3.

Restriction force for each provided axis data is as follows:

No restriction ＜Small＞ ＜Medium＞ ＜large＞ Fixed
JM_OFF → JM_ON → JM_S3ON → JM_S3DIV → JM_S3HOLD

When intending to change elbow position keeping the same position and orientation in RMRC control:

JM_SET : Sets the mode to operate redundant axis control parameter.
For parameter operation method, uses "pa_odr_jou".

JM_RESET : Returns redundant axis control parameter to default value (no restriction).

JM_VSET : Sets the mode to operate redundant axis control parameter at constant velocity.

For parameter operation method, uses "pa_odr_vel".

Return value:

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference:

pa_odr_jou	Redundant axis control ON/OFF
pa_odr_vel	Velocity mode velocity setting

Description example:

```
        :
pa_mod_jou(ARM1, JM_ON);                … Redundant axis control mode
                                            "All axes restriction" selection
pa_ply_pnt(ARM1, PB_FORE, -1, WM_WAIT);    … Playback control
        :
```

pa_odr_jou

7-axis arm function

Function:

Redundant axis control parameter operation

Syntax:

long pa_odr_jou(ARM armno, JOUTYPE jtyp);

armno Arm number (No.).
jtyp Redundant axis transition direction

Explanation:

If redundant axis control parameter is operated, arm position can be changed.
This parameter is valid only when "JM_SET" is selected by "JM_SET".

JT_RIGHT : Shifts redundant axis restriction parameter to the right.
JT_LEFT : Shifts redundant axis restriction parameter to the left.
JT_HOLD : retains redundant axis restriction parameter.

Parameter operation continues until next operation is performed.

Return value:

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference:

pa_mod_jou Redundant axis control mode

Description example:

```
            :
pa_mod_jou(ARM1, JM_SET);       ... Redundant axis restriction parameter operation
                                     mode
pa_odr_jou(ARM1, JT_LEFT);     ... Shifts Redundant axis restriction parameter to
                                     the left.
            :
```

pa_mov_jou

7-axis arm function

Function:

Redundant axis control motion by S3 axis designation

Syntax:

long pa_mov_jou(ARM armno, float s3, long func);

armno	Arm number (No.).
s3	Designates S3 axis target angle [rad]
func	Designation whether to wait or not motion completion

Explanation:

For 7-axis arm, like PA-10, even if tip position and orientation trajectory are the same, plural axis values exist. Therefore, this is the mode to control 7-axis arm as 6-axis one by interpolating a certain axis (S3). Designating S3 axis target angle without changing tip position/orientation, controls redundant axis (elbow) changing S3 axis angle to the target angle.

After performing this processing, redundant axis control mode is in S3 interpolation restriction. The mode continues to be in S3 axis interpolation restriction status if it is not changed.

The explanation on "func" is the same as "pa_mov_XYZ".

Return value:

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

Reference:

pa_mod_jou	Redundant axis control mode setting
pa_odr_vel	Velocity mode velocity setting

Description example:

```
float   s3;
            :
s3 = 80.0*M_PI/180.0;                 … S3 axis target value = 80[deg]
pa_mov_jou(ARM1, s3, WM_WAIT);        … Redundant axis (elbow) control
            :
pa_mov_XYZ(ARM1, 0.0, 100.0, 0.0, WM_WAIT);
```

(Moves 100 mm toward Y (Y=100[mm]) kept on laying redundant axis (elbow) down.)

pa_get_jou

7-axis arm function

Function:

Acquires redundant axis control mode in RMRC control.

Syntax:

long pa_get_jou(ARM armno, long* stat);

armno Arm number (No.).
stat Redundant axis control status

Explanation:
"stat" is set by "JOUMODE" as follows:

stat=JM_OFF : Redundant control is OFF status.
stat=JM_ON : Redundant control is all axes restriction control mode status.
stat=JM_S3ON : Redundant control is S3 axis restriction control mode status.
stat=JM_S3DIV : Redundant control is S3 axis interpolation control mode status.
stat=JM_S3HOLD : Redundant control is S3 axis fixation control mode status.

Return value:

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference:

pa_mod_jou Redundant axis control mode setting.

pa__get__mod

Function:

Acquires motion control calculator status.

Syntax:

```
long pa_get_mod(ARM armno, long* stat);
```

armno　Arm number (No.)
stat　Current motion control calculator status

Explanation:

Acquires motion control calculator status.
Motion control calculator status is as follows:

1　:　Not available
2　:　Not available
3　:　Brake-stop status
4　:　Not available
5　:　Not available
6　:　Not available
7　:　Not available
8　:　Each axis angle control status
9　:　Each axis velocity control status
10:　Direct servo-lock status
11:　Simplified weight compensation status
12:　Weight compensation status
13:　RMRC control status
14:　RMRC redundant axis control status
15:　Each axis control servo-lock status
16:　Not available
17:　Each axis angle correction status
18:　Circle interpolation playback status
19:　Linear interpolation playback status
20:　Arc interpolation playback status
21:　RMRC control servo-lock status
22:　Playback start waiting status (each axis control)
23:　Each axis control servo-lock status (while in playback)
24:　RMRC control servo-lock status (while in playback)
25:　Playback start waiting status (RMRC control)
26:　Playback tip position shifting status
27:　Redundant axis movable status
28:　RMRC real-time status
29:　Playback axis interpolation angle correction status
30:　Interim status shifting to the point after coordinate conversion
31:　Redundant axis movable status (S3 axis interpolation)
32:　Each axis real-time control mode status
33:　Motion between teach data (RMRC control)
34:　Motion between teach data (each axis control)

Return value:

ERR_OK　Normal termination

Others:　Anomalous termination (Refer to error table)

pa_get_ver

Function:

Acquires motion control program version.

Syntax:

```
long    pa_get_ver(ARM armno, float* ver);
```

armno Arm number (No.)
ver Motion control program version.

Explanation:

Acquires motion control CPU program version.

Return value:

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

pa_get_com

Function:

Acquires current arm communication status.

Syntax:

```
long    pa_get_com(ARM armno, long* stat);
```

armno Arm number (No.)

stat Current arm communication status.

Explanation:

Acquires communication status between the controller while in arm control and the servo driver (not communicating / while in communication and actual machine control / while in communication and simulation control.)

Macro definition employed by "stat" is as follows:

STP_STATUS	0	Status not in communication
MOV_STATUS	1	while in communication and actual machine control
SIM_STATUS	2	while in communication with inner servo driver of motion control section and in simulation mode control

Before issuing PA library function loading current arm information, when this definition is used to confirm whether or not the controller is communicating now, if it is communicating, it is clearly seen that current information can be loaded by issuing the library. If not communicating, current information cannot be loaded by even issuing PA library.

Return value:

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

Description example:

```
long    jou;
long    stat;
        :
While in RMRC control
        :
 pa_get_com(ARM1, &stat);          ・・・ Acquires communication status

 if(!stat){                               If not in communication
        pa_sta_arm(ARM0);          ・・・ Starts communication.
 }
 pa_get_jou(ARM0, &jou);・・・Loading current redundant axis control mode.
              :
```

pa__get__sts

Function:

Acquires current arm information.

Syntax:

long pa_get_sts(ARM armno, ARMSTATUSP asts);

armno Arm number (No.)
asts Current arm information

Explanation:

armno	Acquires current arm information of “armno”.
asts.max	Board controllable arm numbers 1or2
asts.arm	Arm identification number 0or1
asts.axis	Arm axis numbers
asts.typ	Arm type
asts.drv	Servo driver classification
asts.dio	Expansion DIO board exist / not exist
asts.remote	operation mode (valid / invalid)
asts.count	Control counter value
asts.error	Error code
asts.angle.s1	Current S1 axis value
:	
asts.angle.w2	Current W2 axis value
asts.noap[0][0]	Current tip orientation matrix
:	
asts.noap[2][3]	Current tip position matrix (Z)
asts.ypr[0]	Current orientation (TAW)
:	

When command processing is finished, the controller computes by adding the count of the inner variable. With this function, comparing inner variable before and after issuing command, users can recognize processing termination for command. . This inner variable is “asts.count”.

Return value:

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference:

pa_get_cnt
pa_get_err
pa_get_agl
pa_get_xyz
pa_get_noa
pa_get_ypr

Description example:

```
ARMSTATUS   asts;
        :
pa_get_sts(ARM1, &asts);
printf( "error:%ld S1:%lf W2:%lf", asts.error , asts.angle.s1 , asts.angle.w2 );
                :
```

pa_get_cnt

Function:

Acquires control count from arm information.

Syntax:

```
long     pa_get_cnt(ARM armno, long* cunt);
```

armno   Arm number (No.)
cunt   Control count information

Explanation:

Acquires control count information from current arm information.

When command processing is finished, the controller computes by adding the count of the inner variable. With this function, comparing inner variable before and after issuing command, users can recognize processing termination for command. This inner variable is control count value.

Return value:

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference:

pa_get_sts
pa_get_err
pa_get_agl
pa_get_xyz
pa_get_noa
pa_get_ypr

pa_get_err

Function:

Acquires error information from arm information.

Syntax:

```
long    pa_get_err(ARM  armno,   long* err);
```

armno　Arm number (No.)
err　Error information (error code)

Explanation:

Acquires error code information from current arm information.

Return value:

ERR_OK　Normal termination
Others:　Anomalous termination (Refer to error table)

Reference:

pa_get_sts
pa_get_cnt
pa_get_agl
pa_get_xyz
pa_get_noa
pa_get_ypr

pa_get_agl

Function:

Acquires axis information from arm information.

Syntax:

```
long    pa_get_agl(ARM  armno,   ANGLEP angle);
```

armno　Arm number (No.)

angle　Current axis value information [rad]

Explanation:

Acquires axis information from arm information.

angle.s1 : Current S1 axis value
angle.s2 : Current S2 axis value
angle.s3 : Current S3 axis value
angle.e1 : Current E1 axis value
angle.e2 : Current E2 axis value
angle.w1 : Current W1 axis value
angle.w2 : Current W2 axis value

Return value:

ERR_OK　Normal termination

Others:　Anomalous termination (Refer to error table)

Reference:

pa_get_sts
pa_get_cnt
pa_get_err
pa_get_xyz
pa_get_noa

pa_get_xyz

Function:

Acquires tip position information from arm information.

Syntax:

```
long        pa_get_xyz(ARM  armno,   VECTOR vec);
```

armno　Arm number (No.)

vec　Current tip position information [mm]

Explanation:

Acquires tip position information from arm information.

vec[0]：Arm tip X coordinate value

vec[1]：Arm tip Y coordinate value

vec[2]：Arm tip Z coordinate value

Return value:

ERR_OK　Normal termination

Others:　Anomalous termination (Refer to error table)

Reference:

pa_get_sts

pa_get_cnt

pa_get_err

pa_get_noa

pa_get_ypr

pa__get__noa

Function:

Acquires tip position/orientation matrix information from arm information.

Syntax:

long　　pa_get_noa(ARM　armno,　MATRIX noap);

armno　　Arm number (No.)

noap　　Current tip position/orientation information

Explanation:

Acquires tip position/orientation matrix information from current arm information.

$$noap[3][4] = \begin{pmatrix} nx & ox & ax & px \\ ny & oy & ay & py \\ nz & oz & az & pz \end{pmatrix}$$

Return value:

ERR_OK　Normal termination

Others:　Anomalous termination (Refer to error table)

Reference:

pa_get_sts

pa_get_cnt

pa_get_err

pa_get_xyz

pa_get_ypr

pa__get__ypr

Function:

Acquires tip orientation information from arm information.

Syntax:

long　　pa_get_ypr(ARM armno, VECTOR ypr);

armno　Arm number (No.)

ypr　　Current tip orientation information [rad]

Explanation:

Acquires tip orientation information from current arm information.

ypr[0] : Arm tip orientation "yaw" value

ypr[1] : Arm tip orientation "pitch" value

ypr[2] : Arm tip orientation "roll" value

Return value:

ERR_OK　Normal termination

Others:　Anomalous termination (Refer to error table)

Reference:

pa_get_sts

pa_get_cnt

pa_get_err

pa_get_xyz

pa_get_noa

pa_get_prm

Function:

Acquires parameter information from arm information.

Syntax:

```
long      pa_get_prm(ARM  armno,   PARAMP prm);
```

armno	Arm number (No.)
prm	Current parameter information

Explanation:

Acquires parameter information from current arm information.

prm.rezl;	Resolver resolution
prm.pul[7];	Position limiter（＋）
prm.pdl[7];	Position limiter（－）
prm.vel[7 + 2];	Velocity limiter
prm.dev[7 + 2];	Default velocity
prm.lim[7 + 2];	
prm.ceh[7 + 2];	
prm.cem[7 + 2];	
prm.cel[7 + 2];	
prm.pg1[7];	Position control gain 1
prm.pg2[7];	Position control gain 2
prm.vg1[7];	Velocity control gain
prm.tg1[7];	(Not available)
prm.pcm[7];	Position control selection matrix
prm.fcm[7];	(Not available)
prm.arl[7];	Arm length
prm.arg[7];	Axis gravity center position
prm.arw[7];	Axis weight
prm.hom[7];	Home position recovery target value
prm.saf[7];	Other point recovery target value
prm.esc[7];	Escape point recovery target value
prm.tol[7];	Tool parameter
prm.fvl[7];	
prm.dmy[7];	(Not available)
prm.spa[7];	Spare

Return value:

ERR_OK　Normal termination

Others:　Anomalous termination (Refer to error table)

Reference:

pa_get_sts
pa_get_cnt
pa_get_err
pa_get_xyz
pa_get_noa
pa_get_ypr

Description example:

```
            :
PARAM   prm;
            :
pa_get_prm(ARM1, &prm);
printf( "S1_max:%ld S1_min:%ld " ,prm.pul[0] ,prm.pdl[0] );
printf( "S2_max:%ld S2_min:%ld " ,prm.pul[1] ,prm.pdl[1] );
            :
```

pa__get__tar

Function:

Acquires target angle and target tip position/orientation matrix information.

Syntax:

```
long      pa_get_tar(ARM armno, ARMTARGETP tar);
```

armno Arm number (No.)

tar Target angle and tip position/orientation information

Explanation:

Acquires arm target value information.

ARMTARGET type consists of data structures below:

```
typedef struct {
        ANGLE     angle;
        MATRIX    noap;
        float     ypr[3];
} ARMTARGET, *ARMTARGETP;
```

For “angle”, each target axis angle every control cycle in axis control is included.

For “noap”, target tip position/orientation every control cycle in RMRC control is included.

$$noap[3][4] = \begin{pmatrix} nx & ox & ax & px \\ ny & oy & ay & py \\ nz & oz & az & pz \end{pmatrix}$$

For “ypr”, Yaw, Pitch and Roll value calculated from tip orientation: “noa” are included

Return value:

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

Reference:

pa_get_agl

pa_get_noa

pa_get_xyz

pa_get_ypr

pa_get_sav

Function:

Acquires each axis servo ON/OFF status.

Syntax:

long pa_get_sav(ARM armno, long* sav);

armno	Arm number (No.)
sav	Servo status

Explanation:

Acquires each axis servo status.

When S1 servo is ON	sav=0x01
When S2 servo is ON	sav=0x02
When S3 servo is ON	sav=0x04
When E1 servo is ON	sav=0x08
When E2 servo is ON	sav=0x10
When W1 servo is ON	sav=0x20
When W2 servo is ON	sav=0x40
All axes servo ON	sav=0x7F

Return value:

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

pa_sav_sts

Function:

Acquires each axis servo status.

Syntax:

```
long      pa_sav_sts(ARM armno, long* sts);
```

armno Arm number (No.)

sts Each axis servo status

Explanation:

Acquires each axis servo status.

sts[0] S1 axis servo status

sts[1] S2 axis servo status

:

sts[6] W2 axis servo status

sts[7] Master servo status

Return value:

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

pa__get__smd

Function:

Acquires “TEACHMODE” from servo.

Syntax:

long pa_get_smd(ARM armno, long* mod);

armno Arm number (No.)
mod 0:OFF
1:ON

Explanation:

Acquires “TEACHMODE” from servo.

Return value:

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

pa__set__ddm

Function:

Dead man SW valid/invalid

Syntax:

```
long    pa_set_ddm(ARM armno, long type, long val);
```

armno Arm number (No.)
type Switch type
val 1 : valid
0 : invalid

Explanation:

Sets dead man SW valid/invalid.

Return value:

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

pa_get_ddm

Function:

Acquires dead man SW valid/invalid status.

Syntax:

long pa_get_ddm(ARM armno, long type, long* val);

armno Arm number (No.)
type Switch type
val 1 : valid
0 : invalid

Explanation:

Acquires dead man SW valid/invalid status.

Return value:

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

pa_set_lok

Function:

TEACHLOCK setting

Syntax:

long pa_set_lok(ARM armno, long mod);

armno Arm number (No.)
mod 1:Teach mode ON
0:Teach mode OFF

Explanation:

Sets TEACHLOCK.

Return value:

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

pa_get_lok

Function:

TEACHLOCK acquisition

Syntax:

```
long      pa_get_lok(ARM armno, long* mod);

armno     Arm number (No.)
mod       1：Teach mode  ON
          0：Teach mode  OFF
```

Explanation:

Acquires TEACHLOCK.

Return value:

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

pa_tct_tim

Function:

Tact time (playback time) acquisition

Syntax:

```
long    pa_tct_tim(ARM armno, long* tim);
```

armno Arm number (No.)

tim Tact time

Explanation:

Acquires tact time (playback time)

Return value:

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

pa_get_max

Function:

Acquires board controllable arm numbers.

Syntax:

long pa_get_max(ARM armno, long* num);

armno Arm number (No.)

num Controllable arm numbers 1 or 2

Explanation:

Acquires board controllable arm numbers.

Return value:

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

pa_get_spt

Function:

Acquires arm identification number.

Syntax:

long　pa_get_spt(ARM armno, long* spt);

armno　Arm number (No.)
spt　0 or 1st

Explanation:

Acquires arm identification number on account of two arms being actuated with one board.

Return value:

ERR_OK　Normal termination
Others:　Anomalous termination (Refer to error table)

pa_set_sim

Function:

Simulation magnification setting

Syntax:

long　　pa_set_sim(ARM armno, long tim);

armno　Arm number (No.)
tim　　Simulation magnification（1～50）

Explanation:

Sets simulation magnification.

Return value:

ERR_OK　Normal termination
Others:　Anomalous termination (Refer to error table)

pa__set__inc

Function:

Real-time velocity setting

Syntax:

long pa_set_inc(ARM armno, float inc);

armno Arm number (No.)

inc Real-time velocity（0.01～1）

Explanation:

Sets real-time velocity.

Return value:

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

pa_get_sim

Function:

Simulation magnification acquisition

Syntax:

```
long    pa_get_sim(ARM armno, long* sim);
```

armno　Arm number (No.)

sim　Simulation magnification（1～50）

Explanation:

Acquires simulation magnification.

Return value:

ERR_OK　Normal termination

Others:　Anomalous termination (Refer to error table)

pa_get_inc

Function:

Real-time velocity acquisition

Syntax:

```
long      pa_get_inc(ARM armno, float* inc);
```

armno　Arm number (No.)

inc　Real-time velocity（0.01～1）

Explanation:

Acquires real-time velocity.

Return value:

ERR_OK　Normal termination

Others:　Anomalous termination (Refer to error table)

pa＿inp＿dio

Function:

Digital input (32ch. unit input)

Syntax:

long　　pa_inp_dio(ARM armno, DIOKIND　kind, DIOSTATUSP dio);

armno　Arm number (No.)
kind　　DIO_INTERNAL（System）
　　　　DIO_EXTERNAL（Expansion DIO board）
dio　　Designates digital input area by structure “DIOSTATUSP”.

Explanation:

Gets the status from standard digital input and sets it in the designated area: “dio”.

Return value:

ERR_OK　Normal termination
Others:　Anomalous termination (Refer to error table)

Reference:

pa_oup_dio　　Digital input (32ch. unit input)
pa_get_dio　　Digital input (1ch. unit input)
pa_set_dio　　Digital output (1ch. unit set)
pa_rst_dio　Digital output (1ch. unit reset)

Description example:

```
                :
DIOSTATUS   dio;
                :
pa_inp_dio(ARM1, DIO_EXTERNAL, &dio);
printf( ″dio_1:%x ″ ,dio.io1 );
printf( ″dio_2:%x ″ ,dio.io2 );
printf( ″dio_3:%x ″ ,dio.io3 );
printf( ″dio_4:%x ″ ,dio.io4 );
                :
```

pa_oup_dio

Function:

Digital output (32ch. unit output)

Syntax:

```
long     pa_oup_dio(ARM armno, DIOKIND  kind, DIOSTATUSP dio);
```

armno	Arm number (No.)
kind	DIO_INTERNAL（System）
	DIO_EXTERNAL（Expansion DIO board）
dio	Designates digital output value by structure “DIOSTATUSP”.

Explanation:

Designates standard digital output value by structure “DIOSTATUSP”.

Return value:

ERR_OK　Normal termination

Others:　Anomalous termination (Refer to error table)

Reference:

pa_inp_dio	Digital input (32ch. unit output)
pa_get_dio	Digital input (1ch. unit output)
pa_set_dio	Digital output (1ch. unit output)
pa_rst_dio	Digital output (1ch. unit output)

Description example:

```
            :
DIOSTATUS   dio;
            :
dio.io1 = 0x00;
dio.io2 = 0x20;
dio.io3 = 0x24;
dio.io4 = 0xff;
pa_oup_dio(ARM1, DIO_EXTERNAL, &dio);
            :
```

pa_get_dio

Function:

Channel unit digital input

Syntax:

```
long    pa_get_dio(ARM armno, DIOKIND  kind,
                    DIOPORT port, DIOCH ch, unsigned char* in);
```

armno	Arm number (No.)
kind	DIO_INTERNAL (System) DIO_EXTERNAL (Expansion DIO board)
(*)port	Designates input port by “enum DIOPORT”.
ch	Designates input channel by “enum DIOCH”.
in	Input data area: If in = 0 : OFF If in < > 0 : ON

Explanation:

Channel unit input for standard/Expansion digital input.
Loads port channel “ch” value indicated by “port”.

<NOTE> (*) Not only digital input information, but also output information can be acquired.

port =

DP_XXXXX: acquires input information as usual.
DPO_XXXXX: is information set to output by PA library.
DPX_XXXXX: is information for current output value (output value created by PA library or information in playback data).

Return value:

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference:

pa_inp_dio	Digital input (32ch. unit input)
pa_oup_dio	Digital output (32ch. unit output)
pa_set_dio	Digital output (1ch. unit setting)
pa_rst_dio	Digital output (1ch. unit resetting)

Description example:

```
            :
unsigned char   io;
            :
pa_get_dio(ARM1, DIO_EXTERNAL, DP_PORT1, DC_CH4, &io);
            :
```

pa__set__dio

Function:

Channel unit setting for digital output.

Syntax:

```
long    pa_set_dio(ARM armno, DIOKIND  kind,
                             DIOPORT port, DIOCH ch);
```

armno	Arm number (No.)
kind	DIO_INTERNAL (System)
	DIO_EXTERNAL (Expansion DIO board)
port	Designates output port by “enum DIOPORT”
ch	Designates output channel by “enum DIOCH”.

Explanation:

Channel unit setting for standard output.
Sets port channel “ch” indicated by “port”.

Return value:

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference:

pa_inp_dio	Digital input (32ch. unit input)
pa_oup_dio	Digital output (32ch. unit output)
pa_get_dio	Digital input (1ch. unit input)
pa_rst_dio	Digital output (1ch. unit resetting)

Description example:

```
            :
pa_set_dio(ARM1, DIO_EXTERNAL, DP_PORT1, DC_CH4);
            :
```

pa_rst_dio

Function:

Channel unit resetting for digital output.

Syntax:

```
long    pa_rst_dio(ARM armno, DIOKIND  kind,
                                         DIOPORT port, DIOCH ch);
```

armno	Arm number (No.)
kind	DIO_INTERNAL(System)
	DIO_EXTERNAL(Expansion DIO board)
port	Designates output port by “enum DIOPORT”.
ch	Designates output channel by “enum DIOCH”.

Explanation:

Channel unit resetting for standard output.
Resets port channel “ch” indicated by “port”.

Return value:

ERR_OK　Normal termination
Others:　Anomalous termination (Refer to error table)

Reference:

pa_inp_dio	Digital input (32ch. unit input)
pa_oup_dio	Digital output (32ch. unit output)
pa_get_dio	Digital input (1ch. unit input)
pa_set_dio	Digital output (1ch. unit setting)

Description example:

```
        :
pa_rst_dio(ARM1, DIO_EXTERNAL, DP_PORT1, DC_CH4);
        :
```

pa_dio_msk

Function:

DIO mask setting

Syntax:

long pa_dio_msk(ARM armno, long dio, long kind, long msk);

armno Arm number (No.)
dio DOMSK or DIMSK
kind Board type
msk Mask bit (System is only lower 8bit, expansion 32bit)

Explanation:

Sets DIO mask.

Return value:

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

pa_get_msk

Function:

DIO mask acquisition

Syntax:

long pa_get_msk(ARM armno, long dio, long kind, long* msk);

armno Arm number (No.)
dio DOMSK or DIMSK
kind Board type
msk Mask bit（System is only lower 8bit, expansion 32bit）

Explanation:

Acquires DIO mask.

Return value:

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

pa__set__tol

Function:

Sets tool information.

Syntax:

long pa_set_tol(ARM armno, float x, float y, float z, float off);

armno	Arm number (No.)
x	Offset value toward "x" from arm tip to tool tip [mm]
y	Offset value toward "y" from arm tip to tool tip [mm]
z	Offset value toward "z" from arm tip to tool tip [mm]
off	Offset value toward "z" from tool tip to work face [mm]

Explanation:

Sets tool information (offset value from arm tip to tool tip) of controller parameter file.
All tool information default values are 0 [mm].
This value cannot be set during RMRC control.
This value is vanishing when power supply is off.
If intending to change parameter file default value, use parameter setting.

As this offset is added for arm mechanical interface coordinate system, added points are kept even if in orientation rotation. Only tip direction changes.

Return value:

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference:

pa_get_prm
pa_set_vel

Description example:

```
        :
pa_set_tol(ARM1, 100.0, 50.0, 300.0, 40.0 );
        :
```

pa__set__vel

Function:

Alters default velocity.

Syntax:

long　　pa_set_vel(ARM armno, VELTYPE vtype, float vel[]);

armno　Arm number (No.)
vtype　Default velocity classification
(*)　vel[]　Default velocity alteration value

Explanation:

Alters default velocity indicated by "vtype" to "vel[rad/sec]".
It vanishes with power supply: OFF.
VT_ONEVEL: Axis default velocity alteration [rad/sec]
VT_XYZVEL: Tip position default velocity alteration [mm/sec]
VT_YPRVEL: Tip orientation default velocity alteration [rad/sec]

(*)　＜NOTE＞
When in "VT_ONEVEL", default velocity for 7 axes can be set by "vel[7]".
When in "VT_XYZVEL、VT_YPRVEL: vel[1].

Return value:

ERR_OK　Normal termination
Others:　Anomalous termination (Refer to error table)

Reference:

pa_get_prm
pa_set_tol

Description example: (1)

```
ANGLE    angle;
float   vel[7];
            :
vel[0] = 0.6;                               ･･･ S1 axis [rad/sec]
vel[1] = 0.6;                               ･･･ S2 axis [rad/sec]
           :
vel[6] = 3.14;                              ･･･ W2 axis [rad/sec]
pa_set_vel(ARM1, VT_ONEVEL, vel ); ... Axis default velocity alteration
angle.s3 = 3.14;
pa_exe_axs(ARM1, S3, &angle, WM_NOWAIT); ... Axis control only for S3 axis
            :
```

Description example: (2)

```
float    vel;
vel      =  40.0;                           ･･･ Tip position default velocity
[mm/sec]
pa_set_vel(ARM1, VT_XYZVEL, &vel ); ･･･ Tip position default velocity alteration
pa_mov_XYZ(ARM1, 50.0, 100.0, 0.0, WM_WAIT);
                         ･･･ RMRC base coordinate position deviation control
```

pa_lod_ctl

Function:

Downloads parameter to the controller.

Syntax:

```
long     pa_lod_ctl(ARM armno, char* file);
```

armno　Arm number (No.)
file　Parameter file name

Explanation:

Downloads parameter designated by “file” to the controller designated by “armno”.
When intending to change parameter file contents, use parameter setting.

Return value:

ERR_OK　Normal termination
Others:　Anomalous termination (Refer to error table)

Description example:

```
        :
pa_lod_ctl(ARM1, ″CTRL.PAR″ );
        :
```

pa_tst_nom

Function:

RETRAC parameter creation mode ON/OFF setting

Syntax:

```
long    pa_tst_nom(ARM armno, long sw);
```

armno　Arm number (No.)

sw　0：OFF

　　1：ON

Explanation:

Sets RETRAC parameter creation mode ON/OFF.

Return value:

ERR_OK　Normal termination

Others:　Anomalous termination (Refer to error table)

Reference:

pa_get_rmd

pa_get_rmd

Function:

RETRAC parameter creation mode ON/OFF acquisition.

Syntax:

```
long     pa_get_rmd(ARM armno, long* sw);
```

armno Arm number (No.)

sw 0:OFF

1:ON

Explanation:

Acquires RETRAC parameter creation mode ON/OFF.

Return value:

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

Reference:

pa_tst_nom

pa_lod_rob

Function:

Robot model file loading

Syntax:

```
long      pa_lod_rob(ARM armno,char *file);
```

armno　 Arm number (No.)
file　　 Robot model file name

Explanation:

Loads robot model file.

Return value:

ERR_OK　Normal termination
Others:　Anomalous termination (Refer to error table)

Reference:

pa_lod_tol
pa_sav_rob

pa_lod_tol

Function:

Tool model file loading

Syntax:

long pa_lod_tol(ARM armno,char *file);

armno Arm number (No.)
file Tool model file name

Explanation:

Loads tool model file.

Return value:

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference:

pa_lod_rob
pa_sav_rob

pa_sav_rob

Function:

Robot model file saving

Syntax:

```
long    pa_sav_rob(ARM armno);
```

armno Arm number (No.)

Explanation:

Saves robot model file.

Return value:

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

Reference:

pa_lod_tol

pa_sav_rob

pa_ena_nom

Function:

RETRAC calculation switching

Syntax:

long pa_ena_nom(ARM armno,long sw);

armno Arm number (No.)

sw 0：T Matrix calculation

1：RETRAC calculation

Explanation:

Switches to RETRAC calculation.

Return value:

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

Reference:

pa_get_nom

pa_thk_nom

pa_get_nom

Function:

Acquires either T-matrix calculation or RETRAC calculation processing.

Syntax:

long pa_get_nom(ARM armno, long* nom);

armno Arm number (No.)
nom 0: in T-matrix calculation
1: in RETRAC calculation

Explanation:

Acquires either T-matrix calculation or RETRAC calculation.

Return value:

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference:

pa_ena_nom
pa_thk_nom

pa_tkn_nom

Function:

Acquires whether or not the ability to perform RETRAC calculation.

Syntax:

long pa_tkn_nom(ARM armno, long* nom);

armno Arm number (No.)
nom 0: Not possible
1: Possible

Explanation:

Acquires whether or not the ability to perform RETRAC calculation.

Return value:

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference:

pa_get_nom
pa_ena_nom

pa__map__ctl

Function:

Mapping area shared with the controller.

Syntax:

long pa_map_ctl(ARM armno);

armno Arm number (No.)

Explanation:

Mapping the controller area designated by “controller.armno” to man-machine controller.

Reference

For mapping details, refer to the chapter 4.

This function is the first one to be called in all PA libraries. Therefore, this function is not performed alone.

Return value:

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

pa_fsh_chk

Function:

Waiting for command completion.

Syntax:

short pa_fsh_chk(ARM armno);

armno Arm number (No.)

Explanation:

When command processing is finished, the controller computes by adding the count of the inner variable. With this function, comparing inner variable before and after issuing command, users can recognize processing termination for command.

This function is the first one to be called in all PA libraries. Therefore, this function is not performed alone.

Return value:

0	Processing is completed.
1	Processing is not completed.

pa_fsh_sub

Function:

Waiting for command completion.

Syntax:

short pa_fsh_sub(ARM armno);

armno Arm number (No.)

Explanation:

When command processing is finished, the controller computes by adding the count of the inner variable. With this function, comparing inner variable before and after issuing command, users can recognize processing termination for command.

This function is employed when issuing following PA libraries. But, this function is not employed alone.

pa_odr_xyz : Tip position offset setting
pa_swt_dio : Teach point DO data valid/invalid setting
pa_set_inc : Real-time velocity setting

Return value:

0 Processing is completed.
1 Processing is not completed.

Reference:

pa_fsh_chk

pa_req_ctl

Function:

Writing completion/interruption occurrence

Syntax:

long pa_req_ctl(ARM armno, long num);

armno Arm number (No.)
num Retry times

Explanation:

The controller recognizes completion of writing data to PCI shared area by "writing completion interruption".
Interruption retry is performed at certain times designated by "num".

This function is called in all PA libraries and not performed alone.

Return value:

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference:

pa_req_sub

pa_req_sub

Function:

Writing completion/interruption occurrence

Syntax:

long pa_req_sub(ARM armno, long num);

armno Arm number (No.)
num Retry times

Explanation:

The controller recognizes completion of writing data to PCI shared area by "writing completion interruption".
Interruption retry is performed at certain times designated by "num".

When command is issued employing "pa_req_ctl", the same as "pa_fsh_sub", this function is employed to issue simultaneously another command.

This function is employed when issuing following PA libraries. But, this function is not performed alone.

pa_odr_xyz : Tip position offset setting
pa_swt_dio : Teach point DO data valid/invalid setting
pa_set_inc : Real-time velocity setting

Return value:

ERR_OK Normal termination
Others: Anomalous termination (Refer to error table)

Reference:

pa_req_ctl
pa_fsh_sub

pa_rst_ctl

Function:

Performs error information resetting.

Syntax:

long pa_rst_ctl(ARM armno);

armno Arm number (No.)

Explanation:

Requests error information resetting, set by arm controller designated by “armno”.

Return value:

ERR_OK Normal termination

Others: Anomalous termination (Refer to error table)

pa_err_mes

Function:

Acquires error message.

Syntax:

```
long	pa_err_mes(ERR errNo ,cahr* err);
```

errNo　Error number

err　The area to load error message.

Explanation:

Acquires an error message responding to a error number.

Return value:

ERR_OK　Normal termination

Others:　Anomalous termination

（＝ERR_MES: No error message responding to the error number.）

Appendix 1

PA library summary table

Table summarizing each PA library control condition. This can be used for programming employing PA libraries.

If the library can be issued, it is indicated with ○. If the library can be issued in any condition, it is indicated with <ALL>.

If each PA library is obtaining synchronization between controllers, it is indicated with ○. If not, it is indicated with ×.

Here, below, shows the summary table for control number and its description.

Arm control number & description table

Status No.	Indicated message	Control description	Status class.
3	Brake stop status	All axes brake-stop	(a)
8	Each axis angle control status	In motion with axis control	(d)
9	Each axis velocity control status	Axis velocity control mode	(f)
10	Servo lock status	All axes servo-lock in direct control	(i)
12	Self weight compensated status	Weight compensation control in direct control	(i)
13	RMRC control status	In motion with RMRC control	(e)
14	RMRC redundant axis interpolation status	Redundant axis correction when switching to RMRC mode	
15	Each Axis control servo lock status	Each axis pause (temporary stop) in playback control Step-stop. Playback control continuation possible.	(b)
17	Playback each axis correction status	Motion created by axis interpolation to current point.	(d)
18	Playback circle interpolation status	Motion created by circle interpolation in playback control.	(e)
19	Playback linear interpolation status	Motion created by linear interpolation in playback control.	(e)
20	Playback arc interpolation status	Motion created by arc interpolation in playback control.	(e)
21	RMRC control servo lock status	RMRC pause (temporary stop) in playback control, Playback step-stop	(c)
22	Waiting Playback start Status	Playback control start waiting Each axis servo-lock	(b)
23	Each axis control servo lock status	Target value lock in axis feedback control	(b)
24	RMRC control servo lock status	Target value lock in RMRC feedback control	(c)
25	Waiting Playback start Status	Waiting for playback control start command. RMRC servo-lock	(c)
26	Playback tip correction status	Motion created by linear interpolation to current point.	(e)
27	Redundant axis control status	Redundant axis parameter operation mode	(h)
28	RMRC real-time control status	Tip position/orientation real-time control mode	(k)
29	Playback each axis interpolation status	Motion created by axis interpolation in playback control	(d)
30	Coordinate conversion position correction status	Shifting position/orientation to playback trajectory by coordinate conversion	(e)
31	Redundant axis S3 interpolation control status	Redundant axis (elbow) in motion without changing tip position/orientation	(h)
32	Axis real-time control status	Each axis real-time control mode	(j)
33	Move between Teaching data (RMRC control)	In motion of RMRC control to move between one Teaching Data and another in playback control.	(e)
34	Move between Teaching data (Each axis control)	In motion of each axis control to move between one Teaching Data and another in playback control.	(d)

Arm Condition Classification

＜STOP＞

Brake-stop ・・・・・・(a)

Axis control servo-lock （Axis feedback） ・・・・・・(b)

RMRC servo-lock （Axis feedback） ・・・・・・(c)

＜IN MOTION＞：Shifts to stop after moving with one motion command.

Axis control （Axis feedback） ・・・・・・(d)

RMRC control （RMRC feedback） ・・・・・・(e)

＜IN MOTION MODE＞：Control is not changed until termination command is issued.

Axis velocity control mode （Axis feedback） ・・・・・・(f)

RMRC velocity control mode （RMRC feedback） ・・・・・・(g)

Redundant axis control mode （RMRC feedback） ・・・・・・(h)

Direct control mode (torque control, axis feedback) ・・・・・・(i)

Axis real-time control mode (axis feedback) ・・・・・・(j)

RMRC real-time control mode (RMRC feedback) ・・・・・・(k)

【Supplementary Explanation】

Supplementary explanation on PA library temporary stop and temporary-stop release function (pa_sus_arm、pa_rsm_arm) is as follows:

Temporary stop (pause) means to stop renewing target value and create servo-stop . It does not mean the whole control stops. Therefore, redundant axis (elbow) might move in RMRC servo-lock.
Temporary-stop release (restart) means basically to restart the prior motion. It might happen not to restart.

“pa_sus_arm” (pause, temporary stop) & “pa_rsm_arm” (restart, temporary-stop release) table to be issued.

Status No.	Control	pa_sus_arm	Status NO. after pause	pa_rsm_arm
3	Brake-stop	(○)	—	—
8	Axis velocity control	○	15	○
9	Axis velocity control	○	15	×
10	Servo-lock	○	15	×
12	Weight compensation	×	—	—
13	RMRC control (RMRC velocity control)	○ ○	21 21	○ ×
14	RMRC redundant axis correction	○	15	○
15	Axis control servo-lock	(○)	—	—
17	Playback axis correction	○	23	○
18	Playback circle interpolation	○	24	○
19	Playback linear interpolation	○	24	○
20	Playback arc interpolation	○	24	○
21	RMRC control servo-lock	(○)	—	—
22	Playback start waiting	○	23	○
23	Axis control servo-lock	(○)	—	—
24	RMRC control servo-lock	(○)	—	—
25	Playback start waiting	○	24	○
26	Playback tip correction	○	24	○
27	Redundant axis control	○	21	×
28	RMRC real-time control	○	21	×
29	Playback axis interpolation	○	23	○
30	Coordinate conversion position correction	○	24	○
31	Redundant S3 axis interpolation control	○	21	○
32	Axis real-time control	○	15	×
33	Move between Teaching data (RMRC control)	○	24	○
34	Move between Teaching data (Each axis control)	○	15	○

○ : Valid (possible)
× : Invalid (not possible)
(○) : Valid, but, not changing status.

Control	Function	ID	3	8	9	10	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	Syncronization
Status Control	pa_stp_arm							<		A		L		L		>														○
	pa_sus_arm							<		A		L		L		>														○
	pa_rsm_arm									○						○		○	○											○
	pa_exe_axs		○							○						○		○	○				○							○
	pa_exe_hom				○	○			○	○						○	○	○	○	○	○	○	○				○			○
	pa_exe_esc				○	○			○	○						○	○	○	○	○	○	○	○				○			○
	pa_exe_saf				○	○			○	○						○	○	○	○	○	○	○	○				○			○
Axis motion control	pa_mov_XYZ					○				○						○		○	○			○	○			○				○
	pa_mov_YPR					○				○						○		○	○			○	○			○				○
	pa_mov_xyz					○				○						○		○	○			○	○			○				○
	pa_mov_ypr					○				○						○		○	○			○	○			○				○
	pa_mov_mat					○				○						○		○	○			○	○			○				○
Tip position/orientation control	pa_axs_pnt					○				○						○		○	○			○	○							○
	pa_mov_pnt					○				○						○		○	○			○	○							○
	pa_ply_pnt									○						○	○			○					○					○
	pa_tct_tim							<		A		L		L		>														×
Playback control	pa_add_pnt		○		○	○	○	○		○						○		○	○			○	○			○	○			○
	pa_del_pnt		○		○	○	○	○		○						○		○	○			○	○			○	○			○
	pa_rpl_pnt		○		○	○	○			○						○		○	○			○	○			○	○			○
	pa_set_pnt		○			○	○			○						○		○	○											○
	pa_set_idn		○			○	○			○						○		○	○											○
	pa_chg_dio		○			○	○			○						○		○	○											○
	pa_vel_pnt							<		A		L		L		>														○
	pa_swt_dio							<		A		L		L		>														×
	pa_set_cmt							<		A		L		L		>														○

Control	Function	ID	3	8	9	10	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	Syncronization
Teach point operation(1)	pa_chg_pnt	PM_TOP PM_NEXT PM_PRIV PM_BTM	○			○				○						○		○	○											○
		PM_JMP	○			○		○		○						○		○	○			○	○			○	○			○
		PM_CIR	○			○		○		○						○		○	○			○	○			○	○			○
		PM_ARC	○		○			○		○						○		○	○			○	○			○	○			○
	pa_jmp_cmt		○			○				○						○		○	○											○
Teach point operation(2)	pa_get_pnt		○		○	○	○	○		○						○	○	○	○	○	○	○	○			○	○			○
	pa_get_cur							<		A		L		L		>														×
	pa_get_num							<		A		L		L		>														×
	pa_get_idn							<		A		L		L		>														×
	pa_get_cpt		○		○	○	○	○		○						○	○	○	○	○	○	○	○			○	○			○
	pa_get_pvl							<		A		L		L		>														×
	pa_get_pdo							<		A		L		L		>														×
	pa_lod_pnt		○															○	○											○
	pa_sav_pnt		○															○	○											○
	pa_set_dlc							<		A		L		L		>														○
	pa_get_dlc							<		A		L		L		>														×
Area-Cube operation	pa_set_cub		○		○	○	○	○		○						○		○	○			○	○			○	○			○
	pa_get_cub		○		○	○	○	○		○						○		○	○			○	○			○	○			○
	pa_cub_len		○		○	○	○	○		○						○		○	○			○	○			○	○			○
	pa_cub_cmt		○		○	○	○	○		○						○		○	○			○	○			○	○			○
	pa_del_cub		○		○	○	○	○		○						○		○	○			○	○			○	○			○
	pa_ena_cub		○		○	○	○	○		○						○		○	○			○	○			○	○			○
	pa_inf_cub		○		○	○	○	○		○						○		○	○			○	○			○	○			○

Control	Function	ID	3	8	9	10	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	Syncronization
Teach data operation	pa_ply_set							<		A		L		L		>														○
	pa_act_pnt		○		○	○	○	○		○						○		○	○			○	○			○	○			○
	pa_ply_mod		○																											○
	pa_chg_key		○			○				○						○		○	○											○
	pa_get_key							<		A		L		L		>														×
	pa_mon_pnt							<		A		L		L		>														×
	pa_get_pmd							<		A		L		L		>														×
	pa_get_prj							<		A		L		L		>														○
	pa_set_prj							<		A		L		L		>														○
	pa_sav_prj		○															○	○											○
	pa_lod_prj		○															○	○											○
Playback JUMP attribute operation	pa_jmp_set							<		A		L		L		>														○
	pa_get_jmp		○		○			○		○						○		○	○			○	○			○	○			○
	pa_set_jmp							<		A		L		L		>														○
	pa_ena_jmp							<		A		L		L		>														○
	pa_get_ena							<		A		L		L		>														×
	pa_del_jmp		○			○				○						○		○	○											○
	pa_sav_ptj		○															○	○											○
	pa_lod_ptj		○															○	○											○
Velocity Control Function	pa_mod_vel	VM_XYZ VM_YPR VM_xyz VM_ypr VM_XYZYPR VM_xyzypr				○				○						○		○		○			○			○				○
		VM_one	○		○	○				○						○		○		○										○
	pa_odr_vel							<		A		L		L		>														○

Control	Function	ID	3	8	9	10	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	Syncronization
Redundant axis control function	pa_mod_jou	JM_OFF																												
		JM_ON																												
		JM_S3ON	○		○	○		○		○						○	○	○	○	○		○	○		○	○				○
		JM_S3DIV																												
		JM_S3HOLD																												
		JM_VSET				○				○						○		○	○											○
		JM_SET				○				○						○		○	○											○
		JM_RESET	○		○			○		○						○														○
	pa_odr_jou							<		A		L		L		>														○
	pa_mov_jou									○						○			○											○
	pa_get_jou							<		A		L		L		>														×
Real-time control function	pa_mod_dpd					○				○						○							○							○
	pa_odr_dpd							<		A		L		L		>														○
	pa_mod_axs					○				○						○		○	○								○			○
	pa_odr_axs							<		A		L		L		>														○
Direct control function	pa_mod_dir	DM_START	○							○						○		○	○											○
		DM_STOP					○																							○
	pa_wet_ded					○	○																							○
	pa_drt_ded		○			○	○																							○
	pa_chk_cnt							<		A		L		L		>														○
	pa_set_tim							<		A		L		L		>														○
	pa_get_tim							<		A		L		L		>														×
	pa_get_drt							<		A		L		L		>														×

Appendix 1 - 8

Control	Function	ID	3	8	9	10	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	Syncronization
Orientation setting & definition function	pa_set_hom		○		○	○		○		○						○		○	○			○	○			○	○			○
	pa_set_esc		○		○	○		○		○						○		○	○			○	○			○	○			○
	pa_set_saf		○		○	○		○		○						○		○	○			○	○			○	○			○
	pa_def_hom		○		○			○		○						○		○	○			○	○			○	○			○
	pa_def_esc		○		○			○		○						○		○	○			○	○			○	○			○
	pa_def_saf		○		○			○		○						○		○	○			○	○			○	○			○
Tip offset function	pa_set_mtx									○		○	○	○	○	○	○			○				○					○	○
	pa_set_mat									○		○	○	○	○	○	○			○				○					○	○
	pa_set_wav							<		A		L		L		>														○
	pa_odr_xyz							<		A		L		L		>														○
	pa_lmt_xyz							<		A		L		L		>														○
	pa_get_mat							<		A		L		L		>														×
	pa_get_sns							<		A		L		L		>														×
	pa_get_lmt							<		A		L		L		>														×
Status information Loading function	pa_get_mod							<		A		L		L		>														×
	pa_get_ver							<		A		L		L		>														×
	pa_get_com							<		A		L		L		>														×
	pa_get_sts							<		A		L		L		>														×
	pa_get_cnt							<		A		L		L		>														×
	pa_get_err							<		A		L		L		>														×
	pa_get_agl							<		A		L		L		>														×
	pa_get_xyz							<		A		L		L		>														×
	pa_get_noa							<		A		L		L		>														×
	pa_get_ypr							<		A		L		L		>														×
	pa_get_prm							<		A		L		L		>														×
	pa_get_tar							<		A		L		L		>														×
	pa_get_sav							<		A		L		L		>														×
	pa_sav_sts							<		A		L		L		>														×
	pa_get_smd							<		A		L		L		>														×

Appendix 1

Control	Function	ID	3	8	9	10	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	Syncronization
Digital input/output function	pa_inp_dio							<		A		L		L		>														×
	pa_oup_dio							<		A		L		L		>														×
	pa_get_dio							<		A		L		L		>														×
	pa_set_dio							<		A		L		L		>														×
	pa_rst_dio							<		A		L		L		>														×
Functionr on parameter	pa_set_tol		○							○						○		○												○
	pa_set_vel		○							○						○		○	○											○
	pa_lod_ctl							<		A		L		L		>														○
Error processing function	pa_rst_ctl							<		A		L		L		>														○
	pa_err_mes							<		A		L		L		>														×
	pa_clr_log							<		A		L		L		>														×
	pa_sav_log							<		A		L		L		>														×

【Other PA library function】

Control	Function
Control	Function
Control minimum required function (Employed as a pair)	{ pa_ini_sys
	pa_ter_sys
	{ pa_opn_arm
	pa_cls_arm
	{ pa_sts_arm
	pa_ext_arm
	{ pa_sta_sim
Function not needed for programming	pa_ext_sim
	pa_map_ctl
	pa_fsh_chk
	pa_fsh_sub
	pa_req_ctl

【Special PA library function】

Control	Function
Simulation rate	pa_set_sim
	pa_get_sim
Real-time speed rate	pa_set_inc
	pa_get_inc

【SystemPA library function 】

Control	Function
Dead-Man Switch disable/enable set and refer	pa_set_ddm
	pa_get_ddm
TEACH-LOCK set and refer	pa_set_lok
	pa_get_lok
Arm max number (To be able to control)	pa_get_max
Self arm number	pa_get_spt

Appendix 2
PA Library Return Value (Error Code)

"Previous error code remaining."

After issuing PA library from the operation control section, when the processing is completed, error code written on ISA (or VME) shared memory at this moment is defined as library return value.

If anomaly occurs during processing in the motion control section, error code fitting to its anomaly becomes return value. If processing is terminated normally, error code fitting to previous error code becomes return value. Because error information on ISA (VME) shared memory is overwritten only when anomaly occurs during processing in the motion control section.

For PA library (refer to appendix 1) not acquired synchronization between controllers, if it is issued from the operation control section, information on ISA (VME) shared memory is loaded. When loading finishes, error code on ISA (VME) shared memory becomes return value. This error code has no connection with PA library processing not acquired synchronization, issued this time. Library acquired synchronization and its error occurred during previous processing are culprits.

Taking into account the above, use PA library return value (error code) practically.

Here, below, explains how to deal with error codes.

① Every time PA library synchronized is issued, check errors. When error occurs, perform brake-stop, etc.

```
if((err = pa_mov_xyz(arm, 0.0,200.0,0.0,WM_WAIT)) != ERR_OK)  Brake-stop.;
```

② Employing function "pa_rst_ctl" for resetting an error, reset (error code: 0) previous error code.

③ When issuing function not synchronized, do not obtain return value.

Appendix 3

Control restart function after temporary stop during playback control

If PA library is issued while in temporary stop (pa_sus_arm) during playback control, two options for playback control can be possible either to restart or not.

- ・Playback control restart: possible
  With temporary-stop release (pa_rsm_arm), playback control can be restarted.
- ・Playback control restart: impossible
  On account of playback control termination, playback control cannot be restarted with temporary-stop release (pa_rsm_arm).
  When intending to perform playback control again, if it is needed, after altering (pa_chg_pnt) the current point, move (pa_mov_pnt) to the current point, start playback control.

There are two playback controls: the one is in RMRC feedback control and the other one, in axis feedback control. Even if issuing the same PA library, on account of a different feedback system, control restart might not work..

Table for PA library function issuing after temporary stop in playback control and playback control restart possibility.

＜Playback control restart function in PA library issued after temporary stop＞

<table>
<tr><th rowspan="2">Function</th><th rowspan="2" colspan="2">Function</th><th colspan="2">Playback Restart</th><th rowspan="2">Remarks</th></tr>
<tr><th>Possible</th><th>Not possible</th></tr>
<tr><td>pa_chg_pnt</td><td colspan="2">Teach point pointer alteration</td><td></td><td>○</td><td></td></tr>
<tr><td>pa_add_pnt</td><td colspan="2">Teach point addition</td><td></td><td>○</td><td></td></tr>
<tr><td>pa_del_pnt</td><td colspan="2">Teach point deletion</td><td></td><td>○</td><td></td></tr>
<tr><td>pa_rpl_pnt</td><td colspan="2">Teach point replacement</td><td></td><td>○</td><td></td></tr>
<tr><td>pa_set_pnt</td><td colspan="2">Teach point attribution setting</td><td>○</td><td></td><td></td></tr>
<tr><td>pa_set_idn</td><td colspan="2">Teach point ID_No. setting</td><td>○</td><td></td><td></td></tr>
<tr><td>pa_chg_dio</td><td colspan="2">Teach point (PTP) DO attribution setting</td><td>○</td><td></td><td></td></tr>
<tr><td>pa_get_pnt</td><td colspan="2">Current point teach point information loading</td><td>○</td><td></td><td></td></tr>
<tr><td>pa_get_cpt</td><td colspan="2">Current point circle (arc) teach data loading</td><td>○</td><td></td><td></td></tr>
<tr><td rowspan="7">pa_mod_jou</td><td rowspan="7">Redundant axis control mode setting</td><td>JM_OFF :No restriction</td><td></td><td>○</td><td></td></tr>
<tr><td>JM_ON :All axes restricted</td><td>○</td><td></td><td></td></tr>
<tr><td rowspan="2">JM_S3ON:S3 axis restriction</td><td></td><td>○</td><td>RMRC feedback control</td></tr>
<tr><td>○</td><td></td><td>Axis feedback control</td></tr>
<tr><td rowspan="2">JM_S3DIV:
S3 axis interpolation</td><td></td><td>○</td><td>RMRC feedback control</td></tr>
<tr><td>○</td><td></td><td>Axis feedback control</td></tr>
<tr><td>JM_S3HOLD:S3 axis fixed</td><td>○</td><td></td><td></td></tr>
<tr><td>pa_set_hom</td><td colspan="2">Home position setting</td><td>○</td><td></td><td></td></tr>
<tr><td>pa_set_esc</td><td colspan="2">Escape orientation setting</td><td>○</td><td></td><td></td></tr>
<tr><td>pa_set_saf</td><td colspan="2">Safety orientation setting</td><td>○</td><td></td><td></td></tr>
<tr><td>pa_def_hom</td><td colspan="2">Current axis value defined as home position</td><td>○</td><td></td><td></td></tr>
<tr><td>pa_def_esc</td><td colspan="2">Current axis value defined as escape position</td><td>○</td><td></td><td></td></tr>
<tr><td>pa_def_saf</td><td colspan="2">Current axis value defined as safety position</td><td>○</td><td></td><td></td></tr>
<tr><td rowspan="2">pa_set_tol</td><td rowspan="2" colspan="2">Tool information setting</td><td colspan="2">/</td><td>RMRC feedback control</td></tr>
<tr><td>○</td><td></td><td>Axis feedback control</td></tr>
<tr><td>pa_set_vel</td><td colspan="2">Default velocity alteration</td><td>○</td><td></td><td></td></tr>
</table>

APPENDIX 4

SAMPLE PROGRAM INSTRUCTION

1．　SAMPLE PROGRAM　:EX1

Sample program “E×1” employs　VisualBASIC、VisualC++ and MFC for each development environment, having similar operation display.
Each is installed to the directory path below:

① Visual Basic Version
¥winpapci¥src¥sample¥VB¥EX1

② Visual C++ Version
¥winpapci¥src¥sample¥VC¥EX1

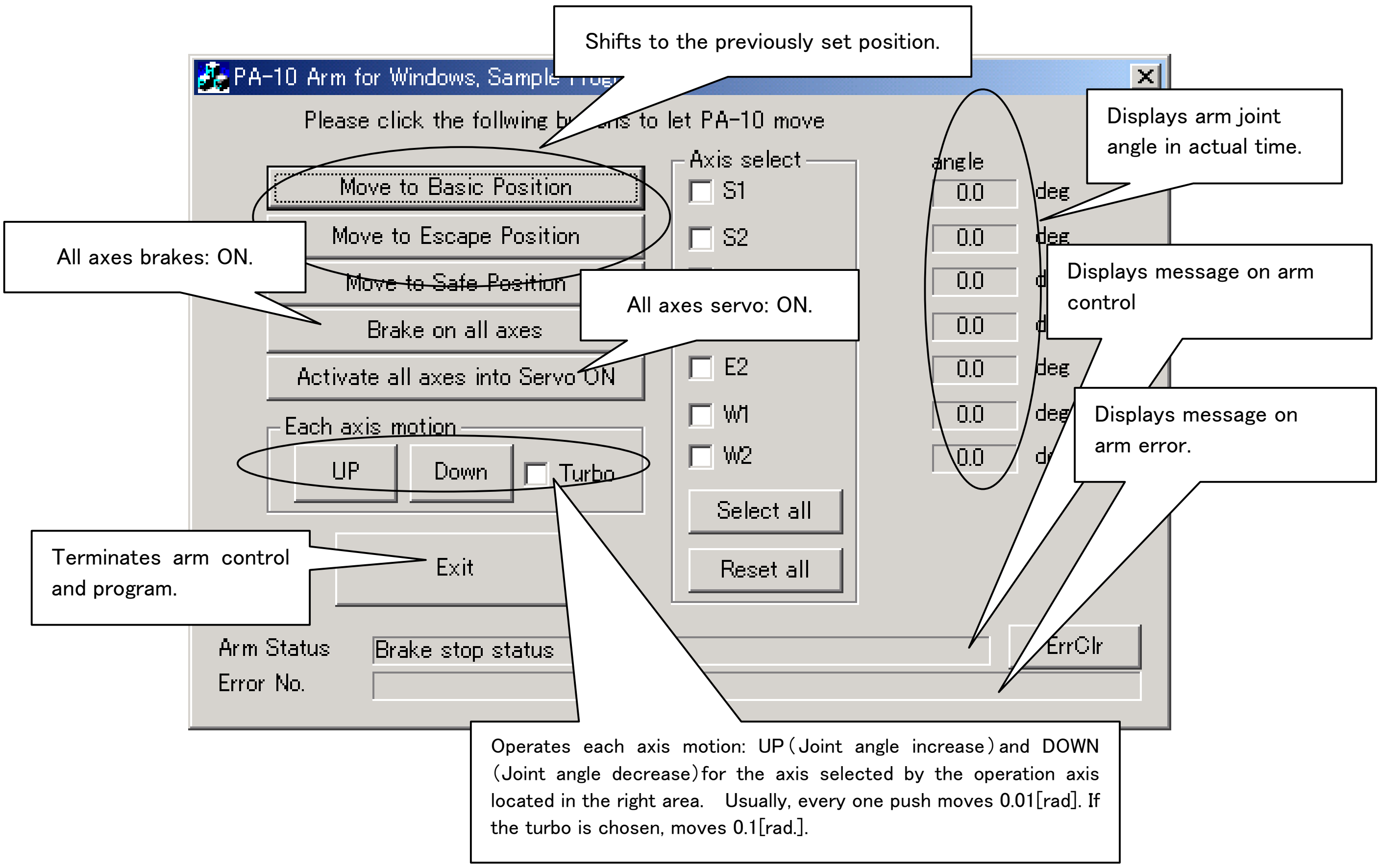
③ MFC Version
¥winpapci¥src¥sample¥MFC¥EX1

”¥winpapci” stands for the directory designation of “winpapci” for installation.

（1）Operation

Screen below displayed when EX1.exe is activated.

As this program operation is equivalent to each development environment, explains the operation employing MFC as an example. Screen below shown when Ex1.exe is activated. Arm is already controllable in actual machine mode, when displayed on screen.



2. SAMPLE PROGRAM：EX2 (VisualBASIC Version)

Sample program "EX2" loads project data on the basis of EX1 and is added a serial operation function. However, this function is created only in VisualBASIC development environment.

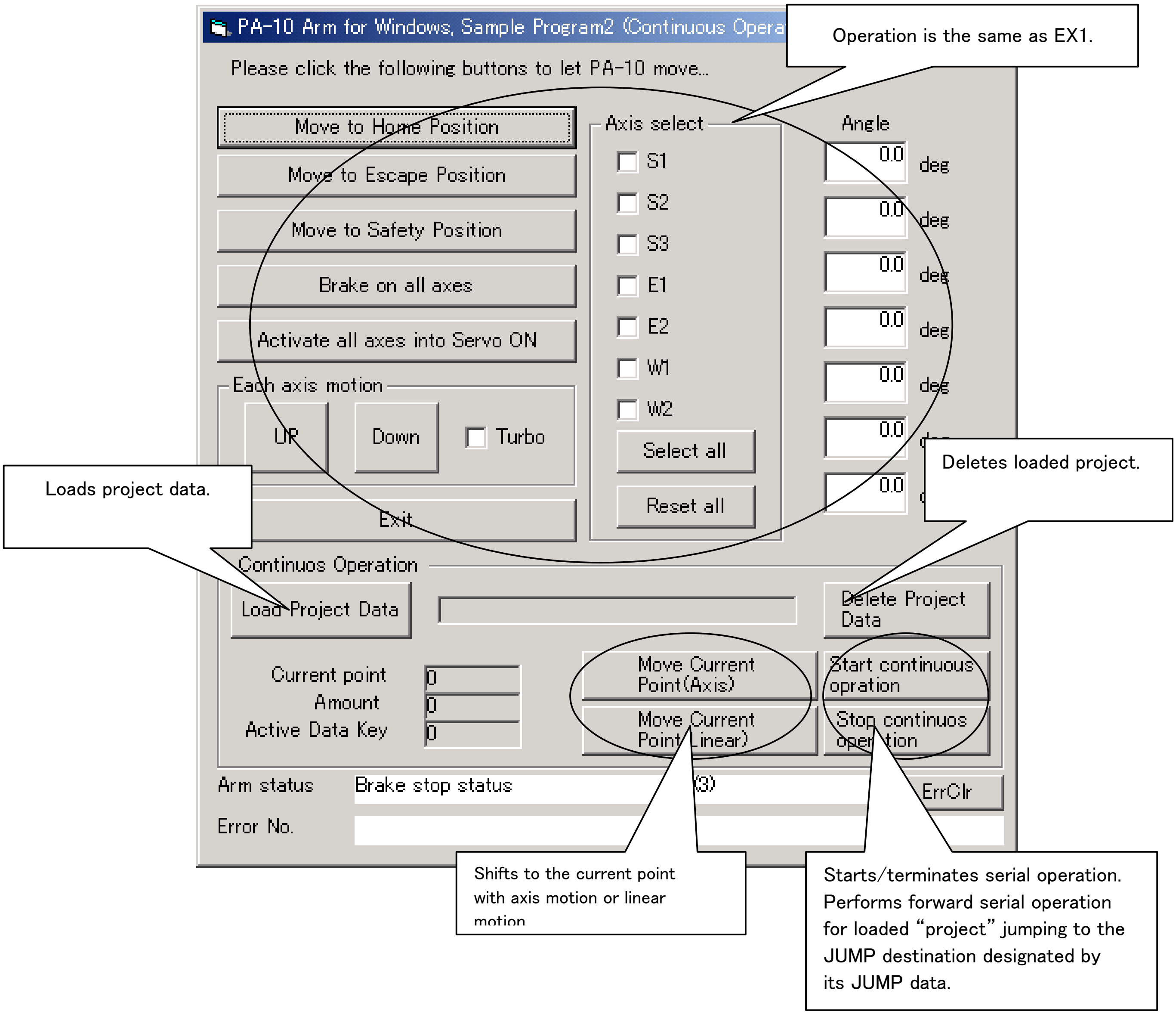
Installed to the following directory path:

¥winpapci¥src¥sample¥VB¥EX2

"¥winpapci" stands for the directory designation of "winpapci" for installation.

(1) Operation

Screen below shown when "EX2.exe" is activated.



3. SAMPLE PROGRAM: EX3 (VisualBASIC Version)

Sample program EX3: programmed to actuate arms with velocity control using game joystick. However, EX3 is created only in VisualBASIC development environment.
Installed to the following directory path:

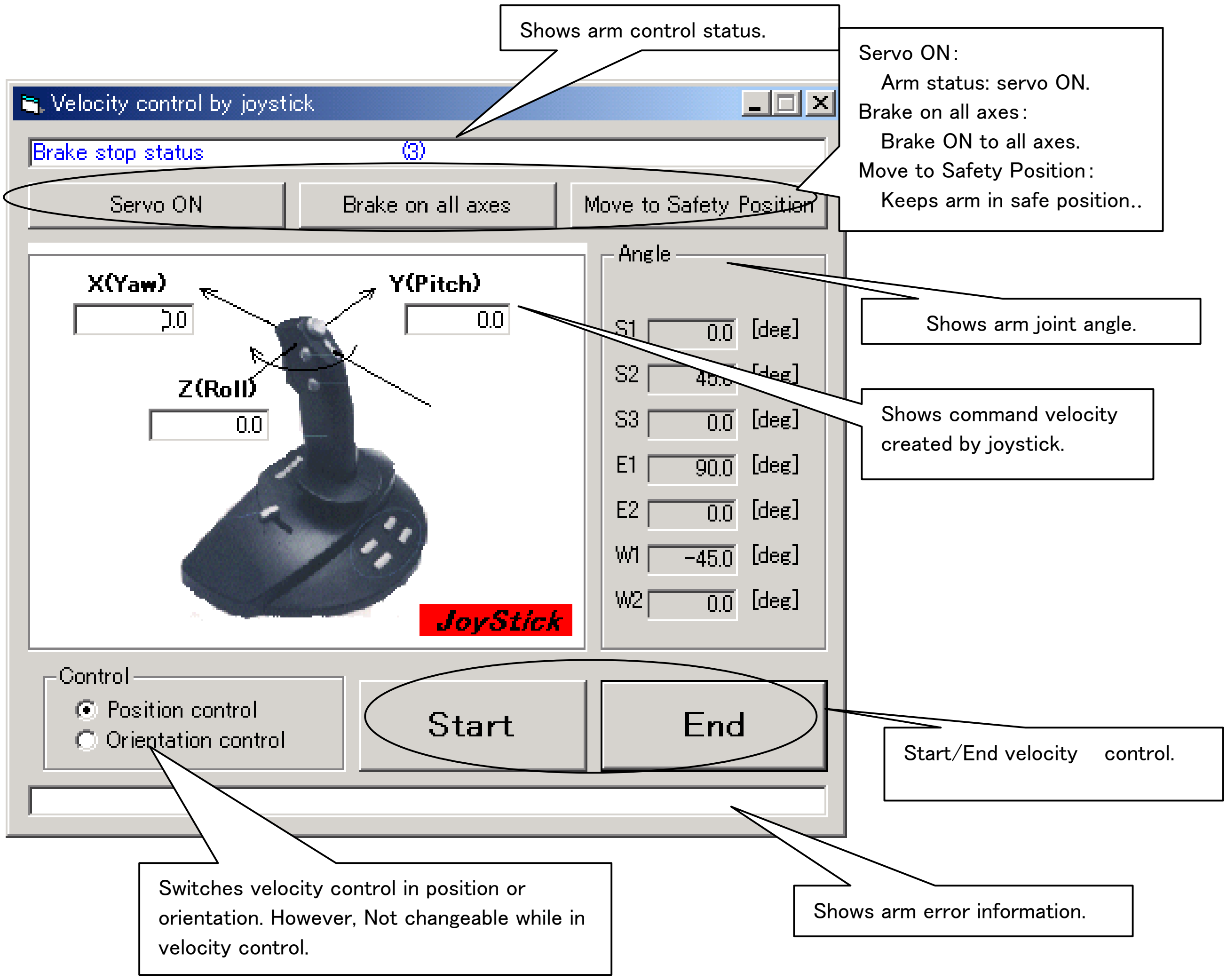
¥winpapci¥src¥sample¥VB¥EX3	EX3 program File
¥winpapci¥src¥sample¥VB¥EX3¥DLL	EX3 Velocity Control DLL File
¥winpapci¥src¥sample¥VB¥EX3¥OCX	EX3 OCX File

”¥winpapci” stands for the directory designation of “winpapci” for installation.

(1) Operation

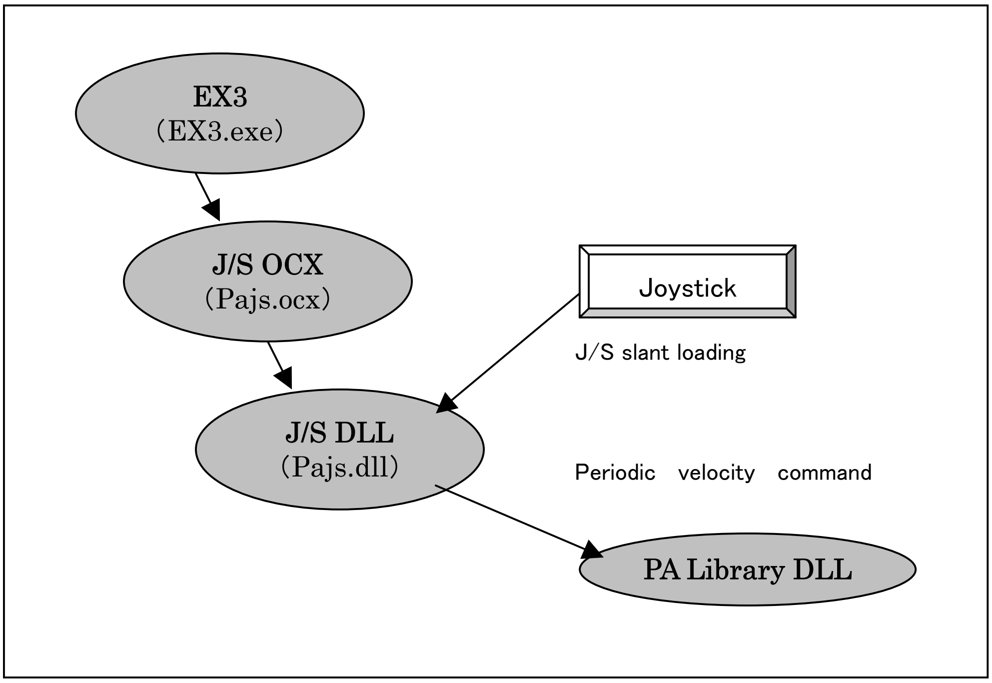
Screen below shows when EX3.exe is activated.

While in velocity control, the arm can be actuated to front/back, right/left and rotated by keeping on pushing the joystick button. Arm motion velocity can be controlled by the joystick slant.



(2) Program

EX3 program motion is as follows:



For EX3, the joystick can be simply moved by inserting OCX for joystick (J/S).

Joystick (J/S) OCX contains properties and methods as follows.

PROPERTY

･pa_arm_no	Sets motion target arm number within 0～15.(Default: 0)
･pa_arrow	Switches into position or orientation velocity control. (Default: Position)
･pa_axis	Switches into base or tip coordinate.(Default: Base coordinate)
･pa_device_no	Selects device number 1 or 2 connected with the joystick.(Default is 1：JOYSTICKID1)
･pa_interval	Sets velocity command output cycle with “mSec” unit. (Default:100 [mSec]. If setting for a long cyclic period it may cause over surveillance time and error-stop.)
･pa_offset_deg	Sets dead zone for joystick input value while in rotational velocity control.(Default: 1000)
･pa_offset_mm	Sets dead zone for joystick input value while in linear velocity control. (Default: 1000)

METHOD（ Method entity presence in J/S DLL, performed on thread. ）

・pa_js_start   Starts velocity control.

Arm initialization operation is performed on another thread. Loading J/S slant at designated cycle. Velocity control command output is performed to the arm.

Velocity control is not interrupted even if dragging EX3 operation display window on account of employing another thread.

Joint angle display on screen cannot be renewed while dragging.

The following parameter is needed to call this method.

Object.pa_js_start(Mode,ArmNo,Axis,Interval,OffsetMM,OffsetDEG,DevNO)

Mode: Arm control mode （0:Actual machine 1:Simulation）

ArmNo: Arm Number

Axis: Coordinates VM_XYZ1（Base coordinate linear velocity control）
VM_XYZ2（Tip coordinate linear velocity control）
VM_YPR1（Base coordinate rotational velocity control ）
VM_YPR2（Tip coordinate rotational velocity control ）

Interval: Velocity command output cycle [mSec]

OffsetDEG: Dead zone when in orientation control

OffsetMM: Dead zone when in position control

DevNO: Joystick device number

・pa_js_continue   Acquires velocity command.
Acquires velocity command value while in velocity control.

The following parameter is needed to call this method.

Object.pa_js_continue(x,y,z,yaw,pitch,roll)

X: Command velocity toward X

Y: Command velocity toward Y

Z: Command velocity toward Z

Yaw: Yaw direction command velocity

Pitch: Pitch direction command velocity

Roll: Roll direction command velocity

・pa_js_stop   Terminates velocity control（thread is also deleted.）
Parameter is not specially needed to call this method.

Object.pa_js_stop()

4. SAMPLE PROGRAM：EX2 (VisualC++ Version)

Sample program "E×1" adds real-time control function employing "pa_odr_dpd･pa_odr_axs" on the basis of EX1. However, this function is created only in VisualC++ development environment.

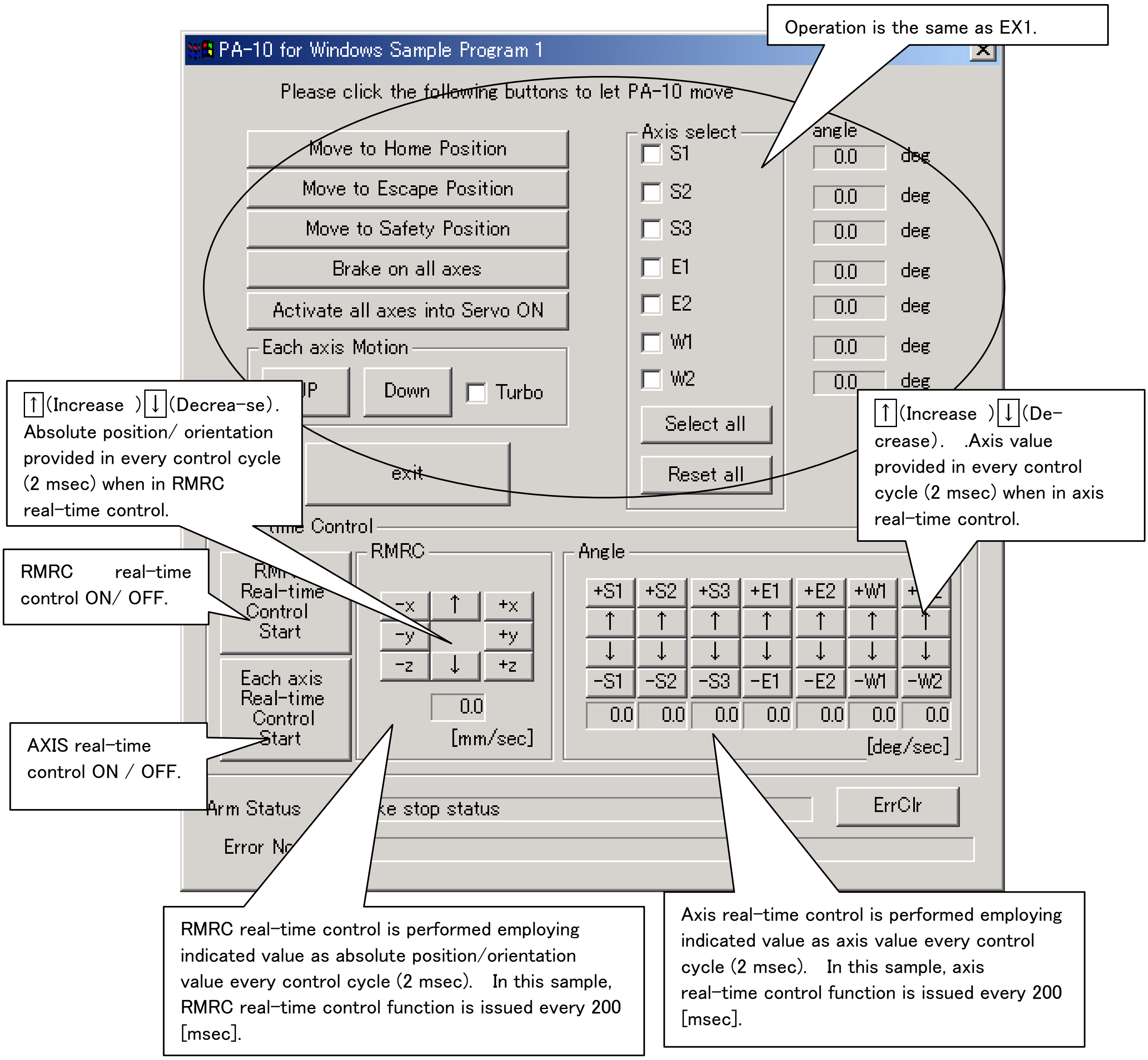
Installed to the directory path below:

¥winpapci¥src¥sample¥VC¥EX2

"¥winpapci" stands for the directory designation of "winpapci" for installation.

(1) Operation

Screen below shown when EX2.exe is activated.



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- WinRT is the brand name of the U. S. BSQUARE Corporation.
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List of Instruction Manuals for PA10 Series (PA10-6CE)

	Subject	Administrative No.
(1)	MITSUBISHI HEAVY INDUSTRIES, LTD. General Purpose Robot PA10 SERIES PA10-6CE INSTRUCTION MANUAL FOR INSTALLATION, MAINTENANCE & SAFETY	91-10014
(2)	MITSUBISHI HEAVY INDUSTRIES, LTD. General Purpose Robot PA10 SERIES PA10-6CE OPERATION MANUAL FOR OPERATION SUPPORT PROGRAM	91-10015
(3)	MITSUBISHI HEAVY INDUSTRIES, LTD. General Purpose Robot PA10 SERIES INSTRUCTION MANUAL FOR SERVO DRIVER	SKC-GC20004
(4)	MITSUBISHI HEAVY INDUSTRIES, LTD. General Purpose Robot PA10 SERIES SOFTWARE INSTALLATION MANUAL (WindowsNT/2000/XP)	SKC-GC20001
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Above documents are described in our home page (http://www.robot-arm.com/), which can be down loaded if required.

Specifications described in this manual are subject to changes for modification without previous notification.

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PROGRAMMING MANUAL
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REV.3

Sales,Manufactures and Afterservices

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