FANUC Robot series

R-30*t*B/R-30*t*B Mate/R-30*t*B Plus/R-30*t*B Mate Plus/ R-30*t*B Mini Plus CONTROLLER

Coordinated Motion Function OPERATOR'S MANUAL

B-83484EN/03

ORIGINAL INSTRUCTIONS

Thank you very much for purchasing a FANUC robot.

Before using the robot, be sure to read the, FANUC Robot series SAFETY HANDBOOK (B-80687EN) and understand its contents.

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In this manual, we endeavor to include all pertinent matters. There are, however, a very large number of operations that must not or cannot be performed. Please assume that any operations that are not explicitly described as being possible are not possible.

B-83484EN/03 SAFETY PRECAUTIONS

SAFETY PRECAUTIONS

This chapter describes the precautions which must be followed to enable the safe use of the robot. Before using the robot, be sure to read this chapter thoroughly.

For detailed functions of the robot operation, read the relevant operator's manual to understand fully its specification.

For the safety of the operator and the system, follow all safety precautions when operating a robot and its peripheral equipment installed in a work cell. For safe use of FANUC robots, you must read and follow the instructions in the FANUC Robot series SAFETY HANDBOOK (B-80687EN).

PERSONNEL

Personnel can be classified as follows:

Operator:

- Turns the robot controller power ON/OFF
- Starts the robot program from the operator panel

Programmer or Teaching operator:

- Operates the robot
- Teaches the robot inside the safeguarded space

Maintenance technician:

- Operates the robot
- Teaches the robot inside the safeguarded space
- Performs maintenance (repair, adjustment, replacement)
- The operator is not allowed to work in the safeguarded space.
- The programmer or teaching operator and maintenance technician are allowed to work in the safeguarded space. Work carried out in the safeguarded space include transportation, installation, teaching, adjustment, and maintenance.
- To work inside the safeguarded space, the person must be trained on proper robot operation.

Table s-1 lists the work outside the safeguarded space. In this table, the symbol "o" means the work is allowed to be carried out by the specified personnel.

Table s-1 Work Performed Outside the Safeguarded Space

	Operator	Programmer or Teaching Operator	Maintenance Technician
Turn power ON/OFF to Robot controller	0	0	0
Select operating mode (AUTO, T1, T2)		0	0
Select remote/local mode		0	0
Select robot program with teach pendant		0	0
Select robot program with external device		0	0
Start robot program with operator's panel	0	0	0

SAFETY PRECAUTIONS B-83484EN/03

	Operator	Programmer or Teaching Operator	Maintenance Technician
Start robot program with teach pendant		0	0
Reset alarm with operator's panel		0	0
Reset alarm with teach pendant		0	0
Set data on teach pendant		0	0
Teaching with teach pendant		0	0
Emergency stop with operator's panel	0	0	0
Emergency stop with teach pendant	0	0	0
Operator panel maintenance			0
Teach pendant maintenance			0

During robot operation, programming and maintenance, the operator, programmer, teaching operator and maintenance engineer take care of their own safety using at least the following safety protectors:

- Use clothes, uniform, overall adequate for the work
- Safety shoes
- Helmet

DEFINITION OF SAFETY NOTATIONS

To ensure the safety of users and prevent damage to the machine, this manual indicates each precaution on safety with "WARNING" or "CAUTION" according to its severity. Supplementary information is indicated by "NOTE". Read the contents of each "WARNING", "CAUTION" and "NOTE" before using the robot.

Symbol	Definitions	
• WARNING	Used if hazard resulting in the death or serious injury of the user will be expected to occur if he or she fails to follow the approved procedure.	
CAUTION	Used if a hazard resulting in the minor or moderate injury of the user, or equipment damage may be expected to occur if he or she fails to follow the approved procedure.	
NOTE	Used if a supplementary explanation not related to any of WARNING and CAUTION is to be indicated.	

TABLE OF CONTENTS

1 OVERVIEW	s-1
· ♥ · · · · · · · · · · · · · · · · · ·	1
1.1 BENEFITS	
1.2 COMPARISON WITH SIMULTANEOUS MOTION	
1.3 OPERATION	
1.4 TERMINOLOGY	
1.4.1 Motion Group.	
1.4.2 Leader Group.	
1.4.3 Follower Group	
1.4.4 Linear Axis	
1.4.5 Rotary Axis	
1.4.6 Axis Offset (A05B-2600-H896 Positioner Only)	
1.4.7 Coordinated Frame	
1.4.8 Follower UFRAME	4
1.4.9 Follower UTOOL	4
1.4.10 Leader UTOOL	
1.4.11 Leader UFRAME	5
1.4.12 Leader World Frame	5
1.5 SETUP STEPS	
1.6 SUPPORTED OPTIONS	6
1.7 RESTRICTIONS OF COORDINATED MOTION	
1.8 COORD-MOTION/HIGH SPEED MOTION ADD-ON	7
1.8.1 Restriction.	7
2 POSITIONER SETTING	۵
2.1 KINEMATICS TYPE	
	9
2.2 AXIS ASSIGNMENT TO POSITIONER WORLD FRAME	10
2.2 AXIS ASSIGNMENT TO POSITIONER WORLD FRAME2.3 KINEMATICS PARAMETERS OF POSITIONER	10 12
2.2 AXIS ASSIGNMENT TO POSITIONER WORLD FRAME	10 12
2.2 AXIS ASSIGNMENT TO POSITIONER WORLD FRAME	10 12 12
2.2 AXIS ASSIGNMENT TO POSITIONER WORLD FRAME	10 12 13 19
2.2 AXIS ASSIGNMENT TO POSITIONER WORLD FRAME	10 12 13 19
2.2 AXIS ASSIGNMENT TO POSITIONER WORLD FRAME 2.3 KINEMATICS PARAMETERS OF POSITIONER 2.3.1 Kinematics Parameters of Positioner (A05B-2600-H896) 2.3.2 Kinematics Parameters of General Positioner (A05B-2600-H874) 3 SETTING UP COORDINATED PAIRS 3.1 SETTING UP COORDINATED PAIRS OVERVIEW 3.2 RESTRICTIONS AND GUIDELINES	10 12 13 19 19
2.2 AXIS ASSIGNMENT TO POSITIONER WORLD FRAME	10 12 13 19 19
2.2 AXIS ASSIGNMENT TO POSITIONER WORLD FRAME 2.3 KINEMATICS PARAMETERS OF POSITIONER 2.3.1 Kinematics Parameters of Positioner (A05B-2600-H896) 2.3.2 Kinematics Parameters of General Positioner (A05B-2600-H874) 3 SETTING UP COORDINATED PAIRS 3.1 SETTING UP COORDINATED PAIRS OVERVIEW 3.2 RESTRICTIONS AND GUIDELINES 3.3 SELECTING CD_PAIRS	10 12 13 19 19 19
2.2 AXIS ASSIGNMENT TO POSITIONER WORLD FRAME 2.3 KINEMATICS PARAMETERS OF POSITIONER 2.3.1 Kinematics Parameters of Positioner (A05B-2600-H896). 2.3.2 Kinematics Parameters of General Positioner (A05B-2600-H874). 3 SETTING UP COORDINATED PAIRS 3.1 SETTING UP COORDINATED PAIRS OVERVIEW. 3.2 RESTRICTIONS AND GUIDELINES. 3.3 SELECTING CD_PAIRS.	10 12 13 19 19 19 19
2.2 AXIS ASSIGNMENT TO POSITIONER WORLD FRAME 2.3 KINEMATICS PARAMETERS OF POSITIONER 2.3.1 Kinematics Parameters of Positioner (A05B-2600-H896) 2.3.2 Kinematics Parameters of General Positioner (A05B-2600-H874) 3 SETTING UP COORDINATED PAIRS 3.1 SETTING UP COORDINATED PAIRS OVERVIEW 3.2 RESTRICTIONS AND GUIDELINES 3.3 SELECTING CD_PAIRS 4 CALIBRATION 4.1 KNOWN FOUR POINT CALIBRATION VS UNKNOWN POINT CALIBRATION	10121319191920
2.2 AXIS ASSIGNMENT TO POSITIONER WORLD FRAME 2.3 KINEMATICS PARAMETERS OF POSITIONER 2.3.1 Kinematics Parameters of Positioner (A05B-2600-H896) 2.3.2 Kinematics Parameters of General Positioner (A05B-2600-H874) 3 SETTING UP COORDINATED PAIRS 3.1 SETTING UP COORDINATED PAIRS OVERVIEW 3.2 RESTRICTIONS AND GUIDELINES 3.3 SELECTING CD_PAIRS 4 CALIBRATION 4.1 KNOWN FOUR POINT CALIBRATION VS UNKNOWN POINT CALIBRATION 4.2 KNOWN FOUR POINT CALIBRATION	101213191919202425
2.2 AXIS ASSIGNMENT TO POSITIONER WORLD FRAME 2.3 KINEMATICS PARAMETERS OF POSITIONER 2.3.1 Kinematics Parameters of Positioner (A05B-2600-H896) 2.3.2 Kinematics Parameters of General Positioner (A05B-2600-H874) 3 SETTING UP COORDINATED PAIRS 3.1 SETTING UP COORDINATED PAIRS OVERVIEW 3.2 RESTRICTIONS AND GUIDELINES 3.3 SELECTING CD_PAIRS 4 CALIBRATION 4.1 KNOWN FOUR POINT CALIBRATION VS UNKNOWN POINT CALIBRATION 4.2 KNOWN FOUR POINT CALIBRATION 4.2.1 Known Four Point Calibration Guidelines	1012131919202425
2.2 AXIS ASSIGNMENT TO POSITIONER WORLD FRAME 2.3 KINEMATICS PARAMETERS OF POSITIONER 2.3.1 Kinematics Parameters of Positioner (A05B-2600-H896) 2.3.2 Kinematics Parameters of General Positioner (A05B-2600-H874) 3 SETTING UP COORDINATED PAIRS 3.1 SETTING UP COORDINATED PAIRS OVERVIEW 3.2 RESTRICTIONS AND GUIDELINES 3.3 SELECTING CD_PAIRS 4 CALIBRATION 4.1 KNOWN FOUR POINT CALIBRATION VS UNKNOWN POINT CALIBRATION 4.2 KNOWN FOUR POINT CALIBRATION 4.2.1 Known Four Point Calibration Guidelines 4.2.2 World Frame of FANUC Positioners	10121319191920252525
2.2 AXIS ASSIGNMENT TO POSITIONER WORLD FRAME. 2.3 KINEMATICS PARAMETERS OF POSITIONER. 2.3.1 Kinematics Parameters of Positioner (A05B-2600-H896). 2.3.2 Kinematics Parameters of General Positioner (A05B-2600-H874). 3 SETTING UP COORDINATED PAIRS. 3.1 SETTING UP COORDINATED PAIRS OVERVIEW. 3.2 RESTRICTIONS AND GUIDELINES. 3.3 SELECTING CD_PAIRS. 4 CALIBRATION. 4.1 KNOWN FOUR POINT CALIBRATION VS UNKNOWN POINT CALIBRATION. 4.2 KNOWN FOUR POINT CALIBRATION. 4.2.1 Known Four Point Calibration Guidelines. 4.2.2 World Frame of FANUC Positioners. 4.2.3 Known Four Point Calibration Procedure.	1012131919202425252629
2.2 AXIS ASSIGNMENT TO POSITIONER WORLD FRAME. 2.3 KINEMATICS PARAMETERS OF POSITIONER. 2.3.1 Kinematics Parameters of Positioner (A05B-2600-H896). 2.3.2 Kinematics Parameters of General Positioner (A05B-2600-H874). 3 SETTING UP COORDINATED PAIRS. 3.1 SETTING UP COORDINATED PAIRS OVERVIEW. 3.2 RESTRICTIONS AND GUIDELINES. 3.3 SELECTING CD_PAIRS. 4 CALIBRATION. 4.1 KNOWN FOUR POINT CALIBRATION VS UNKNOWN POINT CALIBRATION. 4.2 KNOWN FOUR POINT CALIBRATION. 4.2.1 Known Four Point Calibration Guidelines. 4.2.2 World Frame of FANUC Positioners. 4.2.3 Known Four Point Calibration Procedure. 4.3 KNOWN DIRECT CALIBRATION.	1012131919202425252629
2.2 AXIS ASSIGNMENT TO POSITIONER WORLD FRAME. 2.3 KINEMATICS PARAMETERS OF POSITIONER. 2.3.1 Kinematics Parameters of Positioner (A05B-2600-H896). 2.3.2 Kinematics Parameters of General Positioner (A05B-2600-H874). 3 SETTING UP COORDINATED PAIRS. 3.1 SETTING UP COORDINATED PAIRS OVERVIEW. 3.2 RESTRICTIONS AND GUIDELINES. 3.3 SELECTING CD_PAIRS. 4 CALIBRATION. 4.1 KNOWN FOUR POINT CALIBRATION VS UNKNOWN POINT CALIBRATION. 4.2 KNOWN FOUR POINT CALIBRATION. 4.2.1 Known Four Point Calibration Guidelines. 4.2.2 World Frame of FANUC Positioners. 4.2.3 Known Four Point Calibration Procedure. 4.3 KNOWN DIRECT CALIBRATION. 4.4 UNKNOWN POINT CALIBRATION FOR POSITIONERS (INCLUDING GENERAL	101213191920242525252627
2.2 AXIS ASSIGNMENT TO POSITIONER WORLD FRAME. 2.3 KINEMATICS PARAMETERS OF POSITIONER. 2.3.1 Kinematics Parameters of Positioner (A05B-2600-H896). 2.3.2 Kinematics Parameters of General Positioner (A05B-2600-H874). 3 SETTING UP COORDINATED PAIRS. 3.1 SETTING UP COORDINATED PAIRS OVERVIEW. 3.2 RESTRICTIONS AND GUIDELINES. 3.3 SELECTING CD_PAIRS. 4 CALIBRATION. 4.1 KNOWN FOUR POINT CALIBRATION VS UNKNOWN POINT CALIBRATION. 4.2 KNOWN FOUR POINT CALIBRATION. 4.2.1 Known Four Point Calibration Guidelines. 4.2.2 World Frame of FANUC Positioners. 4.2.3 Known Four Point Calibration Procedure. 4.3 KNOWN DIRECT CALIBRATION. 4.4 UNKNOWN POINT CALIBRATION FOR POSITIONERS (INCLUDING GENERAL POSITIONERS).	101213191920242525262531
2.2 AXIS ASSIGNMENT TO POSITIONER WORLD FRAME. 2.3 KINEMATICS PARAMETERS OF POSITIONER. 2.3.1 Kinematics Parameters of Positioner (A05B-2600-H896). 2.3.2 Kinematics Parameters of General Positioner (A05B-2600-H874). 3 SETTING UP COORDINATED PAIRS. 3.1 SETTING UP COORDINATED PAIRS OVERVIEW. 3.2 RESTRICTIONS AND GUIDELINES. 3.3 SELECTING CD_PAIRS. 4 CALIBRATION. 4.1 KNOWN FOUR POINT CALIBRATION VS UNKNOWN POINT CALIBRATION. 4.2 KNOWN FOUR POINT CALIBRATION. 4.2.1 Known Four Point Calibration Guidelines. 4.2.2 World Frame of FANUC Positioners. 4.2.3 Known Four Point Calibration Procedure. 4.3 KNOWN DIRECT CALIBRATION. 4.4 UNKNOWN POINT CALIBRATION FOR POSITIONERS (INCLUDING GENERAL	101213191920242525262931

TABLE OF CONTENTS B-83484EN/03

	4.4.4 Unknown Point Calibration for a Linear Axis	
	4.5 LEADER FRAME SETUP	
	4.5.1 Leader Frame Setup	52
5	MULTIPLE COORD FRAMES FOR ONE CD_PAIR	. 57
	5.1 ENABLE DISABLE MULTIPLE COORD FRAMES	
	5.2 SETUP SCREEN OF MULTIPLE COORD FRAMES	59
	5.2.1 Display the Recorded CD Frame List Screen	59
	5.2.2 Save the CD_Frame	
	5.2.3 Clear the CD_Frames	61
	5.2.4 Restore the CD_Frame	
	5.2.5 Details Screen of the Recorded CD_Frame	
	5.3 SWITCHING THE CD_FRAME BY KAREL PROGRAM	
	5.3.1 Limitations	
	5.3.2 Example of How to Use SET_COORD_FRAME.PC	
	5.3.3 Error Message	
	5.4 NOTES/RESTRICTIONS	65
6	RELATIVE AND SIMULTANEOUS COORDINATED MOTION	67
7	JOGGING	.69
	7.1 JOGGING OVERVIEW	69
	7.2 JOGGING DESIGNATION	69
	7.2.1 Enabling Toggle Coordinate Orientation	
	7.3 LEADER GROUP JOGGING (COORDINATED, FIXED ORIENTATION COORDINATED).	
	7.4 LEADER FRAME JOG FOR FOLLOWER GROUP	73
	7.5 JOGGING EXAMPLES	
	7.6 JOGGING PROCEDURE	75
	7.6.1 Jogging Using Coordinated Motion	
	7.7 CD JOGGING OUTPUT	78
	7.7.1 Setting CD Jogging Output	78
8	PROGRAMMING	. 81
	8.1 PROGRAMMING OVERVIEW	
	8.2 PROGRAM HEADER INFORMATION	
	8.3 COORD COORDINATED MOTION OPTION	
	8.4 COORD[LDR] COORDINATED MOTION OPTION	
	8.5 SPEED DEFINITION	
	8.6 LINEAR MOTION PROGRAMMING	85
	8.7 CIRCULAR MOTION PROGRAMMING	
9	DYNAMIC UFRAME	89
	9.1 SETTING DYNAMIC UFRAME	
	9.2 PROGRAMMING DYNAMIC UFRAME	
	9.3 DYNAMIC UFRAME RESTRICTIONS	
	9.4 OFFSET AND VOFFSET INSTRUCTION	
1	0 TROUBLESHOOTING	97
•	10.1 TROUBLESHOOTING OVERVIEW	
	10.1 TROUBLESHOOTING OVERVIEW	
	10.2 CALIBRATION ERRORS	
	10.3 LINION GODES	90

ADDITIONAL INFORMATION

B-83484EN/03 1 OVERVIEW

1 OVERVIEW

Coordinated motion is a motion control method in which the Tool Center Point (TCP) speed and position of a follower motion group is executed relative to a leader motion group. This method provides constant relative speed between the two motion groups, and provides for path execution by the follower in a moving frame of the leader.

See Figure 1.

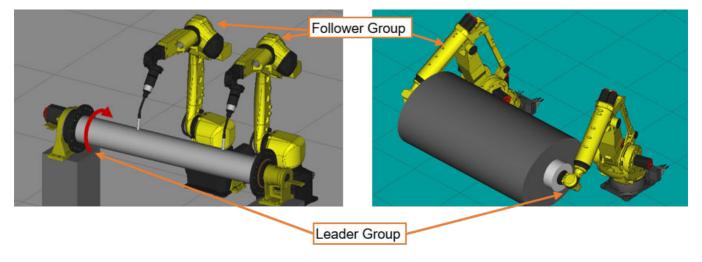


Figure 1 Coordinated Motion Overview

1.1 BENEFITS

You might want to use coordinated motion for the following reasons:

- It reduces the time required for workpiece programming because of the reduction in the number of positions needed.
- It provides absolute relative speed between two moving motion groups.
- It allows you to arc weld more effectively:
 - You can position welds more efficiently.
 - You can weld significantly longer welds than the robot work envelope would normally permit.
 - It eliminates the need for simultaneous motion welding paths.
 - It provides for better utilization of gravity to focus penetration and for weld bead formation.
 - It positions workpieces for subsequent welds during the execution of the current weld path.
 - It provides an effective method for making continuous welds on positioner-mounted workpieces.

1.2 COMPARISON WITH SIMULTANEOUS MOTION

Coordinated motion differs from simultaneous motion in the following ways:

• Simultaneous motion addresses only starting and stopping motion groups at the same time.

1 OVERVIEW B-83484EN/03

In simultaneous motion, relative TCP speed is not controlled automatically. You must do this manually
by programming several regularly-spaced, time-based moves along the weld path, generally every four
to eight millimeters.

1.3 OPERATION

Coordinated motion occurs between coordinated motion group pairs, called CD_pairs. CD_pairs consist of a leader motion group and a follower motion group. The leader group can be any kind of positioner, such as a table. The follower group is usually the robot.

The leader group (for example, a positioner) must have FANUC motors and be controlled by the robot as a separate motion group. This differs from the conventional positioner installation, which typically uses extended axes or uses the multiple-motion group *Independent Axes* configuration.

This new kinematic type is called a *Positioner*. The Positioner can consist of 1-4 axes that can be linear, rotary, or a combination of both.

1.4 TERMINOLOGY

This section contains descriptions of terms that are used in coordinated motion. Become familiar with these terms before you continue with coordinated motion setup, operation, and programming.

1.4.1 Motion Group

A motion group defines a set of motors and axes that are combined to accomplish a motion task. FANUC robots are an example of a motion group, typically Group 1. Additional motion groups are defined to control axes on a piece of equipment other than the robot.

The maximum number of groups that can be supported by a controller is eight. Up to four positioner devices can be added as motion groups to the system.

Each positioner group can have up to four axes.

1.4.2 Leader Group

The leader group has independent motion during coordinated motions. Typically, the leader group is the positioner.

1.4.3 Follower Group

The follower group executes motion with respect to the leader group. During coordinated jogging, for example, when the leader group is moved, the follower group will maintain the same relative position with respect to the leader. Typically, the follower group is the robot.

B-83484EN/03 1 OVERVIEW

There are cases where multiple robot followers will be present in a robot program. If the part paths are identical or mirrored (i.e. a motion segment on the first follower robot and the second, etc. are the same length) then all the follower robots will be executing coordinated motion. In practice, there are small path differences between the follower robots, so the follower with the longest segment will dictate the time for the move and will be exactly coordinated with the leader. The other follower robots will execute at a lower speed than the programmed speed.)

1.4.4 Linear Axis

Linear refers to the mechanical motion produced when the axis motor is run. Linear motion is straight line motion. This motion occurs for lead screw-type drives and rack and pinion-type drives.

1.4.5 Rotary Axis

Rotary refers to mechanical motion that rotates about a fixed point when the axis motor is run. Harmonic drives typically have rotary motion output. The typical positioner has a rotary tabletop axis.

1.4.6 Axis Offset (A05B-2600-H896 Positioner Only)

The axis offset defines the x, y, and z coordinate difference between the center of rotation of two axes of a multiple axis positioner device. The x, y, and z offsets are with respect to the positioner frame x, y, and z origin for the first axis of the positioner. The offsets are calculated automatically when unknown kinematic calibration is performed.

In general, the first axis of a multiple axis positioner will not have an offset. However, subsequent axes will have an offset with respect to the previous axis in a positioner group.

1.4.7 Coordinated Frame

The coordinated frame is the frame of the leader group. This frame is created when the leader and follower are calibrated as a coordinated pair (CD_pair). For example, the coordinated frame is the frame that is "connected" to the leader (positioner) table top, which moves when the table moves. The motion of the follower is executed with respect to this moving frame.

The *origin of the leader frame* is expressed as a position in the robot WORLD frame. It is the transformation from the robot origin to the leader origin.

The *leader TCP* is a position relative to the leader origin. It is expressed as a position in the leader WORLD frame.

1 OVERVIEW B-83484EN/03

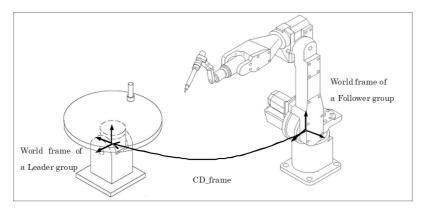


Figure 1.4.7 CD_frame

1.4.8 Follower UFRAME

The follower UFRAME (user frame) has the effect of moving the coordinated frame, when used with coordinated jogging or the program execution of coordinated motion. The UFRAME should be defined relative to the leader WORLD coordinate system, for ease of programming, if UFRAME is to be used in coordinated motion programs.

Changing the UFRAME will shift all of the programmed positions by the same amount for non-coordinated motion programs. It has the effect of shifting the origin of the coordinated frame. When applied to coordinated moves, this provides a convenient way to shift a coordinated motion program, if the relationship between the positioner (leader) and the robot (follower) has been changed. This can occur if the positioner is moved.

The follower UFRAME performs the same function as the user frame in non-coordinated motion.

The follower UFRAME can be configured as a dynamic uframe. This frame moves with the leader and corresponds to the leader frame at the current leader position. The dynamic uframe is useful when the workpiece is shifted from the original taught position, for workcell cloning, or for transferring programs between the controller and ROBOGUIDE.

Refer to the Chapter 9, DYNAMIC UFRAME for more description of the dynamic uframe and setup of the leader frame.

⚠ CAUTION

Unless dynamic uframe is used, do not shift UFRAME to compensate for shifted workpieces or programs. Otherwise, motion might not occur as expected relative to the workpiece.

1.4.9 Follower UTOOL

The follower UTOOL is the standard tool frame. This is the same as the tool frame used for the robot in non-coordinated motion. Refer to the appropriate application-specific *Setup and Operations Manual* or to the *OPERATOR'S MANUAL (Basic Function) (B-83284EN)* for more information.

B-83484EN/03 1 OVERVIEW

Use the six-point method to define UTOOL. Ensure that you have defined the UTOOL correctly prior to CD_pair calibration or programming.

1.4.10 Leader UTOOL

Leader UTOOL only usually has an effect when known four-point CD pair calibration is used.

1.4.11 Leader UFRAME

The leader UFRAME currently has no function in coordinated motion.

1.4.12 Leader World Frame

The origin of the leader world frame is based on the positioner. This frame need not have any alignment with the robot world frame. Refer to Section 1.4.7, Coordinated Frame for more information.

1.5 SETUP STEPS

To use coordinated motion, you must do the following:

- 1. Install appropriate multiple motion group hardware.
- 2. Perform software setup for the positioner.

You must install the multiple motion group as a Positioner. During this setup, you must set up information on the leader group kinematic data and the leader group frame information. Standard positioner products (such as 500kg 1-Axis Positioner iD (hollow type) A05B-2600-H887) have data files supplied for automatic setup.

- **3.** Install the multi-group motion software option.
- 4. Install the coordinated motion software option.
- **5.** Master and calibrate the robot and additional motion groups.
- **6.** Set up UFRAME(s) and UTOOL(s). Refer to Chapter 4, CALIBRATION for information on performing calibration. Refer to the application-specific *Setup and Operations Manual* or the *Basic Operator's Manual* for more information on setting up frames and tools.
- 7. Select motion group pairings as coordinated pairs (CD_pairs). Refer to Chapter 3, SETTING UP COORDINATED PAIRS.
- **8.** Calibrate the CD_pairs. Refer to Chapter 4, CALIBRATION.
- 9. Verify coordinated motion by jogging the CD pairs. Refer to Chapter 7, JOGGING.
- 10. Create coordinated motion teach pendant programs. Refer to Chapter 8, PROGRAMMING.
- 11. Test coordinated motion programs.

Refer to the application-specific *Setup and Operations Manual* or the *OPERATOR'S MANUAL (Basic Function) (B-83284EN)*.

12. Run production with coordinated motion programs.

1 OVERVIEW B-83484EN/03

Refer to the application-specific *Setup and Operations Manual* or the *OPERATOR'S MANUAL (Basic Function) (B-83284EN)*.

13. Troubleshoot any problems. Refer to Chapter 10, TROUBLESHOOTING.

1.6 SUPPORTED OPTIONS

Coordinated motion is supported for the following options:

- Touch Sensing
- Thru Arc Seam Tracking (TAST)
- Automatic Voltage Control Tracking (AVC)
- Root Pass Memorization (RPM)
- Multipass Welding (MPASS)
- Dynamic Path Modifier (DPM)
- Weaving
- Spline Motion Type
- DPM/Spline Add-on

1.7 RESTRICTIONS OF COORDINATED MOTION

Coordinated Motion has the following restrictions:

- The upper limit of CD_pairs is 4.
- Individual axis cannot be Leader group. Please set as Positioner (A05B-2600-H896) or General Positioner (A05B-2600-H874).
- You cannot install REMOTE TCP function in coordinated motion system. If you install REMOTE TCP function, REMOTE TCP is disabled.
- You cannot include the motion group having a continuous rotation axis in coordinated motion program.
- For Extended axis control
 - You can add extended axis to leader and follower.
 - When the robot is mounted to extended axes, these must be integrated rotary or integrated linear axes.
- Coordinated motion is not supported when the follower group is mounted on the leader group. Also, the leader group cannot be mounted on the follower group.
- You can execute weaving only on the follower.
- You cannot use SHIFT functions for coordinated motion program.
- You cannot use LINEAR DISTANCE function with coordinated motion.
- You cannot use CORNER REGION termination type with coordinated motion.
- You cannot use MAX SPEED function with coordinated motion.
- You cannot use Incremental instruction (INC) with coordinated motion.
- You cannot use wrist joint motion instruction (WJNT) with coordinated motion.
- You cannot use SINGULARITY AVOIDANCE function for coordinated motion program.
- You cannot TCP SPEED OUTPUT function with coordinated motion.
- You cannot LINE TRACKING function with coordinated motion.
- You cannot use J7, J8 key for coordinated jogging.

B-83484EN/03 1 OVERVIEW

1.8 COORD-MOTION/HIGH SPEED MOTION ADD-ON

The Coord-Motion/High Speed Motion Add-on (A05B-2600-S564) option improves the trajectory accuracy of high-speed coordinated motion (e.g. teaching speed is 100cm/min or more). This option is effective in applications that require high-speed motion such as laser welding and sealing.

For example, when coordinated motion is performed along a rectangle while rotating the positioner, installing this function will improve the trajectory accuracy as shown in Figure 1.8.

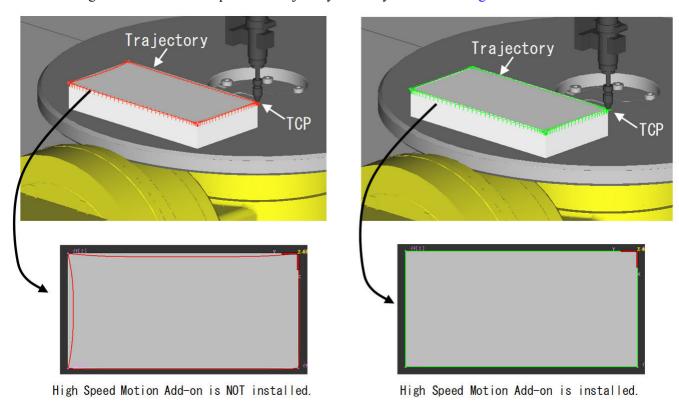


Figure 1.8 Example of improvement by Coord-Motion/High Speed Motion Add-on

1.8.1 Restriction

This option cannot be used with the following options.

- ArcTool / LR ArcTool
- TAST
- AVC
- MP/RPM
- Line Tracking
- *i*RpickTool
- Dynamic Path Modifier
- Universal Sensor IF
- Line Track Coord
- Weaving

This option is available in the following software versions.

1 OVERVIEW B-83484EN/03

- 7DF3/23 (V9.30P/23) or later
- 7DF5/26 (V9.40P/26) or later

B-83484EN/03 2 POSITIONER SETTING

2 POSITIONER SETTING

The required software options and settings depend on whether you use an arbitrarily designed positioner or a FANUC positioner.

FANUC supports a basic type positioner (Positioner, A05B-2600-H896) and a generic type positioner (General Positioner, A05B-2600-H874) as the robot library software that can drive an arbitrarily designed positioner. The General Positioner is an extended version of the Positioner. Unlike the basic positioner, the axes of a General Positioner can be set up at any angle.

When Positioner (A05B-2600-H896) or General Positioner (A05B-2600-H874) is used for the leader, you should set up the positioner. If you use a FANUC positioner, setting is not required.

In order to perform coordinated motion, you must make several selections to define the axes of the leader group. This chapter contains descriptions of some of the key concepts you must understand to define the axes properly during setting.

- Kinematics type
- Axis assignment to positioner's world frame
- Kinematics parameters

2.1 KINEMATICS TYPE

Kinematics defines how a positioner will move in Cartesian space when the motors are turned. This is determined by the direction of each axis, the axis offset information, the gear ratios of each axis and axis type (linear/rotary). During setup, you must select the kinematics type.

Positioner (A05B-2600-H896)

Kinematics parameters are the direction of each axis and the axis offset. Refer to Section 2.2, AXIS ASSIGNMENT TO POSITIONER WORLD FRAME for setting the direction of each axis.

Known Kinematics

When the axis offset is known, select **Known Kinematics** in positioner setup. In this case, the axis-offset information will be requested during axis setup. Refer to Section 2.3, KINEMATICS PARAMETERS OF POSITIONER.

When DCS Position/Speed check function is ordered, you must select this type.

Unknown Kinematics

When the axis offset is not known, select **Unknown Kinematics**. In this case, the offset information will be calculated in the calibration procedure.

General Positioner (A05B-2600-H874)

Kinematics parameters are DH parameters. Select Unknown Kinematics unless you restore the coordinated motion system.

Known Kinematics

Select Known Kinematics when you restore the coordinated motion system. Because DH parameters are stored in the system variables, you should input the previous values.

2 POSITIONER SETTING B-83484EN/03

Refer to Section 4.3, KNOWN DIRECT CALIBRATION about the system variables which need be restored.

Unknown Kinematics

Select Unknown Kinematics generally.

2.2 AXIS ASSIGNMENT TO POSITIONER WORLD FRAME

You must assign an axis and direction (X, Y, Z, -X, -Y, -Z) to each positioner axis. This section explains the axis arrangement, direction and assignment.

Axis Arrangement

Positioner axes must be either parallel or perpendicular to the other axes in the positioner. Axis assignment is arbitrary for single axis positioners.

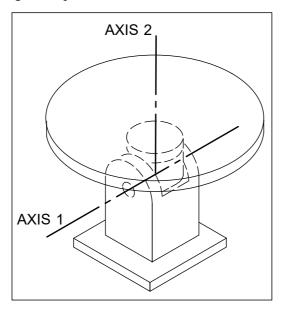


Figure 2.2 (a) Axis arrangement example

Axis Direction

You determine the positive direction of an axis differently for linear and rotary axes. For a rotary axis, the right hand rule for electrical current is applied to determine the positive direction. For linear axis, the positive direction is evident by which direction the axis moves when the + jog key is pressed.

B-83484EN/03 2 POSITIONER SETTING

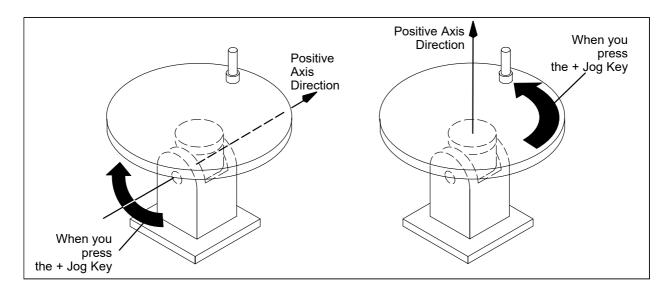


Figure 2.2 (b) Rotary axis selection

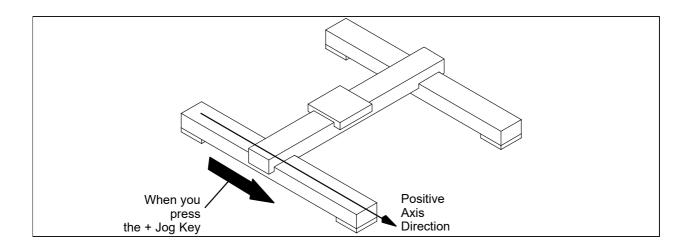


Figure 2.2 (c) Linear axis selection

Axis assignment to world frame

When you assign an axis, you must decide whether it will be X, Y, Z, -X, -Y or -Z of the Positioner's world frame. Positioner's world frame must be the right-handed coordinate system. Refer to the examples below.

2 POSITIONER SETTING B-83484EN/03

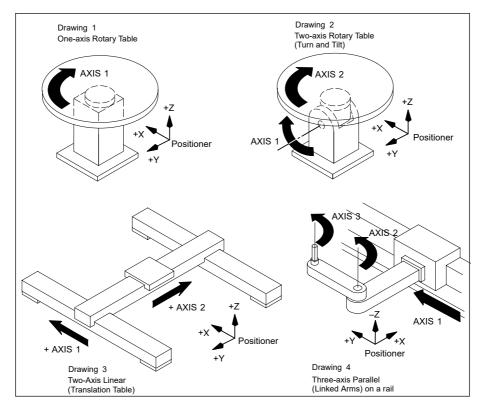


Figure 2.2 (d) Axis assignment to world frame

This example describes axis assignment as illustrated in Figure 2.2 (d). All drawings are at zero position for all axes.

- For example 1, the axis assignment is arbitrary. In this example, this axis is assigned as –Z.
- For example 2, select axis 1 arbitrarily. Axis 2 must not be the same as axis 1 or its negative, because axis 2 is perpendicular to axis 1. In this example, axis 1 is assigned as -Y, and axis 2 is assigned as -Z.
- For example 3, select axis 1 arbitrarily. Axis 2 must not be the same as axis 1 or its negative, because axis 2 is perpendicular to axis 1 such as example 2. In this example, axis 1 is assigned as +X, and axis 2 is assigned as -Y.
- For example 4, select axis 1 arbitrarily. Select axis 2 and axis 3 in the same direction as each other, but not the same direction as axis 1 or its negative. In this example, axis 1 is assigned as +Y, axis 2 and 3 are assigned as -Z.

2.3 KINEMATICS PARAMETERS OF POSITIONER

In this section, Kinematics Parameters of Positioner are explained.

2.3.1 Kinematics Parameters of Positioner (A05B-2600-H896)

During Positioner (A05B-2600-H896) setup, if you selected a Known Kinematics type, you must enter axis offset information. Axis offset is the distance of each axis. In following figure, each axis is at zero position.

B-83484EN/03 2 POSITIONER SETTING

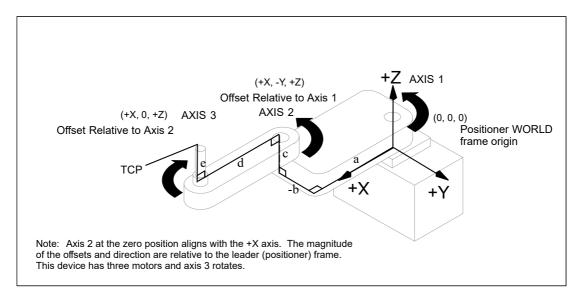


Figure 2.3.1 Axis offset for known kinematics types

For axis 1 of the positioner, the offset values should be:

- $\bullet \quad X = 0$
- $\bullet \quad Y = 0$
- \bullet Z = 0

For axis 2 of the positioner, the offset values should be:

- \bullet X = a
- $\bullet \quad Y = -b$
- \bullet Z = c

For axis 3 of the positioner, the offset values should be:

- \bullet X = d
- Y = 0
- \bullet Z = e

In this drawing, Positioner's TCP position is:

- $\bullet \quad X = a + d$
- $\bullet \quad Y = -b$
- $\bullet \quad Z = c + e$

2.3.2 Kinematics Parameters of General Positioner (A05B-2600-H874)

As for setting Kinematics Type of General Positioner (A05B-2600-H874), you should input Kinematics Parameters, DH Parameters when you select Known Kinematics.

Denavit-Hartenberg (D-H) Parameters

The Denavit-Hartenberg (D-H) parameters define the kinematic model of any positioner that works in coordinated motion with the robot. The common nomenclature that is used to define these parameters for a general device is shown in Figure 2.3.2 (a).

2 POSITIONER SETTING B-83484EN/03

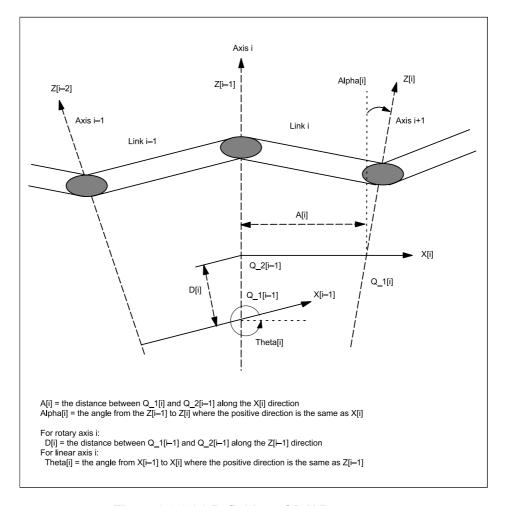


Figure 2.3.2 (a) Definition of D-H Parameters

DH Parameters are the parameters which signify the relative of the neighboring link frame. There are three kinds of DH Parameters of neighboring axis. There are d[], a[], and alpha[]. The link frames are set in every axis. Rotation vector is set as Z direction of the frame, and link direction is set as X direction of the frame basically. However, in fact, when the neighboring link frames are set as A and B, X and Z direct are set so that frame A and frame B are matched perfectly by the following procedure.

- **1.** Move d along the Z direction of the frame
- **2.** Move a along the X direction of the frame after (1)
- **3.** Rotate alpha about the X direction of the frame after (2)

The Z direction of the frame on the J1 axis is set as the J1 axis direction.

Original point of the frame on the J2 axis is set as the intersection point of J1 with J2, and Z direction is set as J2 axis direction. Original point of the frame on more than J3 axis is set as the intersection point of the present axis with the previous axis, and Z direction is set as the present axis direction.

For the configuration of a two-axis positioner where the axes are not orthogonal, you use two of the four parameters only:

• A[i]

This is the distance between axis 1 and 2 when the axes do not intersect.

• Alpha[i]

This is the angle between axis 1 and 2.

Figure 2.3.2 (b) and Figure 2.3.2 (c) show the possible configurations and meanings of the D-H parameters for a two-axis general positioner.

B-83484EN/03 2 POSITIONER SETTING

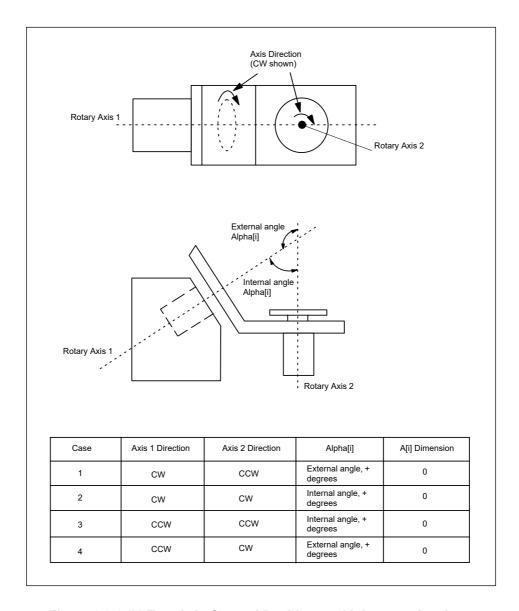


Figure 2.3.2 (b) Two-Axis General Positioner with Intersecting Axes

2 POSITIONER SETTING B-83484EN/03

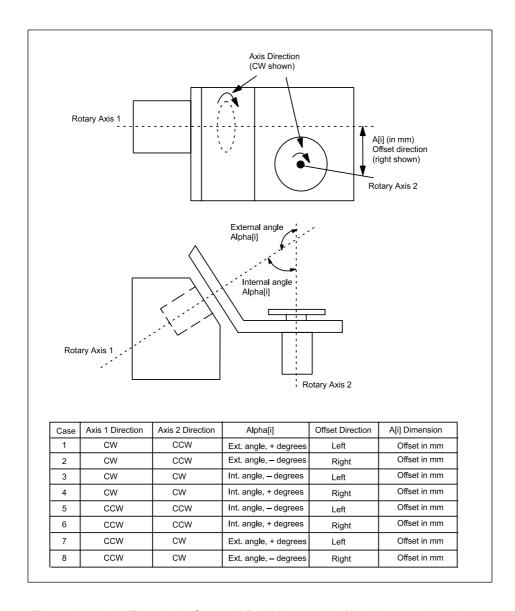


Figure 2.3.2 (c) Two-Axis General Positioner with Non-Intersecting Axes

B-83484EN/03 2 POSITIONER SETTING

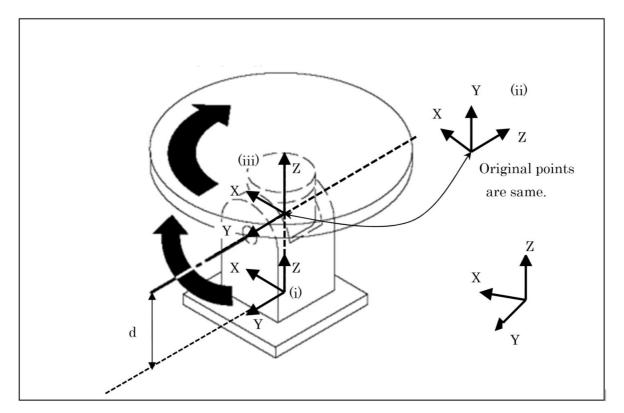


Figure 2.3.2 (d) Link frame of two axes positioner

This example describes the calculation of DH parameters as illustrated in Figure 2.3.2 (d).

At first, any position is set as World frame. In this example, (i) frame is set as World Frame. And, the frame of J1 axis is set so that the Z direction is the J1 axis direction. In this example, (ii) frame is set as the frame of J1 axis.

DH parameters are set so that (i) frame can transfer to (ii) frame.

- d[1] = d
- d[1] = d
- alpha[1] = 90

And, the frame of the J2 axis is set so that Original point is the intersection point of J1 with J2 axis, and the Z direction is the J2 axis direction. In this example, (iii) frame is set as the frame of J2 axis.

DH parameters are set so that (ii) frame can transfer to (iii) frame.

- d[1] = 0
- a[1] = 0
- alpha[1] = -90

2 POSITIONER SETTING B-83484EN/03

3 SETTING UP COORDINATED PAIRS

3.1 SETTING UP COORDINATED PAIRS OVERVIEW

After you have installed and set up the appropriate hardware and software, you must define specific details about the coordinated pairs (CD_pairs). A coordinated pair consists of one leader and one follower motion group that, together, perform coordinated motion.

Table 3.1 lists the motion group pairings that are available to define coordinated pairs. Each row in the table makes up a coordinated pair.

Leader Group(s)	Follower Group(s)	CD_pairs
One table	One robot	1 CD_pair
Two tables	One robot	2 CD_pairs
One table	One robot + one table (not coordinated)	1 CD_pair

Table 3.1 Coordinated Pair Configurations

NOTE

Multi-robot systems add additional CD_pair combinations. Certain combinations of groups are not supported as CD_pairs.

3.2 RESTRICTIONS AND GUIDELINES

When you select a coordinated pair, review the following restrictions and guidelines:

- Each motion group in a robotic system is either a leader or a follower (a group might not be used for coordinated motion).
- Coordinated motion in a robotic system allows you to have multiple leaders and multiple followers.
- A CD pair consists of a single leader and a single follower.
- A leader in one CD pair can be a leader in another CD pair with a different follower.
- A leader in one CD pair cannot be a follower in another CD pair.
- A follower in one CD_pair can be a follower in another CD_pair.
- Coordinated motion is supported for extended axes on leader and follower groups.
- Follower groups can be mounted to extended axes (such as on a swing arm, a track, or a combination. These extended axes must be added sequentially to the robot, starting with axis 7 connected to the robot, and following through the remaining connected extended axes. These must be *integrated rotary* or *integrated linear* axes.
- Do not mount a leader group to an extended axis. Instead make this axis 1 of the positioner group.
- Coordinated motion is not supported when the follower group is mounted on the leader group. Also, the leader group cannot be mounted on the follower group.

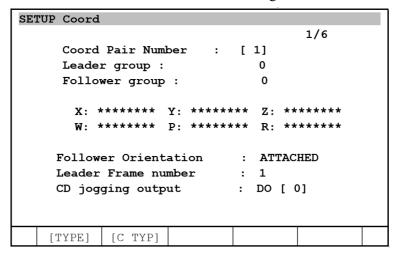
3.3 SELECTING CD_PAIRS

About this task

Use this task to select CD pairs.

Procedure

- 1. Press MENU.
- 2. Select SETUP.
- **3.** Press **F1**, [**TYPE**].
- **4.** Select **Coord**. You will see a screen similar to the following.



5. To display setup information for another pair, move the cursor to **Coord Pair Number** and type the CD_pair number.

NOTE

The group numbers you use depend on the number of groups defined and set up on your controller at installation. If they have been set up, motion groups 1-8 are available for coordinated motion leaders and followers.

- **6.** Move the cursor to **Leader group** and type the group number of the leader.
- **7.** Confirm the change:
 - To confirm the change, press **F4**, **YES**.
 - To cancel the change, press **F5**, **NO**.
- **8.** Move the cursor to **Follower Group** and type the group number of the follower.
- **9.** Confirm the change:
 - To confirm the change, press F4, YES.
 - To cancel the change, press **F5**, **NO**.

NOTE

If you change the leader or follower of an existing CD_pair, the calibration data will be set to zero. After the first calibration, the axis assignment can be changed at CTRL start. This will also cause calibration data to be set to zero.

B-83484EN/03 4 CALIBRATION

4 CALIBRATION

After you have set up the CD_pairs you will use (Chapter 3, SETTING UP COORDINATED PAIRS), you must calibrate each CD_pair. The kinematics type of the CD_pair leader group you set up during installation will determine the kind of calibration you must perform.

The kind of calibration you perform depends on the kinematics type you specified during leader group installation. Refer to Chapter 2, POSITIONER SETTING for more information.

Calibration

CD_pair calibration defines the relationship between the leader and follower, by finding the motion transformation from the follower group (robot) to the leader group (positioner). When you perform calibration, you establish the location of the leader origin with respect to the follower origin. In addition, for unknown kinematics cases, the kinematics of the leader are determined during calibration. Offset information is installed when the axes are installed for *known* type calibration.

The kinematics type, which was established when the leader group axis was installed, will determine the kind of calibration you must perform:

- Known four point for known kinematics types
- Known direct when previous calibration data is to be re-entered
- Unknown point for unknown kinematics types

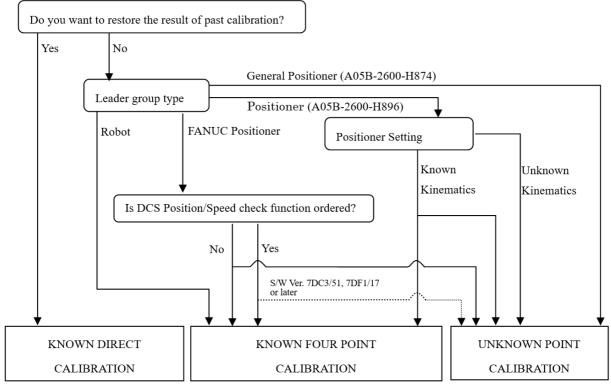


Figure 4 CD_Pair Calibration Types

NOTE

After you have calibrated a CD_pair, you do not need to change the calibration unless the relationship of the leader origin to follower origin changes, the CD_pair groups is changed, the axis type is changed, or the calibration type is changed (at a controlled start).

4 CALIBRATION B-83484EN/03

NOTE

After you have calibrated a CD_pair, you must perform a cold start for the data to take effect.

If you perform calibration manually, follow the procedure described in this chapter.

If you use a FANUC vision sensor to obtain calibration data automatically, refer to the *iRCalibration OPERATOR'S MANUAL (B-82784EN)*. In this case, you will need additional hardware such as a camera and the software option *iRCalibration* Vision Multi-Cal (A05B-2600-J993).

If the system configuration matches either case below, don't perform **known four point calibration** if you have done **unknown point calibration**. If you need to perform **known four point calibration** in such a situation, you first need to initialize the motion parameters at the robot maintenance menu.

Cases:

- When you selected **Known Kinematics** for Positioner (A05B-2600-H896)
- Software version is 7DC3/50, 7DF1/16 or earlier for a FANUC Positioner
- Software version is 7DC3/51, 7DF1/17 or later and also DCS Cartesian Position/Speed Check Function is not installed for a FANUC Positioner

4.1 KNOWN FOUR POINT CALIBRATION VS UNKNOWN POINT CALIBRATION

When the leader group is a FANUC positioner or a positioner (A05B-2600-H896), you can use either the Known four-point calibration or the unknown-point calibration.

Please refer to the following characteristics to choose which one to use.

Known four point calibration characteristics

- The calibration procedure is the same as the procedure for setting a user coordinate system.
- The positioner TCP must be set. That is, you must know the exact position of the pointer tip to be installed in the positioner.
- The X and Y axis directions of the positioner must be taught. In other words, the positioner mechanical unit must have characteristic points that indicates them.
- Calibration accuracy depends on the accuracy of the positioner/robot TCP and that of each four taught points.
- When a ROBOGUIDE workcell is created from a backup, it has an advantage that the positioner would be placed on the workcell just as it is in a real system.
- In general, you have to do this calibration at a position away from where the robot is actually working. If this is assumed to be a cause of inaccuracy in coordinated motion, use the Unknown point calibration instead.

Unknown point calibration characteristics

- Three teaching points are required for each axis of the positioner.
- No need to set the positioner TCP.
- Calibration accuracy depends on the accuracy of the robot TCP and accuracy of the three taught points for each axis.

B-83484EN/03 4 CALIBRATION

• In general, by performing this calibration near the actual working area of the robot, you can achieve a good accuracy of coordinated motion in that area. Good accuracy may not be achieved at a distance from the calibrated position.

4.2 KNOWN FOUR POINT CALIBRATION

Known four point calibration is the recommended method for CD_pairs with a known kinematics leader group. Calibration determines the relationship of the follower to the leader origin, but, in most cases, the origin of the leader group cannot be touched directly by the follower group (robot). This method is also used when it is not possible to teach the x direction and y direction positions near the leader group TCP.

Known four point calibration provides a method for calibrating the CD_pair without touching the leader's origin point compared to three-point frame setup. Known four-point calibration uses three taught positions to set the positioner frame alignment, and a fourth position to set the leader TCP location. The transformation from robot origin to positioner origin will be calculated based on the TCP information plus the axis offset data. The three frame positions must reflect the axis alignment selected during Positioner installation.

In known four point calibration, you define the following points:

- Leader's TCP.
- Orient origin point, which is a "temporary" origin point that can be located at any position within the follower's working motion range.
- X direction point, which aligns with the position X axis.
- Y direction point, which aligns with the position Y axis.

The second, third, and fourth points are used to determine a temporary leader frame. This frame is translated to the TCP position of the leader, which is then translated to the leader origin via the leader axis offset values.

For the definition of the world frame of FANUC positioners, see Section 4.2.2, World Frame of FANUC Positioners.

4.2.1 Known Four Point Calibration Guidelines

When you perform known four point calibration, use the following guidelines:

- Use this method only for known kinematics leader devices.
- The axis direction selected for each axis during the installation of the positioner axes and the axes'
 offsets will determine the way that the follower (robot) motion will coordinate with the leader
 (positioner) motion.
- The method will set only the leader (positioner) frame the alignment is independent of the robot world frame alignment and will calculate the origin point of the positioner frame in robot space (relative to the follower UFRAME).
- Correct alignment of the leader frame is essential. The positioner axis whose axis direction was assigned as +x at axis installation should coincide with (or be parallel to) the +x axis in the positioner frame.

The frame positions you define relative to the Orient Origin Point for the X Direction Point at this time should be aligned exactly with the x-axis of the leader group; Y Direction Point corresponds to the positive y direction (or axis). This will ensure that a +x motion of the leader (positioner) will result in the correct follower (robot) motion in the leader's moving frame. See Figure 4.2.1.

4 CALIBRATION B-83484EN/03

NOTE

The positioner +z direction must be perpendicular to the +x - +y plane formed by the X and Y Direction Points.

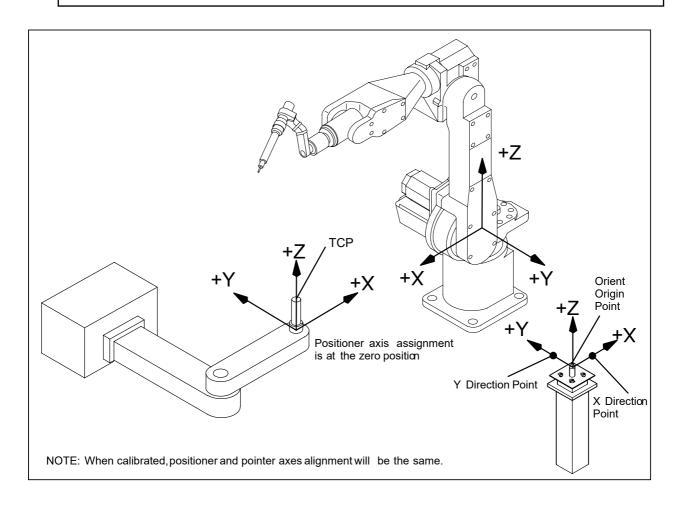


Figure 4.2.1 Defining Points

⚠ CAUTION

Be sure to align the Orient Origin, X Direction, and Y Direction positions carefully. Otherwise, the calculated calibration frame will be incorrect and the coordinated motion will not be accurate.

4.2.2 World Frame of FANUC Positioners

FANUC 1-axis Positioners

FANUC 1-axis Positioners have known kinematics. Known Four-Point Calibration can be used. Figure 4.2.2 (a) through Figure 4.2.2 (c) shows diagrams of the various FANUC 1-axis Positioners with their Faceplate (or TCP) coordinates. Please refer to this TCP frame when using the *Known Four Point Calibration* method.

B-83484EN/03 4 CALIBRATION

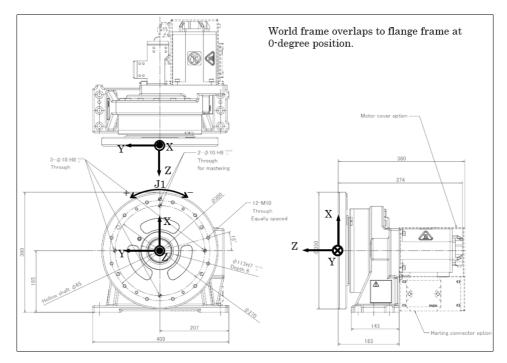


Figure 4.2.2 (a) 300kg/500kg payload 1-axis positioner (Hollow type) world frame and flange frame

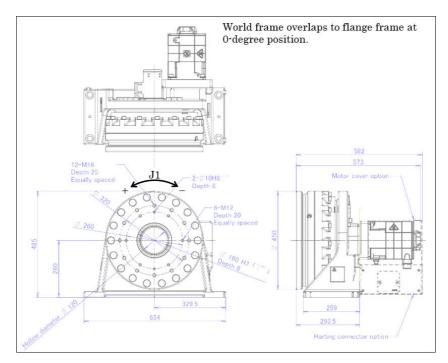


Figure 4.2.2 (b) 1000kg/1500kg payload 1-axis positioner (Hollow type) world frame and flange frame

4 CALIBRATION B-83484EN/03

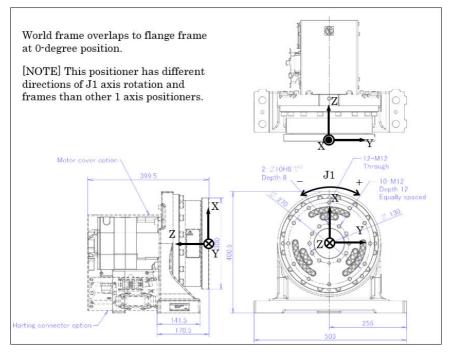


Figure 4.2.2 (c) 1000kg/1500kg payload 1-axis positioner (Compact type) world frame and flange frame

ARC Positioner (H871)

The ARC Positioner has known kinematics. Known Four-Point Calibration can be used. Figure 4.2.2 (d) shows a diagram of the ARC Positioner with its Faceplate (or TCP) coordinate. Please refer to this TCP frame when using the *Known Four Point Calibration* method.

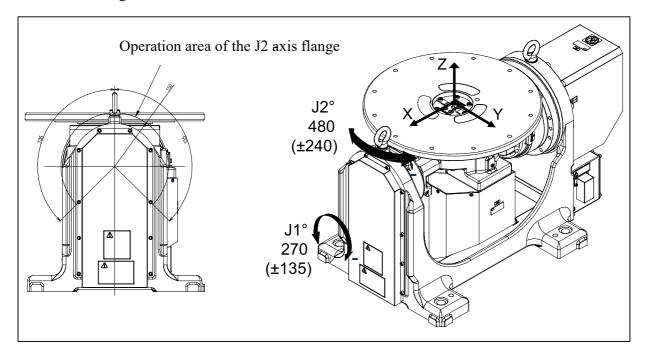


Figure 4.2.2 (d) Arc Positioner TCP Frame

B-83484EN/03 4 CALIBRATION

4.2.3 Known Four Point Calibration Procedure

About this task

Use this procedure to perform four point calibration.

Before you begin

- The follower group and leader group have been mastered and calibrated.
- Axes in the leader group must be either parallel or perpendicular to each other.
- The selection of *axis direction* for the multiple-axis devices must be consistent with the right-hand rule. (Section 2.2, AXIS ASSIGNMENT TO POSITIONER WORLD FRAME)
- The CD pair has been set up (Chapter 3, SETTING UP COORDINATED PAIRS).

Procedure

- 1. Press MENU.
- 2. Select SETUP.
- 3. Press F1, [TYPE].
- 4. Select Coord.
- **5.** Press **F3**, [C_TYPE].
- 6. Select Known 4 Pt.

You will see a screen similar to the following.

NOTE

If you indicated unknown kinematics during installation, you cannot select Known 4 Pt or Known Direct for C_TYPE.

7. Define the Leader's TCP Point: (Figure 4.2.1)

NOTE

The offset that was installed for your last axis during hardware setup of the leader group is the point you need to touch during TCP Point recording.

- a) Move the cursor to Leader's TCP Point.
- b) Jog the follower only, and touch the follower TCP to the leader TCP.

4 CALIBRATION B-83484EN/03

NOTE

The leader frame TCP and the follower tool frame must be defined accurately. Torch orientation is not critical when recording this position.

c) Press and hold SHIFT and press F5, RECORD.

UNINIT is changed to RECORDED.

- **8.** Define the **Orient Origin Point**: (Figure 4.2.1)
 - a) Move the cursor to Orient Origin Point.

NOTE

Jog only the follower in Step 8 (b).

b) Jog the follower (robot) to a position that allows the other calibration positions to be set (point 3, **X Direction Point**, and point 4, **Y Direction Point**).

This is the temporary origin point.

c) Press and hold SHIFT and press F5, RECORD.

UNINIT is changed to RECORDED.

9. Define the **X Direction Point**: (Figure 4.2.1)

NOTE

The +x direction is defined by the vector starting at the Orient Origin Point and going through the X Direction Point.

a) Move the cursor to X Direction Point.

NOTE

Jog only the follower in Step 9 (b).

- b) Jog the follower (robot) along (or parallel to) the x-axis of the positioner.
- c) Press and hold SHIFT and press F5, RECORD.

UNINIT is changed to RECORDED.

- **10.** Define the Y Direction Point: (Figure 4.2.1)
 - a) Move the cursor to Y Direction Point.

NOTE

Jog only the follower in Step 10 (b) and Step 10 (c).

- b) Jog the follower TCP to the **Orient Origin Point**.
- c) Jog the follower to a position along (parallel to) the leader x-y plane in the positive y-axis of the leader frame.
- d) Press and hold SHIFT and press F5, RECORD.
- **11.** Press **F3**, **EXEC**, to execute the calibration.

The leader coordinated frame is displayed in the SETUP Coord screen when this calculation is complete.

12. Perform a cold start.

NOTE

If the calibration was not successful, or if a calibration message is displayed on the prompt line of the teach pendant screen, refer to Table 10.2.

4.3 KNOWN DIRECT CALIBRATION

About this task

Known direct calibration is used for systems that have known kinematics. This is useful if you need to use previously defined calibration information, such as when a system software upgrade is performed. Known direct calibration involves entering the following information manually into the calibration screen:

- The Cartesian position of the leader origin in the robot WORLD frame
- Any frame rotations required to align the leader frame with the follower frame

For known direct calibration to be successful, you must have entered accurate offset values during the installation of the leader group axes.

Use this procedure to perform both known direct calibration for positioners and known direct calibration for general positioners.

Before you begin

- The follower group and leader group have been mastered and calibrated.
- The leader group hardware configuration is correct.
- The CD pair has been set up (Chapter 3, SETTING UP COORDINATED PAIRS).
- The selection of "axis direction" for the multiple-axis devices must be consistent with threedimensional right hand rule conventions for axis labeling. (Not for General Positioner)
- The follower and the leader must be positioned in the workcell exactly. The relationship of the leader origin and the follower origin, including frame rotation planes, must be calculated precisely.

or

Previous calibration data is known and is to be entered manually.

Procedure

1. If you are using known direct calibration to restore calibration data (for example, after reloading system software), set the following system variables to their previous values:

For General Positioners with Rotary axes:

- \$param_group[leader_group].\$dh_a[leader_axis]
- \$param group[leader group].\$dh alpha[leader axis]
- \$param_group[leader_group].\$dh_d[leader_axis]

For General Positioners with Linear axes:

- \$param group[leader group].\$dh a[leader axis]
- \$param group[leader group].\$dh alpha[leader axis]
- \$param group[leader group].\$dh theta[leader axis]

For Positioners:

- \$SCR GRP[leader group].\$ofst[leader axis].\$X
- \$SCR GRP[leader group].\$ofst[leader axis].\$Y
- \$SCR GRP[leader group].\$ofst[leader axis].\$Z
- 2. Press MENU.
- 3. Select SETUP.
- **4.** Press **F1**, [**TYPE**].
- 5. Select Coord.
- 6. Press F2, [C TYPE].
- 7. Select **Known Direct** and press **ENTER**. You will see a screen similar to the following.

```
SETUP Coord
Known type calibration
                                 Coord Pair: 1
Group Number Leader: 3
                                 Follower:
                0.000 Z:
     0.000 Y:
                           0.000
      0.000 P:
                0.000 R:
                           0.000
X:
                              0.0000
                              0.0000
Y:
                              0.0000
 Z:
                              0.0000
W:
                              0.0000
 P:
                              0.0000
R:
```

- **8.** Move the cursor to **X**, type the x value of the leader frame origin point, and press **ENTER**.
- **9.** Move the cursor to **Y**, type the y value of the leader frame origin point, and press **ENTER**.
- **10.** Move the cursor to **Z**, type the z value of the leader frame origin point, and press **ENTER**.
- **11.** Move the cursor to **W**, type the rotation about the follower x axis that the leader frame has relative to the follower frame, and press **ENTER**.
- **12.** Move the cursor to **P**, type the rotation about the follower y axis that the leader frame has relative to the follower frame, and press **ENTER**.
- **13.** Move the cursor to **R**, type the rotation about the follower z axis that the leader frame has relative to the follower frame, and press **ENTER**.
- **14.** When you have set all of the values, press **F3**, **EXEC**, to execute the calibration.

The leader coordinated frame is displayed in the SETUP Coord screen when this calculation is complete.

4.4 UNKNOWN POINT CALIBRATION FOR POSITIONERS (INCLUDING GENERAL POSITIONERS)

Unknown point calibration is used for all leader/follower pairs in which the leader group does not have known kinematics. Most systems use unknown kinematics and unknown calibration type.

Unknown kinematics type is used for turntables or general positioners for which arm length(s) and D-H parameters are not known, or are not known accurately. Unknown point calibration is typically used for all single-axis tables, multiple-axis tables, and linear or linear/rotary positioners.

Calibration is required for each axis of an unknown kinematics device:

- Three points are defined on the circumference of a circle that is perpendicular to the axis of rotation.
- For linear motion axes, two points are taught along the line of motion.

NOTE

For all FANUC positioners, the the *Known Four Point Calibration* method may be used (refer to Section 4.2, KNOWN FOUR POINT CALIBRATION). However, *Unknown Point Calibration* may also be used.

Figure 4.4 (a) and Figure 4.4 (b) show examples of rotary and linear axis unknown kinematics devices that are used as leaders in coordinated motion.

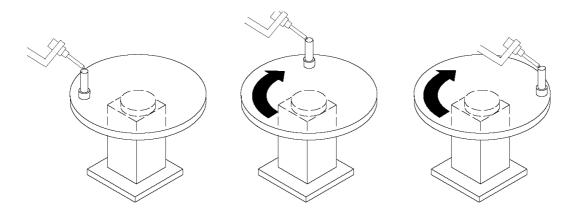


Figure 4.4 (a) Rotary axis calibration

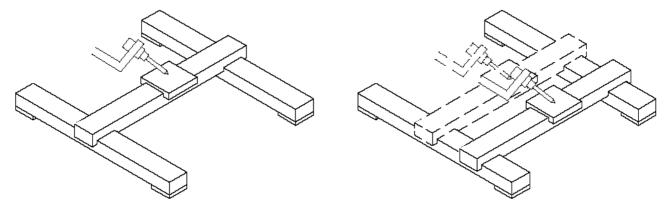


Figure 4.4 (b) Linear axis calibration

Use Section 4.4.3, Unknown Point Calibration for a Rotary Axis to perform unknown point calibration for a rotary axis. Use Section 4.4.4, Unknown Point Calibration for a Linear Axis to perform unknown

point calibration for a linear axis. Use both Section 4.4.3, Unknown Point Calibration for a Rotary Axis and Section 4.4.4, Unknown Point Calibration for a Linear Axis for general positioners with linear and rotary axes.

Conditions for Calibration

Before you perform unknown point calibration, the following conditions must be met:

- The number, direction, and order of axes for the leader group is set and known.
- The leader group hardware configuration is correct.
- The leader frame alignment has been determined. In calibration, a frame will be defined for the leader group. The direction of the axes of the leader frame does not depend on the axis alignment of the follower (robot).
- Mastering and calibration of the leader and follower groups has been completed.
- The CD pair has been set up (Chapter 3, SETTING UP COORDINATED PAIRS).
- The tool frame of the follower group has been defined.
- A mark or pointer has been placed on the last axis of the leader (positioner) device. This pointer reference must be in the plane of rotation of the last axis, level with the surface (on the table top, for example).

4.4.1 ArcTool Tool Frame Six Point Method

Before you begin

NOTE

You can use *i*HMI Guides to perform a similar procedure.

⚠ WARNING

If you are setting up a new frame, make sure that all frame data is zero or uninitialized before you record any positions. Press **F4**, **CLEAR**, to clear frame data.

If you are modifying an existing frame, make sure that all frame data is set the way you want before you change it.

Otherwise, you could injure personnel or damage equipment.

- Make sure that the weld wire stickout length is correct for welding. Typically this is 1/2" 3/4" (12.5mm to 19mm).
- The robot is at the reference position with the TCP (wire tip) touching a pointer tip.

Procedure

- 1. Press MENU.
- 2. Select SETUP.
- **3.** Press **F1**, [**TYPE**].
- 4. Select Frames.

5. To choose the motion group for the frame you are setting up a Multi-Arm controller, press **F3**, **[OTHER]**, and select the group you want. The default motion group is Group 1.

NOTE

The jog group indicated on the status line does not select the motion group in the SETUP Frames Tool screen. Make sure that the jog frame is set to the Tool frame number.

- **6.** If the jog group is not set to the motion group you want to set up:
 - a) Press FCTN, and select Change Group to toggle to the next motion group.
 - b) Press **SHIFT** and **COORD**, and scroll to **Group**, then type the number of the motion group you want to jog.
- 7. If tool frames are not displayed, press F3, [OTHER], and select Tool Frame. If F3, [OTHER], is not displayed, press PREV.
- 8. Press F2, DETAIL.

NOTE

TorchMate adjustment is frame specific. Make sure that your weld programs also use the frame you select in Step 9.

- **9.** To select a frame
 - a) Press F3, FRAME.
 - b) Type the desired frame number.
 - c) Press ENTER.
- **10.** Press **F2**, [METHOD].
- 11. Select Six Point (XZ). You will see a screen similar to the following.

```
SETUP Frames
 Tool Frame Setup/ Six Point
 Frame Number: 1
   X: 0.0 Y: 0.0 W: 0.0
                            Z: 0.0
                             R: 0.0
  Comment: **********
  Approach point 1:
                             UNINIT
  Approach point 2:
Approach point 3:
                            UNTNTT
                            UNINIT
  Orient Origin Point:
                            UNINIT
  X direction Point:
                            UNINIT
                      UNINIT
  Z Direction Point:
 Active TOOL $MNUTOOLNUM[1]=1
```

- **12.** To add a comment
 - a) Move the cursor to the comment line and press ENTER.
 - b) Select a method of naming the comment (Word, Upper Case, or Lower Case).
 - c) Press the appropriate function keys to enter the comment.
 - d) When you are finished, press ENTER.

13. Record Approach point 1 and the Orient Origin Point:

- a) Make sure that the robot is at the reference position with the torch parallel to the z-axis, and that the tip of the wire is touching the tip of the pointer.
- b) Move the cursor to **Approach point 1**.
- c) Press and hold the **SHIFT** key and press **F5**, **RECORD**.
- d) Move the cursor to **Orient Origin Point**.
- e) Press and hold the SHIFT key and press F5, RECORD.

14. Define the **X Direction Point**:

- a) Move the cursor to X Direction Point.
- b) Change the jog coordinate system to WORLD.
- c) Jog the robot along the +X direction by at least 250 mm.
- d) Press and hold the SHIFT key and press F5, RECORD.
- e) Move the cursor to Orient Origin Point.

⚠ WARNING

In Step 14 (f), DO NOT press **SHIFT** and **FWD**. Otherwise, the robot will execute the currently selected program, causing unexpected results.

f) Press and hold the **SHIFT** key and press **F4**, **MOVE_TO**, until the TCP has returned back to the touch block pointer tip.

15. Define the **Z** Direction Point:

- a) Move the cursor to **Z Direction Point**.
- b) Change the jog coordinate system to WORLD.
- c) Jog the robot along the +z direction by at least 250 mm.
- d) Press and hold the **SHIFT** key and press **F5**, **RECORD**.
- e) Move the cursor to **Orient Origin Point**.

⚠ WARNING

In Step 15 (f), DO NOT press **SHIFT** and **FWD**. Otherwise, the robot will execute the currently selected program, causing unexpected results.

- f) Press and hold the **SHIFT** key and press **F4**, **MOVE_TO**, until the TCP has returned back to the touch block pointer tip.
- **16.** Record Approach point 2 (see Figure 4.4.1 (a)):

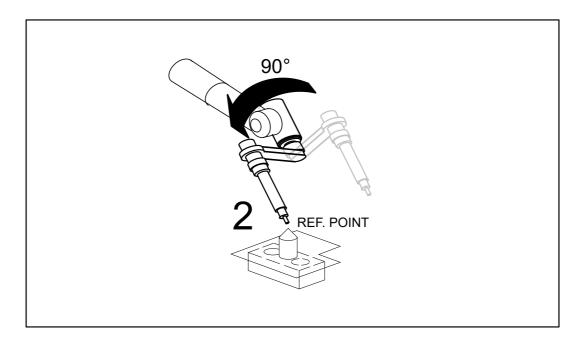


Figure 4.4.1 (a) Approach point 2

- a) Jog the robot in WORLD +z approximately 50 mm.
- b) Move the cursor to **Approach point 2**.
- c) Rotate axis 6 (faceplate) in JOINT coordinate system at least 90 tool coordinates.
- d) Jog the robot in WORLD coordinate system (using X, Y, and Z axes only) so that the TCP touches the touch block pointer tip.
- e) Press and hold the SHIFT key and press F5, RECORD.
- f) Jog the robot in WORLD +z approximately 50 mm.
- g) Move the cursor to **Orient Origin Point**.

⚠ WARNING

In Step 16 (h), DO NOT press **SHIFT** and **FWD**. Otherwise, the robot will execute the currently selected program, causing unexpected results.

h) Press and hold the **SHIFT** key, and press **F4**, **MOVE_TO**, until the TCP has returned back to the touch block pointer tip.

17. Record Approach point 3:

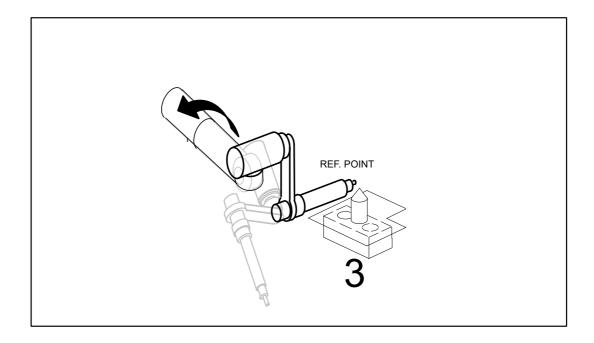


Figure 4.4.1 (b) Approach Point 3

- a) Jog the robot in WORLD +z approximately 50 mm.
- b) Move the cursor to **Approach point 3**.
- c) Rotate the TCP about the WORLD +x-axis (w) by approximately 35° to 90°.
- d) Jog the robot in WORLD coordinate system (using the X, Y, and Z axes only) so that the TCP touches the touch block pointer tip.
- e) Press and hold the SHIFT key and press F5, RECORD.
- f) Jog the robot in WORLD +z approximately 50 mm.
- g) Move the cursor to Orient Origin Point.

⚠ WARNING

In Step 17 (h), DO NOT press **SHIFT** and **FWD**. Otherwise, the robot will execute the currently selected program, causing unexpected results.

h) Press and hold the **SHIFT** key and press **F4**, **MOVE_TO**, until the TCP has returned back to the touch block pointer tip.

NOTE

Approach points will be recorded incorrectly if they point directly at each other. See Figure 4.4.1 (c).

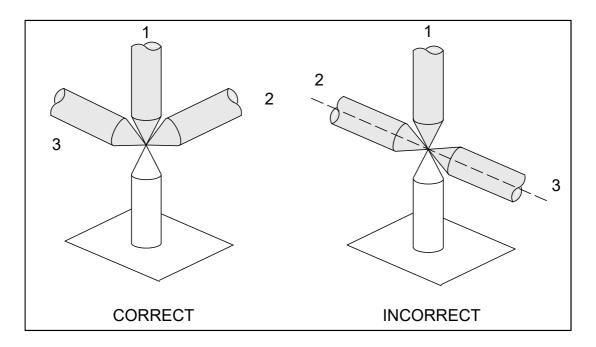
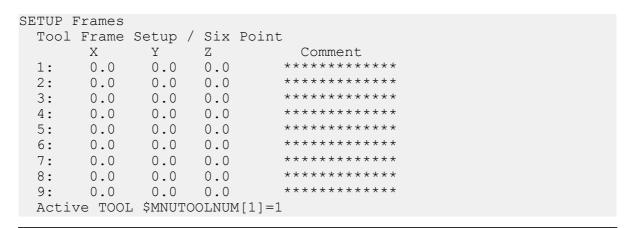


Figure 4.4.1 (c) Teaching Approach Points

- i) The Six Point Method of setting up a new tool frame is now complete.
- **18.** To move to a recorded position, scroll to any of the six positions, press and hold the **SHIFT** key, and press **F4**, **MOVE_TO**.
- **19.** To display the settings for all the frames, press **PREV** repeatedly until you see a screen similar to the following.



⚠ CAUTION

Step 20 erases TCP data. Do not perform Step 20 unless you want to erase the TCP data. Otherwise, you will have to re-record the TCP data.

- **20.** To set the numerical values to zero, move the cursor to the frame number and press **F4**, **CLEAR**.
- **21.** To select the tool frame to use, press **F5**, **SETIND**. Type the number of the tool frame you want and press **ENTER**.

When you are finished setting the frame configuration, save the information to a default device (MC:) or write down the values so that you can reload the configuration data if necessary. Otherwise, if the configuration is altered, you will have no record of it.

- **22.** To check that the tool frame has been defined properly:
 - a) Move the cursor to the **Orient Origin Point**.
 - b) Press and hold the **SHIFT** key and press **F4**, **MOVE_TO**, until the TCP has returned back to the touch block pointer tip.
 - c) Press COORD until TOOL is displayed.
 - d) Jog about the +x (w), +y (p), or +z (r) axes.
 - e) Determine whether the TCP remains close to the pointer tip while jogging, as shown in Figure 4.4.1 (d)

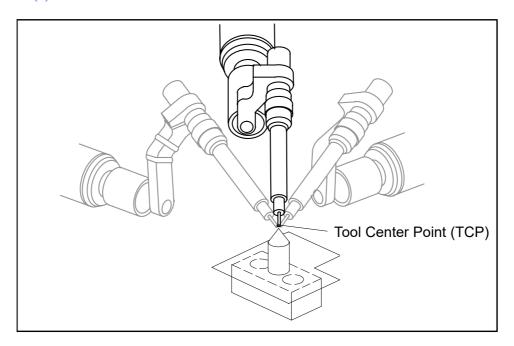


Figure 4.4.1 (d) Verifying the Tool Frame

f) If the TCP does not remain close to the pointer tip, repeat ArcTool Tool Frame Six Point Method to redefine the tool frame.

4.4.2 Calibration Type Selection

If Software version is more than V8.30P/07 (7DC1/07), the leader group is General Positioner (A05B-2600-H874), and the following conditions are met, the calibration type can be selected.

Conditions

- The leader group is General Positioner.
- J1 of General Positioner is rotary axis.
- There are more than two coordinated pairs of which the leader group is same General Positioner.

• The coordinated pair of General Positioner and other robot has been already calibrated in unknown point calibration.

When the upper conditions are met, the following screen is displayed after unknown point calibration is executed.

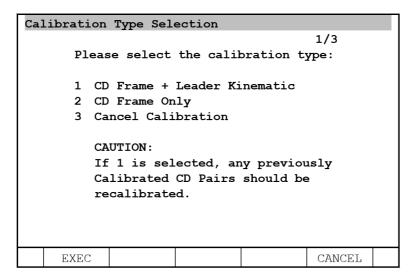


Figure 4.4.2 (a) Calibration Type Selection screen

Selection Method

If some coordinated pairs of one Positioner and some robots are used, select choice 2. If kinematics parameters of Positioner are calibrated and the coordinated pairs, which have been already calibrated, are not used, select choice 1.

- Choice 1 is unknown point calibration which is the same as ordinary. Because kinematics parameters of Positioner are updated, calibrate all the coordinated pairs of which the leader group is General Positioner and which have been already calibrated in unknown point calibration.
- Choice 2 is unknown point calibration which does not update kinematics parameters of Positioner and update the coordinate frame. If this choice is selected, you need not calibrate all the coordinate pairs of which the leader group is General Positioner and which have already been calibrated in unknown point calibration.
- Choice 3 cancels this calibration.

Explanation

The coordinated frame and kinematics parameters, DH parameters, are calibrated at the same time in unknown point calibration of which the leader group is General Positioner. If there are more than two coordinated pairs of which the leader group is the same General Positioner, and each pairs are calibrated, DH parameters of General Positioner are calibrated and updated more than twice. In other words, the coordinate frames of all the pairs other than last calibrated pair are wrong because DH parameters have been updated.

In order to avoid this problem, if there are more than two coordinated pairs of which the leader group is the same General Positioner, and one pair has already been calibrated, select the two following methods when the other pairs are calibrated.

- Calibrate only the coordinate frame so that DH parameters are not updated.
- Calibrate both the coordinate frame and DH parameters.

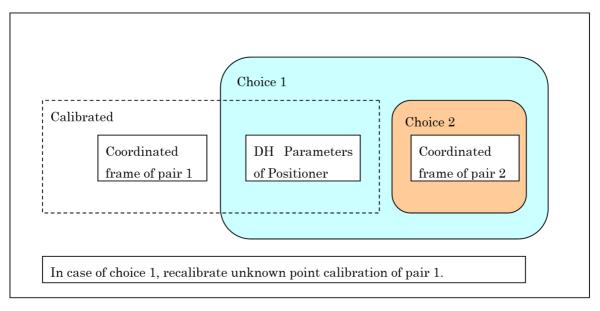


Figure 4.4.2 (b) Calibration Type Selection

4.4.3 Unknown Point Calibration for a Rotary Axis

Before you begin

- The number of the positioner and order of axes for the leader group is set and known.
- Mastering and calibration of the leader and follower groups has been completed.
- The tool frame and user frame (if applicable) of the follower group have been defined.
- A mark or pointer has been placed on the last axis of the leader device (positioner).
- The CD pair has been set up (Chapter 3, SETTING UP COORDINATED PAIRS).

Hint It is recommended that you define the positions you use in the calibration in a program so that the program can be executed later in the event that the CD_pair calibration data is lost. Add some JOINT motion instructions between the calibration positions so that the robot does not hit the positioner. A typical calibration program has 6 to 8 positions per axis. After you have created this program, you can execute the program in single step mode while recording the CD_pair calibration positions in the coordinate calibration screen on the SETUP menu. Each axis will be calibrated. Note that all axes, except the one being calibrated, must be at their zero positions.

NOTE

When you calibrate axes, you must start at the base axis and finish with the tabletop or work surface axis. See Figure 4.4.3 (a).

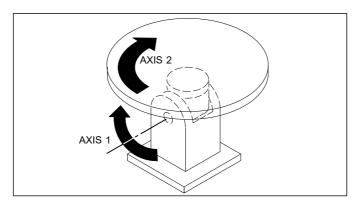


Figure 4.4.3 (a) Unknown Point Calibration Overview for a Rotary Axis

Procedure

- 1. Press MENU.
- 2. Select SETUP.
- **3.** Press **F1**, [**TYPE**].
- 4. Select Coord.
- **5.** Press **F2**, **[C TYPE]**. You will see a screen similar to the following.

```
SETUP Coord
                           Coord Pair: 1
Unknown type calibration
Group Number Leader: 3
                            Follower:
           Y: 0.000
 X: 0.000
                            Z: 0.000
 W: 0.000
             P: 0.000
                               0.000
                           R:
                            (Total:2)
Axis Number:
                         1
Axis Type:
                         ROTARY
Axis Direction:
                         +Z
Point 1:
                         UNINIT
 Point 2:
                         UNINIT
 Point 3:
                         UNINIT
```

NOTE

For general positioner, axis direction will be determined automatically as the +z direction of an attached frame. This value can not be changed.

- **6.** Move all axes of the leader to their zero positions.
- 7. Move the cursor to Axis Number and enter the number of the axis you are calibrating.
- **8.** Move the cursor to **Axis Direction** and change it if necessary.

⚠ CAUTION

When recording calibration points for a positioner, move only that axis when performing calibration on multi-group positioners. The other axes of the positioner must remain at their zero positions, otherwise, an incorrect calibration can occur. The follower (robot) can be moved freely during calibration.

9. Record **Point 1**:

- a) Move the cursor to **Point 1**.
- b) Jog the follower (robot) so that the pointing device touches the marked position on the leader. See Figure 4.4.3 (b).

c) Press and hold SHIFT and press F5, RECORD.

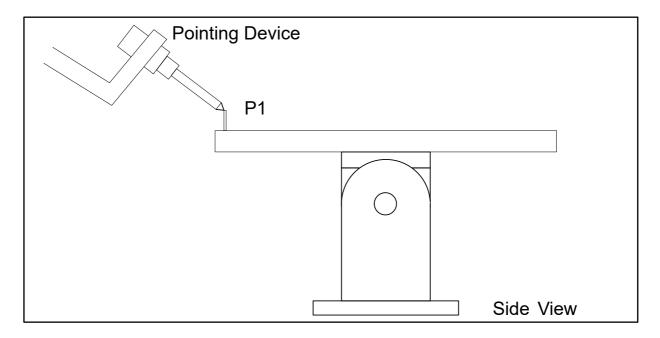


Figure 4.4.3 (b) Defining Point 1 for Axis 1

NOTE

For the next two points, if the total positive rotation is less than 60°, split the available angular motion into two portions of roughly equal size. Very small angular moves of less than 20° might yield less accurate calibration information.

10. Record **Point 2**: (Figure 4.4.3 (c))

- a) Move the cursor to Point 2.
- b) Jog the first axis only of the leader from 30 to 90 degrees in the positive direction.
- c) Jog the follower (robot) so that the pointing device touches the marked position on the leader.
- d) Press and hold SHIFT and press F5, RECORD.

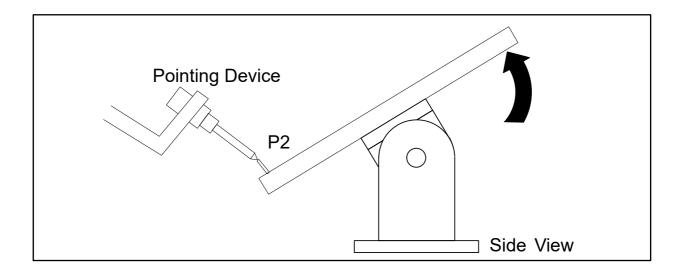


Figure 4.4.3 (c) Defining Point 2 for Axis 1

- **11.** Record **Point 3**: (Figure 4.4.3 (d))
 - a) Move the cursor to **Point 3**.
 - b) Jog the first axis only of the leader another 30 to 90 degrees in the positive direction.
 - c) Jog the follower (robot) so that the pointing device touches the marked position on the leader.
 - d) Press and hold SHIFT and press F5, RECORD.

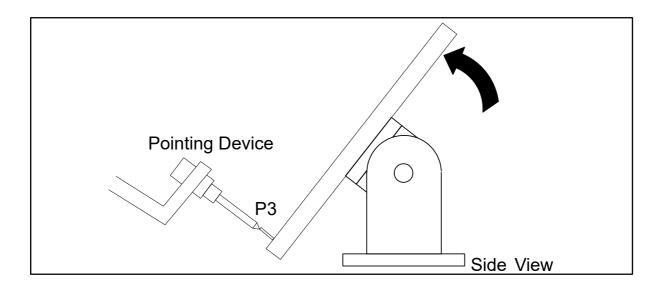


Figure 4.4.3 (d) Defining Point 3 for Axis 1

- **12.** If your positioner has a single axis, press **F3**, **EXEC**, to complete the CD_pair calibration. Otherwise, go to Step 13.
- **13.** Record **Point 1** (second axis):

- a) Move the cursor to **Point 1**.
- b) Move the robot to **Point 1** you defined in Step 9.

You can do this as follows: Move the robot clear of the positioner, change to Group 2, press **SHIFT** and **F4**, **MOVE_TO**. This moves Group 2 to P[1]. Change to Group 1, press **SHIFT** and **F4**, **MOVE_TO**.

Make sure axes 1 and 2 are each in the zero position. See Figure 4.4.3 (e).

NOTE

If you have written a calibration teach pendant program, move the cursor to the position that is the Point 1 position, and press **SHIFT** and **FWD**.

NOTE

Use the same pointer or reference mark for all axes.

c) Press and hold SHIFT and press F5, RECORD.

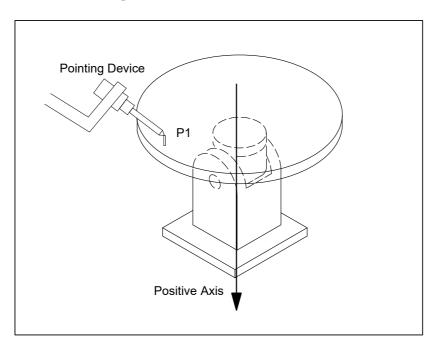


Figure 4.4.3 (e) Defining Point 1 for Axis 2

- **14.** Record **Point 2** (second axis): (Figure 4.4.3 (f))
 - a) Move the cursor to Point 2.
 - b) Jog the second axis only of the leader from 30 to 90 degrees in the positive direction.
 - c) Jog the follower (robot) so that the pointing device touches the marked position on the leader.
 - d) Press and hold SHIFT and press F5, RECORD.

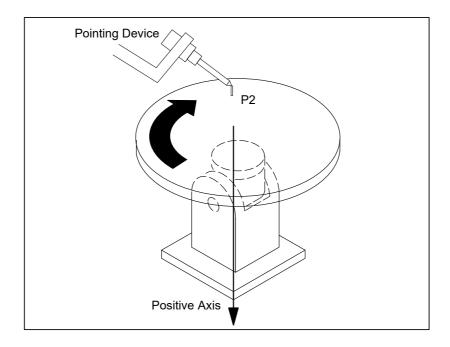


Figure 4.4.3 (f) Defining Point 2 for Axis 2

- **15.** Record **Point 3** (second axis): (Figure 4.4.3 (g))
 - a) Move the cursor to **Point 3**.
 - b) Jog the second axis only of the leader another 30 to 90 degrees in the positive direction.
 - c) Jog the follower (robot) so that the pointing device touches the marked position on the leader.
 - d) Press and hold SHIFT and press F5, RECORD.

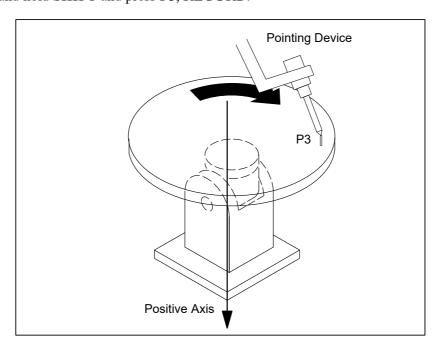


Figure 4.4.3 (g) Defining Point 3 for Axis 2

- **16.** Repeat Step 6 through Step 12 for all of the rotary axes of the positioner.
- **17.** Perform Section 4.4.4, Unknown Point Calibration for a Linear Axis for all of the linear axes of the positioner.

18. When all of the axes (rotary and linear) have been calibrated, press **F3**, **EXEC**, to execute the calibration. The leader coordinated frame is displayed in the SETUP Coord screen when this calculation is complete.

19. Turn off the controller and then turn it on again to enable this data for system use.

NOTE

If the calibration was not successful, or if a calibration message is displayed on the prompt line of the teach pendant screen, refer to Table 10.2.

NOTE

If Software version is later than V8.10P/07 (7DC1/07) and the leader group is General Positioner (A05B-2600-H874), Calibration Type Selection can be displayed when **F3**, **[EXEC]**, is pressed. Refer to Section 4.4.2, Calibration Type Selection for the selection method.

4.4.4 Unknown Point Calibration for a Linear Axis

Before you begin

NOTE

When you calibrate axes, you must start at the base axis and finish with the tabletop or work surface axis. See Figure 4.4.4 (a).

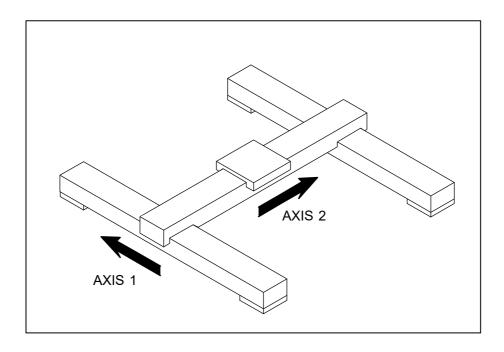


Figure 4.4.4 (a) Unknown Point Calibration Overview for a Linear Axis

Procedure

- 1. Press MENU.
- 2. Select SETUP.
- **3.** Press **F1**, [**TYPE**].
- 4. Select Coord.
- **5.** Press **F2**, **[C TYPE]**. You will see a screen similar to the following.

```
SETUP Coord
Unknown type calibration
                              Coord Pair: 1
 Group Number Leader: 3
                              Follower:
 X: 0.000 Y: 0.000
W: 0.000 P: 0.000
                             Z: 0.000
                             R: 0.000
                          2 (Total:2)
Axis Number:
                          LINEAR
Axis Type:
Axis Direction:
                          +Y
 Point 1:
                           UNINIT
Point 2:
                          UNINIT
```

- **6.** Move all axes of the leader (positioner) to their zero positions.
- 7. Move the cursor to Axis Number and enter the number of the axis you are calibrating.
- **8.** Move the cursor to **Axis Direction** and change it if necessary.

⚠ CAUTION

When recording calibration points for a leader axis, move only that axis. The other leader group axes must remain at their zero positions; otherwise, calibrations might be incorrect.

9. Record **Point 1**:

- a) Move the cursor to **Point 1**.
- b) Jog the follower (robot) only so that the pointing device touches the marked position on the leader. See Figure 4.4.4 (b).
- c) Press and hold SHIFT and press F5, RECORD.

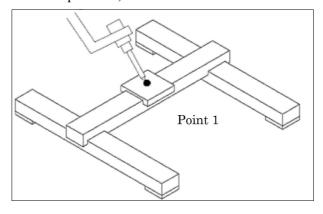


Figure 4.4.4 (b) Defining Point 1 for Axis 1

10. Record **Point 2**: (Figure 4.4.4 (c))

- a) Move the cursor to Point 2.
- b) Jog the first axis only of the leader 150 mm or more in the positive direction.
- c) Jog the follower (robot) so that the pointing device touches the marked position on the leader.
- d) Press and hold SHIFT and press F5, RECORD.

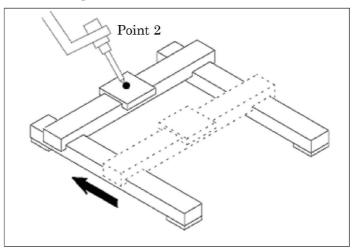


Figure 4.4.4 (c) Defining Point 2 for Axis 1

11. Record **Point 1** (second axis):

- a) Move the cursor to **Point 1**.
- b) Move the robot to **Point 1** you defined in Step 2.

You can do this as follows: Move the robot clear of the positioner, change to Group 2, press **SHIFT** and **F4, MOVE_TO**. This moves Group 2 to P[1]. Change to Group 1, press **SHIFT** and **F4, MOVE_TO**.

Make sure axes 1 and 2 are each in the zero position. See Figure 4.4.4 (c).

NOTE

If you have written a calibration teach pendant program, move the cursor to the position that is the Point 1 position, and press **SHIFT** and **FWD**.

NOTE

Use the same pointer or reference mark for all axes.

c) Press and hold SHIFT and press F5, RECORD.

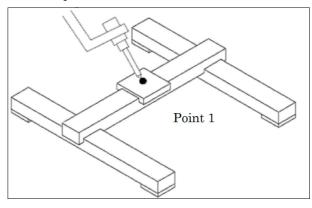


Figure 4.4.4 (d) Defining Point 1 for Axis 2

- 12. Record Point 2 (second axis): (Figure 4.4.4 (e))
 - a) Move the cursor to **Point 2**.
 - b) Jog the second axis only of the leader 150 mm or more in the positive direction.
 - c) Jog the follower (robot) so that the pointing device touches the marked position on the leader.
 - d) Press and hold SHIFT and press F5, RECORD.

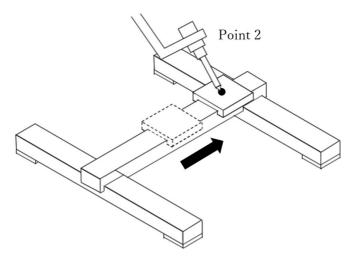


Figure 4.4.4 (e) Defining Point 2 for Axis 2

- **13.** Repeat Step 6 through Step 10 for all of the linear axes of the positioner.
- **14.** Perform Section 4.4.3, Unknown Point Calibration for a Rotary Axis for all of the rotary axes of the positioner.
- **15.** When all of the axes (rotary and linear) have been calibrated, press **F3**, **EXEC**, to execute the calibration.
- **16.** Turn off the controller and then turn it on again to enable this data for system use.

The leader coordinated frame is displayed in the SETUP Coord screen when this calculation is complete.

What to do next

NOTE

If the calibration was not successful, or if a calibration message is displayed on the prompt line of the teach pendant screen, refer to Table 10.2.

4.5 LEADER FRAME SETUP

Leader frames function as TOOL frames of leader groups. You can use this frame to define the orientation of the work piece that is mounted on the leader's face plate. Just as you teach a USER frame, you will also want to teach a leader frame to assist you in the teaching process.

With leader frame jogging, when the leader (table) is rotated, the follower (robot) TCP will maintain its relative distance and orientation along the current jog path. See Figure 4.5.

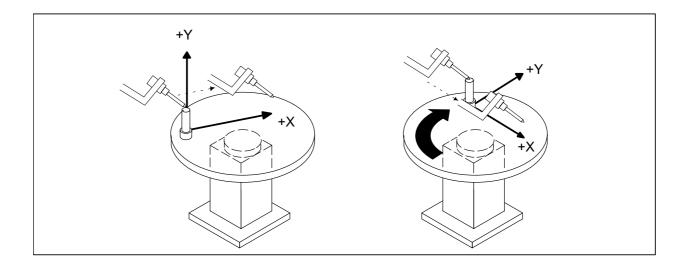


Figure 4.5 Leader Frame Jogging

4.5.1 Leader Frame Setup

Before you begin

- The coordinate pairs must be calibrated.
- The workpiece of the coordinate motion application is located on the leader group face plate.

Procedure

- 1. Press MENU.
- 2. Select SETUP.
- **3.** Press **F1**, [**TYPE**].
- **4.** Select **Coord**. You will see a screen similar to the following.

```
SETUP Coord

Coord Pair Number: [1]

Leader Group: 2

Follower Group: 1

X: 800.000 Y: 0.000 Z: 0.000

W: 0.000 P: 0.000 R: 0.000

Follower orientation: BOTH

Use Leader Frame number: 1
```

- **5.** Press **F2**, [C_TYPE].
- **6.** Select Leader Frame. You will see a screen similar to the following.

```
SETUP Coord
Leader's Frame Setup
                              Coord Pair:
Group Number Leader:
                               Follower:
Leader Frame:
 X: 0.000 Y: 0.000
W: 0.000 P: 0.000
                               Z:
                                   0.000
                                   0.000
                               R:
Leader Frame number:
                           :
                                    1
                               UNINIT
Origin Point:
                           :
X Direction Point:
                               UNINIT
Y Direction Point:
                           : UNINIT
```

NOTE

If you do not see the option to select Leader Frame, you need to calibrate the coordinate pair.

NOTE

The default value of all leader frames for x, y, z, w, p, and r, is zero.

- **7.** You can select the leader frame whose values you wish to define:
 - a) Move the cursor to Leader Frame number.
 - b) Type the number of the leader frame and press ENTER.

8. Record **Origin Point**:

- a) Move the cursor to **Origin Point**.
- b) Jog the follower (robot) so that the pointing device touches the marked position on the leader. See Figure 4.5.1 (a).
- c) Press and hold SHIFT and press F5, RECORD.

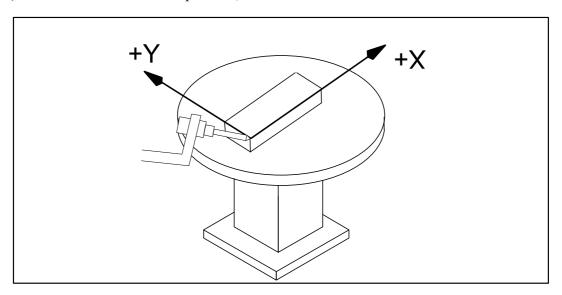


Figure 4.5.1 (a) Defining the Origin Point

9. Record **X Direction Point**:

- a) Move the cursor to **X Direction Point**.
- b) Jog the follower (robot) so that the pointing device touches a point along the +x axis. See Figure 4.5.1 (b).

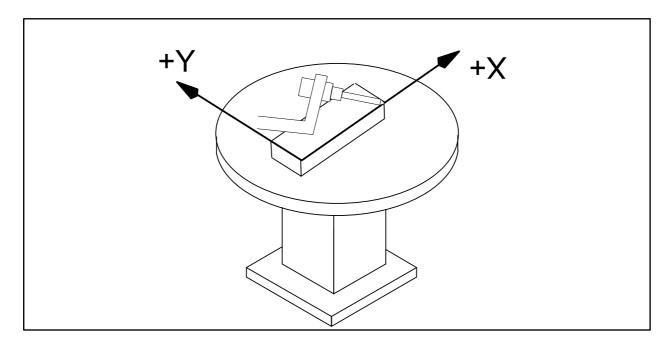


Figure 4.5.1 (b) Defining the X Direction Point

NOTE

If the follower (robot) TCP cannot touch a point along the +x axis, jog the leader to a position where this can be done.

c) Press and hold SHIFT and press F5, RECORD.

10. Record Y Direction Point:

- a) Move the cursor to Y Direction Point.
- b) Jog the follower (robot) so that the pointing device touches a point along the +y axis. See Figure 4.5.1 (c).

NOTE

If the follower (robot) TCP cannot touch a point along the +y axis, jog the leader to a position where this can be done.

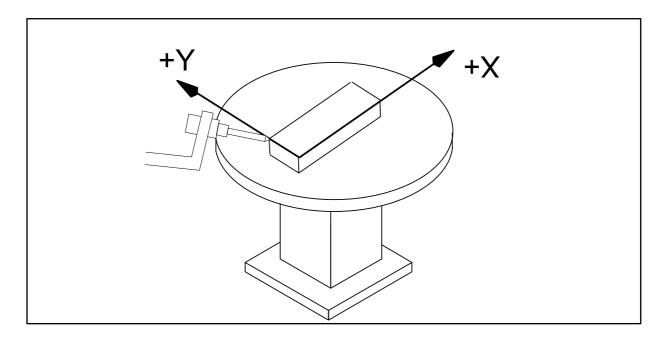


Figure 4.5.1 (c) Defining the Y Direction Point

- c) Press and hold \pmb{SHIFT} and press $\pmb{F5}, \pmb{RECORD}.$
- 11. To display the new leader frame values, press and hold SHIFT, and press F3, EXEC.

5 MULTIPLE COORD FRAMES FOR ONE CD_PAIR

By using **Multiple Coord Frames for one CD_pair**, you can register multiple (up to 10) CD_frames for each CD pair and switch to the registered CD frame by a screen setting or a KAREL program.

For example, this function is effective in the coordinated motion between a robot on a long rail axis and a positioner as shown below. In such a system, if the rail axis and the rotation axis of the positioner are strictly linear, we can expect high accuracy coordinated motion in the entire motion range of the robot.

The accuracy, however, of the coordinated motion may be poor depending on the robot position due to various factors such as machining errors, deflection of the rail axis, jigs and workpieces affected by gravity, and the accuracy of the CD_pair calibration. By using this function, multiple CD_frames can be registered to one CD_pair and switched according to the robot's position to achieve highly accurate coordinated motion in the entire motion range of the robot.

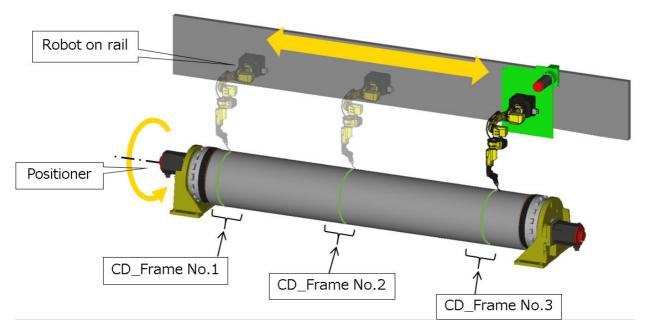


Figure 5 Example of a coordinated motion system between a robot on a long rail axis and a positioner

This function is available in the following software versions:

- 7DF1/35(V9.10P/35) or later
- 7DF3/19(V9.30P/19) or later
- 7DF5/17(V9.40P/17) or later

5.1 ENABLE DISABLE MULTIPLE COORD FRAMES

About this task

Use this procedure to enable or disable Multiple Coord Frames for one CD pair.

Procedure

- Press the MENU key.
 The screen menu will be displayed.
- 2. Select SETUP.
- **3.** Press **F1**, [**TYPE**].
- 4. Select Coord.

The coordinated motion setup screen will be displayed as shown below.

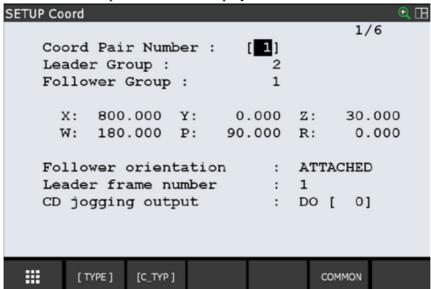


Figure 5.1 (a) Coordinated motion setup screen

5. Press the F5, COMMON.

The following screen will be displayed.

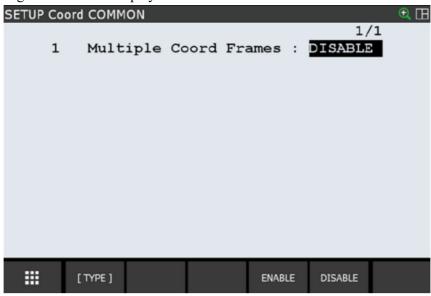


Figure 5.1 (b) SETUP Coord COMMON screen

6. Move the cursor to **Multiple Coord Frames** to enable/disable it.

7. In order to return to **SETUP Coord** screen, press the **PREV** key.

5.2 SETUP SCREEN OF MULTIPLE COORD FRAMES

When this function is enabled, you can register up to 10 CD frames for one CD pair.

5.2.1 Display the Recorded CD Frame List Screen

About this task

When this function is enabled, the **F3**, **SAVE/SET** key will be displayed in the **SETUP Coord** screen. If the CD_pair has been calibrated, pressing the **F3**, **SAVE/SET** will display the recorded CD frames list screen.

Use this procedure to display the recorded CD frame list screen.

Procedure

- **1.** Press the **MENU** key.

 The screen menu will be displayed.
- 2. Select SETUP.
- **3.** Press the **F1**, [**TYPE**].

 The screen switching menu will be displayed.
- 4. Select Coord.

When this function is enabled, the **F3**, **SAVE/SET** will be displayed in the **SETUP Coord** screen as shown below.

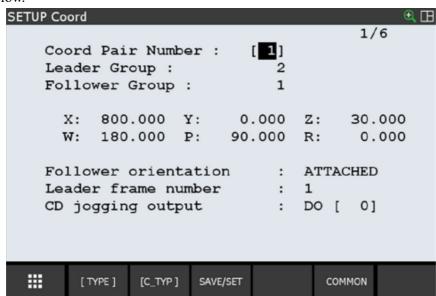


Figure 5.2.1 (a) SETUP Coord

- **5.** Press the **F3**, **SAVE/SET** key.
 - If the CD_pair has not been calibrated, the message Calibration is not completed will be displayed. It is necessary to calibrate the CD_pair first. See Chapter 3, SETTING UP COORDINATED PAIRS for more information on CD pair calibration.
 - If the CD_pair has been calibrated, the following screen will be displayed.

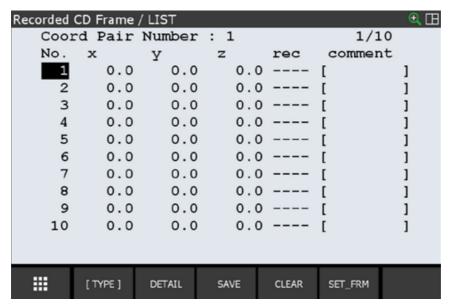


Figure 5.2.1 (b) Recorded CD Frame / LIST screen

6. In order to return to the **SETUP Coord** screen, press the **PREV** key

5.2.2 Save the CD_Frame

About this task

Use this procedure to save the current CD_frame to an arbitrary CD_frame number

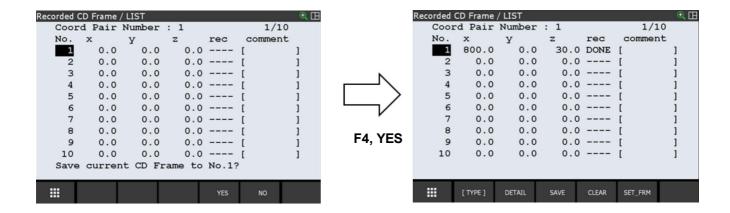
Procedure

- 1. Move the cursor to the number to register the CD frame.
- **2.** Press the **F3**, **SAVE** key.

Save current CD Frame to No.x is displayed.

3. To save, press **F4**, **YES**.

When saved, the **rec** item on the screen will be **DONE**.



5.2.3 Clear the CD_Frames

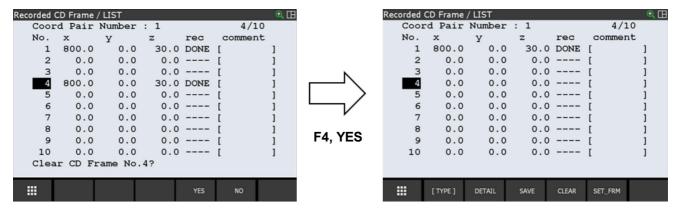
About this task

Use this procedure to clear the recorded CD frame.

Procedure

- 1. Move the cursor to the recorded CD frame number that you want to clear.
- 2. Press the F4, CLEAR key.

 Clear CD Frame No.x is displayed.
- **3.** To clear, press the **F4**, **YES**.



5.2.4 Restore the CD_Frame

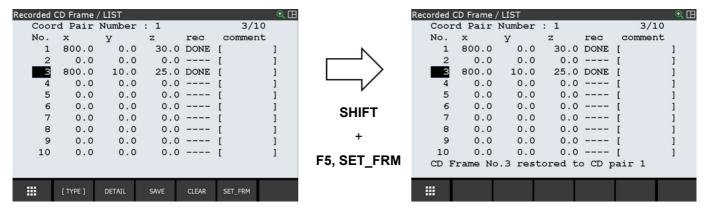
About this task

Use this procedure to restore the recorded data to the current CD frame.

Procedure

1. Move the cursor to the recorded CD frame number that you want to restore.

- **2.** Press and hold the **SHIFT** key and press **F5**, **SET_FRM**.
 - If the SHIFT key is not be pressed, the message Set frame must be shifted will be displayed.
 - If the rec item is not DONE, the message Not recorded in CD Frame No.x will be displayed.
- **3.** After the restoration, the message CD Frame No.x restored to CD pair will be displayed.



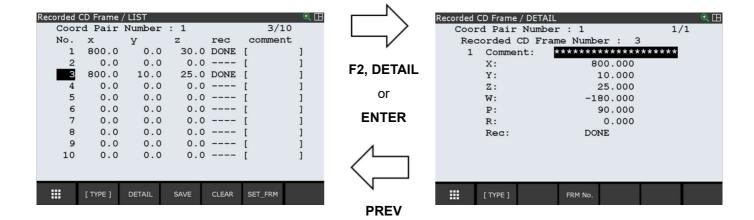
5.2.5 Details Screen of the Recorded CD_Frame

About this task

On the recorded CD_frame details screen, you can check the position/orientation data of the CD_frame and enter a comment. Comments entered in the **Recorded CD Frame / DETAIL** will also be displayed in the **Recorded CD Frame / LIST** screen.

Procedure

- 1. Move the cursor to CD frame number that you want to check the details.
- **2.** Press the **F2**, **DETAIL** key or the **ENTER** key. The details screen of the CD frame will be displayed.
- **3.** To edit a comment:
 - a) Move the cursor to the comment line and press the **ENTER** key.
 - b) Select the method of naming the comment.
 - c) Press the appropriate function keys to add the comment.
 - d) When you are finished, press the ENTER key.
- **4.** In order to return to the **Recorded CD Frame** /LIST screen, press the **PREV** key.



5.3 SWITCHING THE CD_FRAME BY KAREL PROGRAM

About this task

The registered CD_frame can be switched within the TP program by using the KAREL program SET COORD FRAME.PC pre-loaded within this function.

Procedure

- **1.** Set \$KAREL ENB = 1 to display KAREL in program list menu.
- **2.** Use the CALL instruction in the TP program to execute SET_COORD_FRAME.PC. To call SET_COORD_FRAME.PC, add two arguments as below:
 - SET COORD FRAME(CD pair number, CD frame number)

Argument 1 : CD_pair number, 1 to 4 Argument 2 : CD_frame number, 1 to 10

• Ex) Restore the CD_frame data of CD_frame No.2 to CD_pair 1:

CALL SET COORD FRAME(1,2)

5.3.1 Limitations

The last leader/follower group motions before calling SET_COORD_FRAME.PC must be non-COORD motion.

If the last motion is COORD, the alarm **CD-052** CD Frame changed during COORD will be posted.

⚠ CAUTION

After the alarms CD-032 CD Pair %d Copy %d is used and CD-052 CD Frame changed during COORD occur, the CD_frame has already been switched. Use caution when resuming the coordinated motion or when using the coordinated jogging.

It is not possible to switch the CD_frame while the leader/follower groups are moving. The last term type before calling SET COORD FRAME.PC must be FINE.

5.3.2 Example of How to Use SET_COORD_FRAME.PC

```
[Explanation]
      P[1] 100% FINE
                                             1: Non-COORD motion
     CALL SET_COORD_FRAME(1,1)
                                             2 : Restore the CD frame data of No.1.
3 :L
     P[2] 100mm/s CNT100 COORD
                                             3 : COORD motion with restored CD_frame
                                             4: COORD motion with restored CD frame
4 :L
      P[3] 100mm/s FINE COORD
                                             5: Non-COORD motion
5 :L
     P[4] 100mm/s FINE
     CALL SET COORD FRAME(1,5)
                                             6 : Restore the CD frame data of No.5.
6:
7 :C
     P[5]
                                             7 : COORD motion with restored CD frame
     P[6] 50mm/s FINE COORD
```

Figure 5.3.2 Example of how to use SET COORD FRAME.PC

5.3.3 Error Message

If the following message is displayed when executing SET_COORD_FRAME.PC, please check the remedy of each case.

• Argument missing(1: CD pair num[1-4])

Argument 1 is not assigned. Please assign CD pair number 1 to 4.

• Illegal parameter(1: CD pair num[1-4])

Argument 1 is out of range or not integer. Please check Argument 1.

• Argument missing(2: CD Frame num[1-10])

Argument 2 is not assigned. Please assign CD frame number 1 to 10.

• Illegal parameter(2: CD Frame num[1-10])

Argument 2 is out of range or not integer. Please check Argument 1.

• LINE TRACK COORD is not supported

LINE TRACK COORD is not supported.

• Coord Frame switching is disabled

Multiple Coord Frames is **DISABLE**. Please refer to Section 5.1, ENABLE DISABLE MULTIPLE COORD FRAMES and set it to **ENABLE**.

• CD pair %d is invalid

The specified CD pair is invalid. Please check the CD pair number.

• CD FRAME No.%d of CD pair %d is invalid

The specified CD frame number of the CD pair is invalid. Please check the CD frame number.

• CD-032 CD Pair %d Copy %d is used

The CD_frame data of the specified CD_frame number has been restored to the CD_pair. This message indicates that the CD_frame has been switched, and no countermeasures are required.

• CD-052 CD Frame changed during COORD

The CD_frame has been switched during or immediately after COORD motion. Please call SET_COORD_FRAME.PC after the non-COORD motion.

5.4 NOTES/RESTRICTIONS

• It is not possible to switch the CD_frame while the leader/follower groups are moving. When they are moving, the following alarm will be posted.

CD-034 CD XF update fail. G%d moving

• Do not switch the CD_frame while the COORD motion is paused. If it is switched, the alarm **CD-052** CD Frame changed during COORD is posted when the motion is resumed.

NOTE

After the alarms CD-035 CD Pair %d Copy %d is used and CD-052 CD Frame changed during COORD occur, the CD_frame has already been switched. Use caution when resuming the coordinated motion or when using the coordinated jogging.

• Variable Remote TCP function is not supported.

6 RELATIVE AND SIMULTANEOUS COORDINATED MOTION

In this section, the Relative and Simultaneous coordinated motion of several robots on one controller is described.

Consider the case of three robots, two handling and one arc robots in one controller, as shown in Figure 6. The handling robots are holding a large work piece while the arc robot is welding the work piece.

The coordinated motion pairs are defined as the following:

- G1: Arc Robot
- G2: Handling Robot
- G3: Handling Robot
- Pair 1: G2 leader, G1 follower
- Pair 2: G2 leader, G3 follower

In case of Pair1, during the teaching, the focus is more on the relative motion of the follower, G1, with respect to the leader, G2. On the other hand, in case of Pair2, the focus is more on the leader of the coordinated motion, G2. The reason is that the follower of Pair2, G3, does not have any motion with respect to the leader, G2. Pair1's coordinated motion is called *Relative Motion*, and Pair2's motion is called *Simultaneous Motion*.

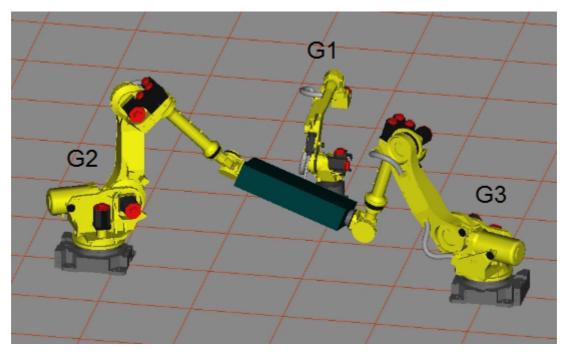


Figure 6 Relative and Simultaneous Coordinated Motion

Table 6 Relative and Simultaneous Motion

Item	Relative Motion	Simultaneous Motion
Description	The relative motion of the follower to the leader is more important.	The motion of the leader is more important. The follower matches the motion of the leader.
Leader Motion Type	If the motion type is CIRCULAR or ARC, it is changed to LINEAR.	Programmed motion type.

Item	Relative Motion	Simultaneous Motion
Leader Speed	Maximum speed.*	Program speed.
Relative Motion Type of Follower to Leader	Programmed motion type.	If the motion type is CIRCULAR or ARC, it is changed to LINEAR.**
Coordinated Jogging	No restrictions.	Follower always follows the leader.
Move Time of the Leader	If the move time of the leader is dominant in the planning phase, the warning message CD-020 Not reach relative speed is shown.	No restrictions.
Speed of Non-coordinated motion group in Coordinated Motion	Maximum speed.*	Program speed.

^{*} The move time of coordinated motion is the longest one among all groups.

To enable the simultaneous motion in the coordinated motion follow this procedure:

1. Calculate the group mask of each handling robot. For instance, the group mask for the handling robots shown in Figure 6 is calculated as follows:

G2:
$$2^{(2-1)} = 2$$

G3: $2^{(3-1)} = 4$
(G1 = 1, G4 = 8, G5 = 16)

- **2.** Calculate the total mask of all the handling robots by adding the values calculated in the previous step. For the example case, this value is 6(2+4).
- **3.** Set \$CD PARAM.\$MH ROB GMSK to the calculated value.

If all follower robots are handling robots, the leader is treated as the leader of the simultaneous motion. If a non-handling follower robot exists, the leader is treated as the leader of relative motion.

In the example case of Figure 6, G2 is treated as the leader of the relative motion, because G1 is the non-handling follower of G2. So, if the motion type of G2 is CIRCULAR, it will change to LINEAR motion at the maximum speed.

For coordinated jogging, a handling follower robot follows the leader. In the example case, if \$CD_PARAM.\$MH_ROB_GMSK is not set C21, C23, and C231 coordinated jog modes are all available. But when this system variable is used to set a simultaneous motion, C21 will no longer be available. The reason is that in this mode the handling robot G3 is not following the leader G2, and the motion of G2 without G3 following it might result in damage to the work piece.

To use the jog mode C21, please set \$CD_PARAM.\$MH_JOG_ENB to zero.

^{**} Since the TCP of the follower does not move with respect to the leader, the motion is a zero distance motion.

B-83484EN/03 7 JOGGING

7 JOGGING

7.1 **JOGGING OVERVIEW**

Coordinated jogging of a CD_pair allows one leader and its followers to be jogged in a coordinated manner. The jog speed of the coordinated pair is determined by the speed of the leader group. The relationship of the follower TCP to the leader frame is fixed during the jogging of the CD_pair.

How you jog CD_pairs depends on the kinds of groups used in the pairs:

• Fixed Orientation

Fixed Orientation jogging is used to jog leader and follower groups together. Only the location of the TCP of the follower is preserved with respect to the Leader frame. The orientation of the follower remains constant with respect to the robot WORLD frame.

Coordinated

Coordinated jogging is used to jog leader and follower groups together. The orientation and TCP of the follower are maintained with respect to the leader frame is maintained.

• Coordinated sub-group

Coordinated sub-group jogging is used when integrated extended axes (sub-groups) are used in leader groups. This type of jogging is only available in cases where auxiliary axes are included in the leader group.

• Leader Frame (LDR)

Leader Frame (LDR) jogging is used to jog the follower group in the leader group frame.

⚠ WARNING

The farther the follower TCP is from the rotary leader axis center you are jogging, the farther and faster the follower (robot) will move for the same override percentage. Be aware of this when you jog; otherwise, you could injure personnel or damage equipment.

7.2 **JOGGING DESIGNATION**

You select whether to perform coordinated motion jogging using the FCTN menu. The status line at the top of the screen displays whether coordinated motion jogging will be performed when you press the jog keys, and if it is used, the status line also indicates the type of coordinated jogging. The form is C#* or F#*, where # is the number of the leader group and * is the number of the follower group.

In Figure 7.2 (a), the leader group is group 2, the follower group is group 1. If subgroup jogging is used, the "C" is an "S", and will jog the extended axis of the leader group.

PROGRAM NAME C21 JOINT 10%

Figure 7.2 (a) Coordinated Jogging Display

In Figure 7.2 (b), the leader group is group 2, the follower group is group 1. Subgroup jogging is used, so an "S" is displayed instead of a "C".

7 JOGGING B-83484EN/03

PROGRAM NAME S21 JOINT 10%

Figure 7.2 (b) Coordinated Subgroup Jogging Display

In Figure 7.2 (c), the leader group is group 2, the follower group is group 1. Fixed Orientation coordinated jog is selected, so an "F" is displayed instead of a "C".

PROGRAM NAME F21 JOINT 10%

Figure 7.2 (c) Fixed Orientation Coordinated Jogging Display

Table 7.2 lists various jogging designations for a leader group 2 and follower groups 1 and 3.

Table 7.2 Coordinated Motion Jogging Designations

Designation	Description
C21	Jog leader (2) and follower (1), coordinated
F21	Jog leader (2) and follower (1), coordinated with fixed orientation
G1	Jog follower (1) only, non-coordinated
G2	Jog leader (2) only, non-coordinated
S23	Sub-group jog leader (2) and follower (3), coordinated
G2/S	Sub-group jog leader (2), non-coordinated
LDR2	Follower group is jogged in Leader frame.

7.2.1 Enabling Toggle Coordinate Orientation

Before you begin

The coordinate pairs must be calibrated.

Procedure

- 1. Press MENU.
- 2. Select SETUP.
- **3.** Press **F1**, [**TYPE**].
- **4.** Select **Coord**. You will see a screen similar to the following.

```
SETUP Coord
Coord Pair Number: [1]
Leader Group: 2
Follower Group: 1
X: 800.000 Y: 0.000 Z: 0.000
```

B-83484EN/03 7 JOGGING

W: 0.000 P: 0.000 R: 0.000

Follower orientation: BOTH

Use Leader Frame number: 1

- **5.** Move the cursor to **Follower orientation**.
- **6.** Press **F4**, [CHOICE], and select a setting.
 - **ATTACHED**: While maintaining the relationship of the follower TCP to the leader frame, both XYZ and Orientation movement are allowed during coordinated jogging.
 - **FIXED**: While maintaining the relationship of the follower TCP to the leader frame, Orientation remains constant during coordinated jogging.
 - **BOTH**: You can toggle between ATTACHED and FIXED.

7.3 LEADER GROUP JOGGING (COORDINATED, FIXED ORIENTATION COORDINATED)

In coordinate jogging applications, the work piece is located on the leader group and the follower group (robot) performs an application on the workpiece. When you teach a program under these circumstances, you would normally jog the workpiece, jog the follower to the new workpiece location, then teach the position.

Leader Group coordinate jogging provides a simple coordinate frame which allows you to jog the follower easily relative to the work piece. Two types of leader group jogging are available:

- Follower TCP maintains a relative position to the leader in location, and relative orientation is fixed. See Figure 7.3 (b) and Figure 7.3 (c)Section 7.3, LEADER GROUP JOGGING (COORDINATED, FIXED ORIENTATION COORDINATED).
- Follower TCP maintains a relative position to the leader in location, but the relative orientation can change. See Figure 7.3 (d) and Figure 7.3 (e).

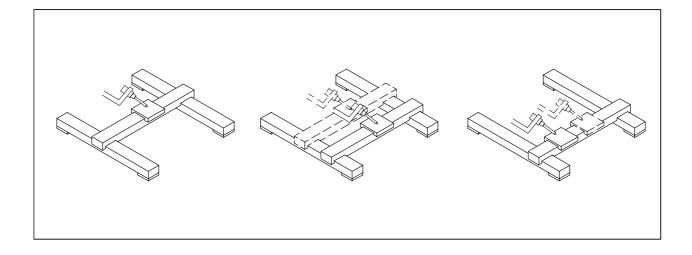


Figure 7.3 (a) Linear Leader Coordinated Jogging

7 JOGGING B-83484EN/03

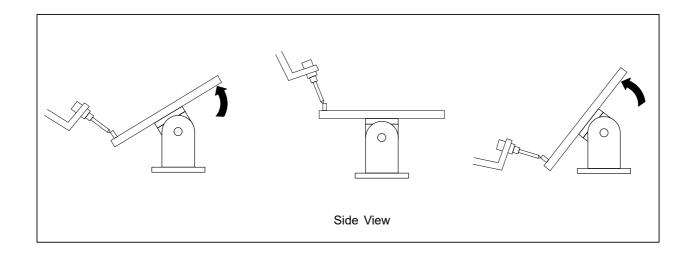


Figure 7.3 (b) Rotary Leader Coordinated Jogging (C21)-Tilt (Attached Orientation)

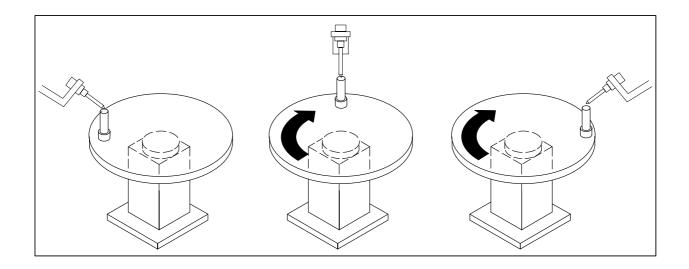


Figure 7.3 (c) Rotary Leader Coordinated Jogging (C21)-Turn (Attached Orientation)

B-83484EN/03 7 JOGGING

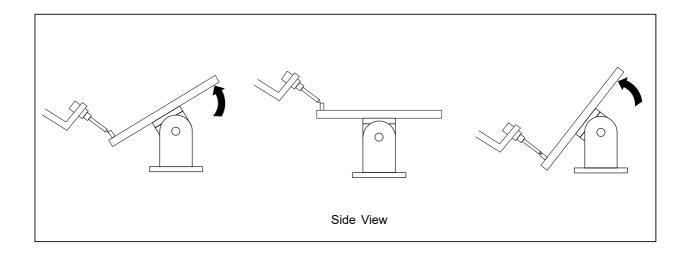


Figure 7.3 (d) Rotary Leader Coordinated Jogging (F21) - Tilt (Fixed Orientation)

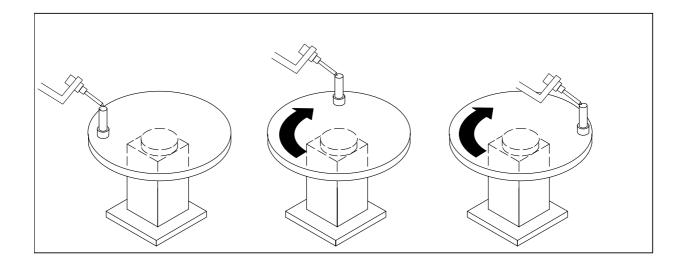


Figure 7.3 (e) Rotary Leader Coordinated Jogging (F21) - Turn (Fixed Orientation)

7.4 LEADER FRAME JOG FOR FOLLOWER GROUP

In addition to the existing jog modes, JOINT, JOG, WORLD, USER, TOOL, and PATH, a new jog coordinate mode called LDR (leader frame) is available for the robot (follower).

With leader frame jogging, the robot will jog along the leader frame which, in Figure 7.4 (a), is on the table. When the leader group moves, i.e when the table moves, the leader frame will also change accordingly. See Figure 7.4 (a).

7 JOGGING B-83484EN/03

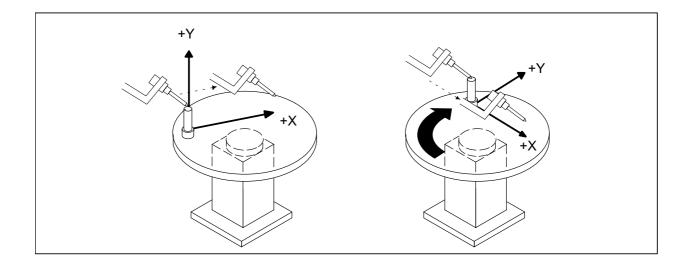


Figure 7.4 (a) Leader Frame Jogging

If the jog group is a leader group, then leader frame jogging will be turned off and you will not be able to use the LDR jog mode. If the jog group is a follower group, the LDR jog coordinate will be displayed in the status bar as LDR 2, where 2 is the leader group number. See Figure 7.4 (b).

POSITION G1 LDR2 50%

Figure 7.4 (b) LDR Jogging Display

G1 in the status bar indicates that the current jog group is Group 1.

If there is more than one leader group for the follower group, you can switch between leader groups using the TOGGLE LDR GROUP function that is available on the FCTN menu. Refer to Section 7.6, JOGGING PROCEDURE for information on jogging the robot.

7.5 **JOGGING EXAMPLES**

Table 7.5 lists the kinds of coordinated motion jogging that are available.

Table 7.5 Kinds of Coordinated Motion Jogging (Group 1: follower, Group 2: leader)

Display	Description	Effect of JOINT Jog Type	Effect of WORLD, TOOL, or USER Jog Type
C21	Coordinated group jog	Coordinated frame of the leader moves in JOINT Follower moves with the coordinated frame without changing relative position in the leader frame	No effect for coordinated positioner

B-83484EN/03 7 JOGGING

Display	Description	Effect of JOINT Jog Type	Effect of WORLD, TOOL, or USER Jog Type
F21	Fixed orientation coordinated group jog	Coordinated frame of the leader moves in JOINT.	No effect for coordinated positioner
		Follower moves with the coordinated frame without changing relative location in the leader frame, and orientation remains the same	
S21	Coordinated subgroup jog (Integrated extended axes)	Coordinated frame of the leader moves in JOINT Follower moves with the coordinated frame without changing relative position in the leader frame	Coordinated frame of the leader moves by only X, Y, or Z (dependent on axis assignment, effective for integrated linear axes) Follower moves with the coordinated frame
G1	Follower group jog (robot)	No coordinated motion Only the follower moves in JOINT	No coordinated motion Only the follower moves in WORLD, TOOL, or USER frame
G2	Leader group jog (positioner)	No coordinated motion Only the leader moves in JOINT	No effect for coordinated positioner
LDR2(G1)	Follower (robot) jog	Follower jogging occurs with respect to the leader frame.	Appears to jog like a JOG frame or a USER frame, but this frame moves if the leader group axes are moved.

7.6 **JOGGING PROCEDURE**

Use Section 7.6.1, Jogging Using Coordinated Motion to jog the robot using coordinated motion.

7.6.1 Jogging Using Coordinated Motion

Before you begin

- All personnel and unnecessary equipment are out of the workcell.
- All EMERGENCY STOP faults have been cleared.

7 JOGGING B-83484EN/03

• All other faults have been cleared and the fault light is not illuminated.

⚠ WARNING

Make certain that all safety requirements for your workplace have been followed; otherwise, you could injure personnel or damage equipment.

Procedure

1. Hold the teach pendant and continuously press the DEADMAN switch on the back of the teach pendant.



Figure 7.6.1 (a) Teach Pendant Deadman Switch

2. Turn the teach pendant enable switch to the ON position.



Figure 7.6.1 (b) Teach Pendant Enable Switch

B-83484EN/03 7 JOGGING

NOTE

If you release the DEADMAN switch while the teach pendant is ON, an error will occur. To clear the error, continuously press the DEADMAN switch and then press the **RESET** key on the teach pendant.



Figure 7.6.1 (c) Teach Pendant Reset Key

⚠ WARNING

The farther the follower TCP is from the leader axis you are jogging, the farther the follower (robot) will move for the same override percentage. Be aware of this when you jog; otherwise, you could injure personnel or damage equipment.

- **3.** If you want to jog using coordinated motion, for coordinated group jogging,
 - a) Press FCTN.
 - b) Move the cursor to CHANGE GROUP and press ENTER.
 - c) Enter the number of the leader group.
 - d) Press FCTN.
 - e) Move the cursor to **TOGGLE COORD JOG** and press **ENTER**.

C#* or F#* will be displayed in the status line, where a "#" is the leader group, and a "*" is the follower group. "F" indicates that the orientation of the follower group is fixed. You will see a screen similar to the following.

PROGRAM NAME C21 JOINT 10%

- f) To change the number of the follower group, press FCTN and select TOGGLE COORD JOG. Do this until the CD_pair you want is displayed.
- g) To change to a fixed orientation coordinate jogging mode (orientation does not change), select **TOGGLE COOR ORNT**. For more information on the types of Leader coordinate jogging modes available, refer to Section 7.3, LEADER GROUP JOGGING (COORDINATED, FIXED ORIENTATION COORDINATED).

NOTE

In setup screen of coordinated motion, if **Follower Orientation** is not **BOTH**, you cannot change the orientation. Refer to Section 7.2.1, Enabling Toggle Coordinate Orientation.

h) To end coordinated jogging, press FCTN and select TOGGLE COORD JOG.

7 JOGGING B-83484EN/03

NOTE

Set the jog speed to a low percentage (%) value if you are inexperienced in jogging the robot, or if you are uncertain how the robot will move.

Select a jog speed by pressing and releasing the appropriate jog speed key until the jog speed you want is displayed in the upper right hand corner of the teach pendant screen.

In the next step, the robot will move. To stop the robot immediately any time during jogging, release the DEADMAN switch or press the **EMERGENCY STOP** button.

- 5. To jog, press and hold the SHIFT key and continuously press the jog key that corresponds to the positioner axis you want to move in a coordinated fashion with the follower (robot). To stop jogging, release the jog key.
- **6.** When you are finished jogging, turn the teach pendant enable switch to OFF, and release the DEADMAN switch.

7.7 CD JOGGING OUTPUT

In coordinate jogging, you can assign output signals to each CD pair. When a CD pair is in motion, the assigned output signal turns on. To assign output signals to a CD pair follow Section 7.7.1, Setting CD Jogging Output.

Example

In case of two CD pairs and the assigned output signals as the following, the output will be as shown in Table 7.7 for different jog modes.

CD Pair 1: Leader G2, Follower G1 = DO[1]

CD Pair 2: Leader G2, Follower G3 = DO[2]

Table 7.7 Output Signals in the Example Case

Display	DO[1]	DO[2]
G2	OFF	OFF
C21	ON	OFF
C23	OFF	ON
C213	ON	ON

7.7.1 **Setting CD Jogging Output**

Procedure

1. Press MENU.

B-83484EN/03 7 JOGGING

- 2. Select SETUP.
- **3.** Press **F1**, [**TYPE**].
- **4.** Select **Coord**. You will see a screen similar to the following.

```
SETUP Coord
Coord Pair Number: [1]
Leader Group: 2
Follower Group: 1
X: 800.000 Y: 0.000 Z: 0.000
W: 0.000 P: 0.000 R:0.000
Follower orientation: BOTH
User Leader Frame number: 1
CD jogging output: DO [1]
```

- **5.** Move the cursor to **CD jogging output**.
- **6.** Set signal type and signal number.

7 JOGGING B-83484EN/03

B-83484EN/03 8 PROGRAMMING

8 PROGRAMMING

8.1 PROGRAMMING OVERVIEW

To use coordinated motion within a teach pendant program, you must include the COORD motion option in the appropriate motion instructions. This chapter contains information on using coordinated motion in a teach pendant program.

To use coordinated motion in a teach pendant program, you must:

- 1. Modify the program header information.
- 2. Include the COORD coordinated motion option and define the speed in the motion instructions that will perform coordinated motion.
- **3.** Execute the program.

Coordinated Motion Program Execution

In the example shown in Section 8.1, Coordinated Motion Program Example, G2 is the leader group, G1 is the follower group. In this example, coordinated motion will be performed in lines 2, 3, and 4. If the follower is a robot and the leader is a single-axis tabletop, when line 2 of the program is executed, the leader and follower will move together, and the TCP speed relative to the tabletop will be 20mm/sec. The two groups will start at the same time and finish at the same time. The motion path of the follower, although it appears to be an arc or circular, will travel along a straight line relative to the moving frame of the leader. The move to P[6] will be a normal linear move.

Coordinated Motion Program Example

```
1: J P[1] 100% FINE
2: L P[2] 20mm/sec FINE COORD
3: L P[3] 20mm/sec CNT100 COORD
4: C P[4] P[5] 20mm/sec CNT100 COORD
5: L P[6] 20mm/sec FINE
```

8.2 PROGRAM HEADER INFORMATION

You must specify motion groups appropriately in the group mask portion of the program header for programs in which you want to use coordinated motion. If more than one CD_pair is defined, the group mask must contain only the groups in the CD_pair for which coordinated motion is to be executed. If multiple pairs are included in the TP programs for Coordinated motion, COORD[x] should be used to specify the leader group number through value x. For example, if pair 1 has G1 vs. G2, pair 2 has G1 vs. G3, and pair 3 has G2 and G3. When a TP program has group mask G123, then COORD[1] will specify Group 1 as leader.

You access the program header information on the DETAIL screen of the SELECT menu. You set the group mask prior to recording any positions. Refer to the *OPERATOR'S MANUAL (Basic Function)* (*B-83284EN*) or the application-specific *Setup and Operations Manual* for more information on modifying program header information.

8 PROGRAMMING B-83484EN/03

8.3 COORD COORDINATED MOTION OPTION

You must include the COORD coordinated motion option in each motion instructions that will perform coordinated motion, as follows:

```
L P[2] 20mm/sec FINE COORD
```

You can include the COORD motion option in Cartesian motion instructions.

Conditions

Before you record coordinated motion instructions, make sure that the tool frame for the follower group have been defined properly.

Limitations

Coordinated motion in a program has the following limitations:

- You cannot use the INC incremental motion option in motion instructions that contain the COORD motion option.
- You cannot use the Wjnt wrist joint motion option in motion instructions that contain the COORD motion option.
- You can execute weaving only on the follower group (robot).
- You cannot use program shift or mirror image copy.
- UTOOL and UFRAME for the leader group (positioner) are not supported.
- The COORD motion option can be applied to a robot-only move (when the positioner does not move). The effect is the same as a non-coordinated linear or circular move.
- You cannot put a non-coordinated linear or circular motion instruction of termination type CNT1-CNT100 before a coordinated motion instruction. See Figure 8.3.
- For Coordinated motion RPM and Multipass, the starting position for tracking and replay must be linear and must contain the COORD option.

```
Correct:
  1: L P[1] 250mm/sec CNT0
2: L P[2] 20mm/sec FINE COORD
1: J P[1] 100% CNT100
2: L P[2] 20mm/sec FINE COORD
Incorrect:
  1: L P[1] 250mm/sec CNT100
2: L P[2] 20mm/sec FINE COORD
```

Figure 8.3 Coordinated Motion Termination Type Example

8.4 COORD[LDR] COORDINATED MOTION OPTION

COORD[LDR] is a motion option that allows you to specify the leader group number. It can be used in place of COORD when it is necessary to specify the leader group number.

```
L P[1] 25mm/sec CNT100 COORD [ 1 ]
```

You can also use COORD [R[]] to specify the leader group number in a register.

In a multi-arm system, it is possible that one robot could function as a leader at one time, but then function as a follower at another time. If the COORD option is used in a system where the program group

B-83484EN/03 8 PROGRAMMING

mask has more than one *potential leader*, the alarm **CD-009** More than one leader is posted. An example system shown in Table 8.4 is illustrated in Figure 8.4 (a) and Figure 8.4 (b).

Table 8.4 CD Pair Examples

CD_PAIR setup	Leader	Follower
CD_PAIR[1]	G1	G3
CD_PAIR[2]	G2	G4
CD_PAIR[3]	G1	G2
CD_PAIR[4]	G1	G4

In Figure 8.4 (a), only one leader is possible for each program.

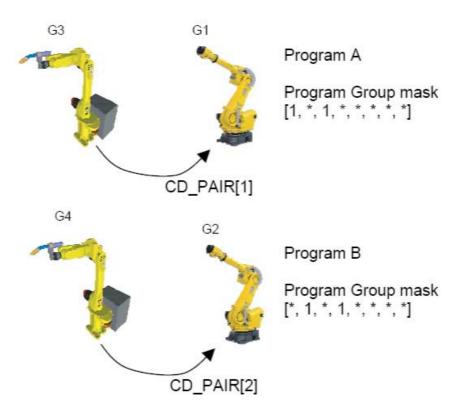


Figure 8.4 (a) One Possible Leader

In Figure 8.4 (b), there are two potential leaders. In this case, you could use COORD[1] in Program C to specify group 1 as the leader.

8 PROGRAMMING B-83484EN/03

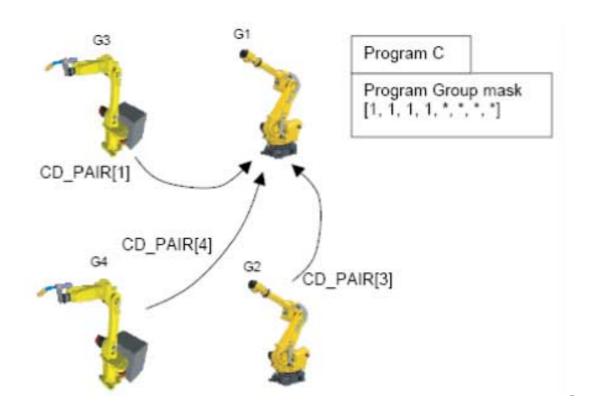


Figure 8.4 (b) Two Possible Leaders

In the following example,

```
P[1] 25mm/sec CNT100 COORD [ 1 ]
```

Group 1 is the leader group and

- the LDR group must be in the program group mask
- the LDR group will be the ONLY leader among the groups

Limitations

- If the leader group number changes within the same program
 - they must be separated by at least one non-COORD motion

and

 the non-COORD motion immediately before the COORD[LDR] motion must use the FINE termtype

• Dynamic switching of the leader group number in consecutive COORD [LDR] motion, as shown in the following example, is not allowed. The CD-029 Illegal to switch leader alarm will be posted.

B-83484EN/03 8 PROGRAMMING

```
L P[1] 25mm/sec CNT100 COORD [ m ]
L P[2] 25mm/sec CNT100 COORD [ n ]
```

8.5 SPEED DEFINITION

Two speeds are controlled during the execution of coordinated motion: the leader speed and the follower speed:

- The follower (robot) speed is continuously adjusted to maintain the TCP speed of the motion instruction in the program. This speed is relative to the coordinated frame of the leader.
- For typical moves, the leader group runs at 100% of its speed and the follower speed is adjusted continuously to maintain program speed.
- If the follower segment time is longer than the positioner move would take at 100%, then the positioner speed is adjusted so that it takes the same amount of time as the follower to complete the move. The follower (robot) segment time is the calculated time for the robot to move the distance from P[n] to P[n+1] at the programmed speed. The follower's motion time is made equal to the calculated segment time. This ensures that the motions begin and end simultaneously.

If the follower reaches an axis speed limit during coordinated motion, the coordinated path is maintained, but the relative motion speed between the leader and follower will be slower than the speed specified in the motion instruction. When this occurs, a warning is displayed.

8.6 LINEAR MOTION PROGRAMMING

Linear motions are executed in the coordinated frame at the programmed speed. For each linear segment, record the start and end positions such that the position and orientation of the tool are correct for the given weld joint. The position of the leader group can be changed between the start and end positions, especially if the endpoint is not reachable by just moving the robot, or, for the case that tool orientation can be maintained better via a movement of the workpiece.

When linear motion is executed, note that the speed is judged at the TCP relative to the workpiece, so the axes might appear to be moving faster or slower than the programmed speed during coordinated motion. Also note that most linear moves that are executed in a rotating coordinated frame will appear to be circular, or elliptical when viewed.

Programming Guidelines

When programming a linear coordinated motion instruction, keep in mind the following guidelines:

- Divide the motion so that half is performed by the robot and half is performed by the table. This will reduce the time required on that segment. Preferably, this will have the two groups moving in opposite directions.
- Try to orient the workpiece so that a preferred (application-dependent) position is achieved.
- Try to arrange the leader and follower at the end position of the segment so that
 - The next path segment can be executed without stopping the process.
 - The next path segment is in a preferred position.
 - The distance to the next path segment is minimized.
- A fast linear coordinated move can be used for an air cut move, which might be quicker than a joint air cut move.

8 PROGRAMMING B-83484EN/03

• You can minimize the motion of either the leader or follower group, especially in cases where the leader or follower is close to an axis limit, or the follower group is approaching singularity or wrist flip positions. This benefit also applies to Circular motion.

- A coordinated motion from P[n] to P[n+1] should not be defined by recording P[n], then coordinated jogging to P[n+1]. The effect of doing this is that the follower motion in the coordinated frame will be of zero length and the motion will be executed at the maximum speed of the leader group axis (axes).
- Work and travel angles will be executed as though there were no leader group motion when viewed
 with respect to the workpiece being welded. If torch orientation of the first and second positions is
 maintained relative to the workpiece, the entire path will maintain the torch orientation relative to the
 workpiece.

8.7 CIRCULAR MOTION PROGRAMMING

Circular motions executed in the moving coordinated frame generally appear as circular motions, except in cases where the motion is predominantly executed on the leader group (positioner).

As with linear motion, the relative positions of the positioner and robot for the START, VIA, and END positions of the circular move are not critical except that the VIA position is located between the START and END position with respect to the workpiece. When teaching the positions on circular weld paths, ensure that the torch positions are correct for each point; changing the leader position between points is permitted.

Programming Guidelines

When you program a circular coordination motion instruction, keep in mind the following guidelines:

- The smoothest execution tends to occur when the predominant motion occurs on the positioner.
- Try to orient the workpiece so that a preferred (application-dependent) position is achieved.
- Try to arrange the leader and follower positions at the end position of the segment so that
 - The next path segment can be executed without stopping the process.
 - The next path segment is in a preferred position.
 - The distance to the next path segment is minimized.
- A fast linear coordinated move can be used for an air cut move, which might be quicker than a joint air cut move.
- You can minimize the motion of either the leader or follower group, especially in cases where the leader or follower is close to an axis limit, or the follower group is approaching singularity or wrist flip positions.

It is possible to define circular positions that can not be executed in program mode. Typically, this is caused by one or more joints going into singularity. In those cases, do the following:

- 1. Stop execution.
- 2. Select coordinated jogging mode.
- 3. Jog the leader group to a position in which the singularity no longer exists.
- **4.** Touch up the position in this new position.
- **5.** Re-teach the next position by the same method until the motion problem no longer exists.
- **6.** Try a complete execution of the circular move.
- 7. If you cannot complete the move, rotate the leader axis only (G2) until the workpiece is in a section of the robot work envelope that does not cause the motion problem to occur, then record the new position.

B-83484EN/03 8 PROGRAMMING

⚠ WARNING

As with non-coordinated circular moves, if you abort a program during the execution of a circular move, and if you jog the robot out of the plane of the motion, the resumed motion will include the robot's current location. This might cause the tool to hit the positioner or workpiece. Be sure to execute the program at a low override for safety; otherwise, the robot could injure personnel or damage equipment.

In order to execute a circular motion that changes the motion plane during execution, two circular moves must be defined for the circular path. In Figure 8.7, to rotate the table top (axis 2) while rotating axis 1, you must program two arcs:

- The first arc is created using points [P1], P[2] (via), and P[3]
- The second arc is created using points P[3], P[4] (via), and P[5]

The VIA position Cartesian data is used during single step execution.

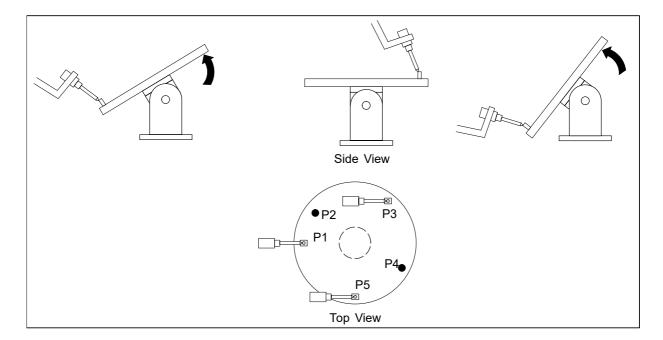


Figure 8.7 Coordinated Circular Motion

8 PROGRAMMING B-83484EN/03

B-83484EN/03 9 DYNAMIC UFRAME

9 DYNAMIC UFRAME

When Coordinated Motion is used, Dynamic Uframe provides the method to record the Follower's position in relative form not in absolute form. By enabling this function, when the leader moves, the specified Follower Uframe varies.

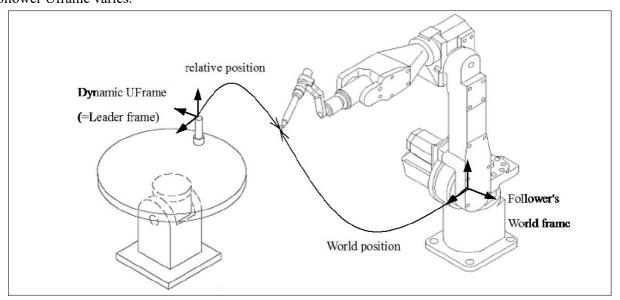


Figure 9 Dynamic UFrame

So, when the Follower robot's position is touched-up using the Uframe, the relative position based on the Uframe (which is linked with leader frame) will be recorded. Since the position data is stored in relative form, TPE Offset can work in relative frame. Before setting this function, the operator needs to finish the calibration of Coordinated motion and the setting of Leader frame. Dynamic Uframe is available as a separate option, CD Dynamic Uframe, which requires the Coordinated Motion option to be installed.

- If the Follower Uframe number is zero, no Dynamic Uframe is used.
- If the Follower Uframe number is not zero, the specified Uframe of the Follower group will be updated based on the current position of the leader and the current leader frame number.

The Follower Uframe origin and orientation are at the same physical location as the leader frame origin at the current leader position.

If Dynamic Uframe is enabled, the Follower Uframe is updated whenever the leader stops moving. The Follower Uframe is not updated while the leader is moving. Any change to the leader frame will become effective to the Follower Uframe at the end of the next leader motion.

The Dynamic Uframe is useful when transferring programs from one robot cell to another or for using programs created in ROBOGUIDE. The Dynamic Uframe is also useful for when the part being held by the leader is in a different location than when originally taught. The leader frame can be updated to reflect the current part location and the Follower path can usually be executed without touchup even when the leader has large position changes.

NOTE

When relocating or copying a robot system that uses Coordinated Motion, there is an advantage that the TP programs can be used as they are just by re-performing CD-PAIR Calibration.

9 DYNAMIC UFRAME B-83484EN/03

To use this function CD Dynamic UFrame option (A05B-2600-R700) or CD Dynamic UFrame Arc option (A05B-2600-R845) is required.

9.1 SETTING DYNAMIC UFRAME

About this task

Use this task to set the dynamic UFrame.

When the CD Dynamic Uframe option is installed, a menu item appears on the Coordinated Motion Setup page that allows the setting of the Follower Uframe number.

```
SETUP Coord
 Coord Pair Number :
                             [1]
Leader Group :
                                1
 Follower Group :
                                2
      0.000 Y: 1500.000
0.000 P: 0.000
  X:
                                    Z: 0.000
                                    R: 0.000
Follower orientation
                                    ATTACHED
Leader Frame number
                                :
                                    5
Follower UFrame number
Old Value: 0
```

NOTE

If **CD Dynamic UFrame option** or CD Dynamic UFrame Arc option is not installed, **Follower UFRame number** will not be displayed.

Procedure

1. Select Leader Frame number.

The selected leader frame is with the Follower Uframe. Use Section 4.5.1, Leader Frame Setup to perform leader frame setup.

2. Cycle power.

The selected Uframe of the Follower is treated as Dynamic Uframe. This means that the Leader Frame position based on the Follower's world frame will be set to the Follower's Uframe. When this number is 0, Dynamic UFrame is disabled. (default: 0).

For example, if **Leader Frame number** is 1 and **Follower Uframe number** is 9, the position of the leader frame 1 with respect to the Follower's world frame is set to the UFRAME[9] of the Follower. So, UFRAME[9] content dynamically varies depending on the leader's position. And when one changes **Follower UFrame number** or **Leader Frame number** setting, cycle power operation is needed.

When one changes Follower UFrame number or Leader Frame number setting, cycle power operation is needed.

The Dynamic Uframe is effective with or without coordinated motion. The Follower Uframe is updated at the end of leader motion whether it is coordinated or non-coordinated motion. The Follower group can use the Dynamic Uframe the same as other Uframes.

B-83484EN/03 9 DYNAMIC UFRAME

9.2 PROGRAMMING DYNAMIC UFRAME

On the TP program, use the UFrame number set as the Dynamic UFrame for the position to which you want to apply the TP offset in the relative frame. On this TP program, we assume that the Leader frame number is 1 and the Follower UFrame number is 9. Here, note that the positions P[5] - P[9] are the follower's TCP position based on leader frame 1. Other positions are based on the follower's world frame. Since P[5] - P[9] are relative, based on leader frame 1 i.e. the work frame, the OFFSET, PR[100] works on the work frame.

```
1: UFRAME NUM = 0;
2: ;
3:J P[1] 100% CNT100;
4:J P[2] 100% CNT100;
5: ;
6: UFRAME NUM = 9;
7: CALL VISTEST ;
8: UFRAME NUM = 0;
9: ;
10:J P[3] 100% CNT100;
11:J P[4] 100% CNT70;
12: ;
13: UFRAME NUM = 9;
14: ;
15:L P[5] 500mm/sec FINE OFFSET, PR[100];
16: Arc Start[23.0Volts, 175.0Amps] ;
17:C P[6] OFFSET, PR[100]
P[7] 100cm/min CNT100 COORD OFFSET, PR[100];
18: Arc Start[22.0Volts, 175.0Amps];
19:C P[8] OFFSET, PR[100]
P[9] 100cm/min FINE COORD OFFSET, PR[100];
20: Arc End[16.0Volts, 125.0Amps, 0.0s];
21: ;
22: UFRAME NUM = 0;
23:L P[10] 500mm/sec CNT100;
24:L P[11] 2000mm/sec CNT70;
```

9.3 DYNAMIC UFRAME RESTRICTIONS

This function cannot be used with the following motion functions.

- CD Dynamic UFrame option (A05B-2600-R700)
 - Weaving
 - TAST
 - Touch sensing
 - Multi-Pass
 - Any option that is not supported by Coordinated motion
- CD Dynamic UFrame Arc option (A05B-2600-R845)

Any option that is not supported with Coordinated motion

9 DYNAMIC UFRAME B-83484EN/03

⚠ WARNING

The value of the User Frame that is used as Dynamic UFrame changes according to the motion of the leader group. So if one operates the normal motion by using the User Frame that is used as Dynamic UFrame, the robot may move to unexpected direction by the change of the leader robot's position. Please don't use the User Frame that is used as Dynamic UFrame when operating the other (normal) motion.

The option, CD Dynamic Uframe Arc (R845) has been added in V8.30 (7DC3). It includes the existing option CD Dynamic Uframe (R700). R845, allows Dynamic Uframe to support Touch Sensing, Weaving, TAST and Multi-Pass/RPM.

If you use R845 for Touch Sensing, you will need to finish the coordinated pair setup and the leader frame setup, configure leader frame number and follower uframe number first, and teach the Touch Frame later. Touch Sensing re-mastering is required after the TP program is transferred to a different controller, since a different leader frame results in a different search start position.

9.4 OFFSET AND VOFFSET INSTRUCTION

In the TP program, use the UFrame number set as Dynamic UFrame for the position to which you want to apply OFFSET or VOFFSET instruction in relative frame.

NOTE

If the software version is 7DC1/15 (V8.10P/15), 7DD0/08 (V8.13P/08), 7DC2/01 (V8.20P/01) or later, you can use both the OFFSET and the VOFFSET instruction for Dynamic UFrame.

If not, you can only use the OFFSET instruction for Dynamic UFrame.

NOTE

If you use iRVision to obtain an offset value, note the following;

- **1.** For [Application Frame] in the camera calibration setup menu,
 - if the camera is not mounted on the positioner, you must select the base frame of the Robot or an UFrame which is not used for Dynamic UFrame.
 - if the camera is mounted on the positioner and its position can vary together with Dynamic UFrame, you must select the Dynamic UFrame.
- **2.** You must select the Dynamic UFrame for [Offset Frame] in Vision Process setup menu.
- **3.** Don't move Dynamic UFrame (positioner axes) during the process from the RUN_FIND instruction to the GET_OFFSET instruction. If the position of Dynamic UFrame changes during this process, you cannot obtain correct offset data.

Please also refer to the *iRVision OPERATOR'S MANUAL (Reference) (B-83914EN-1)*.

Measure an offset value on the Dynamic UFrame and store it into a position register. Use this position register for the OFFSET instruction.

If you use iRVision to measure an offset value, the output is obtained in a vision register. In this case, use the PR[a]=VR[b]. OFFSET instruction to copy the offset data from the vision register to a position

B-83484EN/03 9 DYNAMIC UFRAME

register. For details of this instruction, refer to the *iRVision OPERATOR'S MANUAL (Reference)* (B-83914EN-1).

In the following TP programs, we assume that the Leader frame number is 1 and the Follower UFrame number is 9 (UF9).

NOTE

Positions P[5], P[6], P[7], P[8] and P[9] are follower's TCP positions based on the Leader frame 1 (UF9). And any other positions are based on the follower's world frame. P[5]-P[9] are relative based on the Leader frame 1 (UF9), i.e. workpiece frame, the OFFSET or VOFFSET instruction works on the workpieceframe.

Programming - OFFSET instruction

In the sample program below, a user-defined program CAL_OFST calculates PR[100] as an offset value on UF9.

```
1: UFRAME NUM = 0;
2:
     ;
3:J P[1] 100% CNT100;
4:J P[2] 100% CNT100;
6: CALL CAL OFST ;
7:
8: UFRAME NUM = 0;
9:
10:J P[3] 100% CNT100;
11:J P[4] 100% CNT70;
12:
13: UFRAME NUM = 9;
14:
15:L P[5] 500mm/sec FINE OFFSET, PR[100];
16: Weld Start[1,175.0Amps,23.0Volts,0.00];
17:C P[6] OFFSET, PR[100]
     P[7] 100cm/min CNT100 COORD OFFSET, PR[100];
18: Weld Start[1,175.0Amps,22.0Volts,0.00];
19:C P[8] OFFSET, PR[100]
     P[9] 100cm/min FINE COORD OFFSET, PR[100];
20: Weld End[1,125.0Amps,16.0Volts,0.0s];
21:
22: UFRAME NUM = 0;
23:L P[10] 500mm/sec CNT100;
24:L P[11] 2000mm/sec CNT70;
```

Figure 9.4 (a) OFFSET Instruction Sample Program

Refer to Figure 9.4 (a)		
Program line no. Description		
1	Initialize UFrame number	
6	Calculate the offset on UF9 (Result is output to PR[100]	
8	Select UF again in case CAL_OFST changes it	
13	Select Dynamic UFrame	
15	Offset P[5] based on the offset calculated in line 6	

9 DYNAMIC UFRAME B-83484EN/03

Refer to Figure 9.4 (a)		
Program line no. Description		
17	Offset P[6] and P[7] based on the offset calculated on line 6	
19	Offset P[8] and P[9] based on the offset calculated on line 6	
22	Change back to the original UFrame	

Programming - VOFFSET instruction

Use *i*RVision to measure an offset value on the Dynamic UFrame and store it into an vision register. Use this vision register for VOFFSET instruction.

In the sample program below, a user-defined program CAL_VOFST calculates VR[1] as an offset value on UF9.

```
1: UFRAME NUM = 0;
3:J P[1] 100% CNT100;
4:J P[2] 100% CNT100;
5:
6: CALL CAL VOFST ;
7:
8: UFRAME_NUM = 0;
9:
     ;
10:J P[3] 100% CNT100;
11:J P[4] 100% CNT70;
12:
13: UFRAME NUM = 9;
15:L P[5] 500mm/sec FINE VOFFSET, VR[1];
16: Weld Start[1,175.0Amps,23.0Volts,0.00]; 17:C P[6]
VOFFSET, VR[1]
P[7] 100cm/min CNT100 COORD VOFFSET, VR[1];
18: Weld Start[1,175.0Amps,22.0Volts,0.00]; 19:C P[8]
VOFFSET, VR[1]
P[9] 100cm/min FINE COORD VOFFSET, VR[1];
20: Weld End[1,125.0Amps,16.0Volts,0.0s]; 21:
22: UFRAME NUM = 0;
23:L P[10] 500mm/sec CNT100;
24:L P[11] 2000mm/sec CNT70;
```

Figure 9.4 (b) VOFFSET Instruction Sample Program

Refer to Figure 9.4 (b)		
Program line no. Description		
1	Initialize UFrame number	
6	Calculate the offset on UF9 (Result is output to VR[1]	
8	Select UF again in case CAL_VOFST changes it	
13	Select Dynamic UFrame	
15	Offset P[5] based on the offset calculated in line 6	
17	Offset P[6] and P[7] based on the offset calculated on line 6	
19	Offset P[8] and P[9] based on the offset calculated on line 6	

B-83484EN/03 9 DYNAMIC UFRAME

Refer to Figure 9.4 (b)		
Program line no. Description		
22 Change back to the original UFrame		

9 DYNAMIC UFRAME B-83484EN/03

B-83484EN/03 10 TROUBLESHOOTING

10 TROUBLESHOOTING

10.1 TROUBLESHOOTING OVERVIEW

This section contains information on solving problems that arise when you are setting up and using coordinated motion.

- Refer to the calibration error table in Section 10.2, CALIBRATION ERRORS if you have an error during calibration.
- Refer to the coordinated motion error codes listed in Section 10.3, ERROR CODES if you want to look up a specific coordinated motion error code.

10.2 CALIBRATION ERRORS

Refer to Table 10.2 for information on errors that can be displayed on the teach pendant prompt line during calibration. These messages do not appear on the alarm log.

Table 10.2 Calibration Messages

Prompt Line Message	Description
Record must be shifted	The RECORD function key was pressed before or without pressing the SHIFT key.
Move to must be shifted	A MOVE_TO function key operation was attempted before or without pressing the SHIFT key.
Cannot move to uninitialized point	A MOVE_TO function key operation was attempted on a point that has not been not recorded.
Point Not Recorded	 This will happen only under the following circumstances: An internal memory allocation error has occurred. The system is out of memory. The CD (coordinated motion) system variables have not been loaded.
All points have to be recorded for calibration	An EXEC calibration operation was attempted before all positions were recorded.
Pair calibrated. Please cold start.	A successful calibration matrix was calculated. In order for it to take effect, the system requires a COLD START.
Position data will be cleared!	This is the message normally displayed when changing the value of either the leader or follower in a CD_pair. Verify the change, and the CD_XF transform will be uninitialized.
Exec must be shifted	An EXEC calibration operation was attempted before or without pressing the SHIFT key.

10 TROUBLESHOOTING B-83484EN/03

Prompt Line Message	Description
Recorded points are on one line	Rotary axis calibration positions all lie on a single line. Re-record all calibration positions using the correct method.
Improper axis direction	On a multiple-axis positioner, one or more axes have been labeled incorrectly. Verify that the desired frame has been defined, and that all axes have been labeled correctly.
Recorded points are too close	This will be displayed in the following cases:
	 For a rotary axis, two positions have been recorded at the same location. Three positions have been recorded at the same location. The follower has been moved, but the leader has not been moved, for calibration positions. For a linear axis, the positions are in the same location.
Improper points are recorded	 This will be displayed in the following cases: One position has been recorded using a different UTOOL. Rotary non-orthogonal axes have been defined. Rotary non-parallel axes have been defined. For a linear or rotary axis, the move on the robot is not along the axis of the positioner. For an integrated linear extended axis of a leader, the move on the robot is not along the axis of the positioner.

10.3 ERROR CODES

Error codes appear on the alarm log.

Refer to the *Error Code Manual (MARRUEROR02171E)* or the *OPERATOR'S MANUAL (Alarm Code List) (B-83284EN-1)* for a complete listing of error codes.

ADDITIONAL INFORMATION

FANUC Robot series R-30iB/R-30iB Mate/R-30iB Plus/R-30iB Mate Plus/R-30iB Mini Plus CONTROLLER

Coordinated Motion Function OPERATOR'S MANUAL

Corrected the figure of the ARC Positioner TCP frame

1. Type of applied technical documents

Name	FANUC Robot series R-30iB/R-30iB Mate/R-30iB Plus/R-30iB Mate Plus/R-30iB Mini Plus CONTROLLER Coordinated Motion Function OPERATOR'S MANUAL
Spec.No./Ed.	B-83484EN/03

2.Summary of Change

Group	Name/Outline	New, Add, Correct, Delete	Applicable Date
Basic			
Optional Function	Corrected Figure 4.2.2 (d) and added Figure 4.2.2 (e)	Correct Add	Immediately
Unit			
Maintenance Parts			
Notice			
Correction			
Another			

Title	FANUC Robot series R-30 <i>i</i> B/R-30 <i>i</i> B Mate/R-30 <i>i</i> B Plus/ R-30 <i>i</i> B Mate Plus/R-30 <i>i</i> B Mini Plus CONTROLLER Title Coordinated Mation Function OPERATOR'S MANUAL	Ed 1	Draw B-83484EN/03-001		001
Occidinated motion function of Livitor 3	Corrected the figure of the ARC Positioner TCP	Date 2022. 9/26	FA	NUC CORPORATION	Sheet 1/3

Corrected Figure 4.2.2 (d) and added Figure 4.2.2 (e).

ARC Positioner (H871)

The ARC Positioner has known kinematics. Known Four-Point Calibration can be used. Figure 4.2.2 (d) and Figure 4.2.2 (e) show diagrams of the ARC Positioner with its world and flange frame respectively. If you need to set a tool frame (TCP), such as when using the Known Four Point Calibration method, please refer to this flange frame. If not set, the tool frame will be the same as the flange frame.

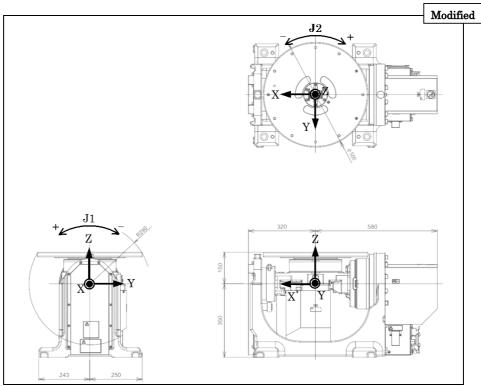


Figure 4.2.2 (d) Arc positioner world frame

Title	R-30 <i>i</i> B Mate Plus/R-30 <i>i</i> B Mini Plus CONTROLLER	Ed 1	Draw	B-83484EN/03-001	
	Corrected the figure of the ARC Positioner TCP frame	Date 2022. 9/26	FA	NUC CORPORATION	Sheet 2/3

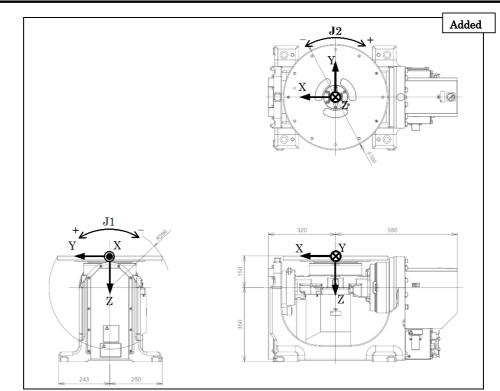


Figure 4.2.2 (e) Arc positioner flange frame

[Version history]

Ed	Date	Description
01	2022/09/26	The first edition registration

Title	FANUC Robot series R-30 <i>i</i> B/R-30 <i>i</i> B Mate/R-30 <i>i</i> B Plus/ R-30 <i>i</i> B Mate Plus/R-30 <i>i</i> B Mini Plus CONTROLLER Title Coordinated Motion Function OPERATOR'S MANUAL	Ed 1	Draw	Draw B-83484EN/03-001	
	Corrected the figure of the ARC Positioner TCP frame	Date 2022. 9/26	FA	NUC CORPORATION	Sheet 3/3

B-83484EN/03 INDEX

INDEX

A	KINEMATICS PARAMETERS OF POSITIONER 12 Kinematics Parameters of Positioner (A05B-2600-H896) 12
ArcTool Tool Frame Six Point Method 34 AXIS ASSIGNMENT TO POSITIONER WORLD FRAME 10	KINEMATICS TYPE 9 KNOWN DIRECT CALIBRATION 31
Axis Offset (A05B-2600-H896 Positioner Only) 3	KNOWN FOUR POINT CALIBRATION 25 Known Four Point Calibration Guidelines 25
В	Known Four Point Calibration Procedure 29 KNOWN FOUR POINT CALIBRATION VS UNKNOWN
BENEFITS 1	POINT CALIBRATION 24
C	L
CALIBRATION 23 CALIBRATION ERRORS 97 Calibration Type Selection 40 CD JOGGING OUTPUT 78 CIRCULAR MOTION PROGRAMMING 86 Clear the CD_Frames 61 COMPARISON WITH SIMULTANEOUS MOTION 1 COORD COORDINATED MOTION OPTION 82 COORD-MOTION/HIGH SPEED MOTION ADD-ON 7 COORD[LDR] COORDINATED MOTION OPTION 82 Coordinated Frame 3	LEADER FRAME JOG FOR FOLLOWER GROUP 73 Leader Frame Setup 52 LEADER FRAME SETUP 51 Leader Group 2 LEADER GROUP JOGGING (COORDINATED, FIXED ORIENTATION COORDINATED) 71 Leader UFRAME 5 Leader UTOOL 5 Leader World Frame 5 Limitations 63 Linear Axis 3 LINEAR MOTION PROGRAMMING 85
D	M
Details Screen of the Recorded CD_Frame 62 Display the Recorded CD Frame List Screen 59 DYNAMIC UFRAME 89 DYNAMIC UFRAME RESTRICTIONS 91	Motion Group 2 MULTIPLE COORD FRAMES FOR ONE CD_PAIR 57
	N
E	NOTES/RESTRICTIONS 65
ENABLE DISABLE MULTIPLE COORD FRAMES 57 Enabling Toggle Coordinate Orientation 70 ERROR CODES 98	0
Error Message 64 Example of How to Use SET_COORD_FRAME.PC 64	OFFSET AND VOFFSET INSTRUCTION 92 OPERATION 2 OVERVIEW 1
F	P
Follower Group 2 Follower UFRAME 4 Follower UTOOL 4	POSITIONER SETTING 9 PROGRAM HEADER INFORMATION 81 programming
J	overview 81 PROGRAMMING 81
JOGGING 69 JOGGING DESIGNATION 69 JOGGING EXAMPLES 74	PROGRAMMING DYNAMIC UFRAME 91 PROGRAMMING OVERVIEW 81
JOGGING OVERVIEW 69 JOGGING PROCEDURE 75	R
Jogging Using Coordinated Motion 75	RELATIVE AND SIMULTANEOUS COORDINATED MOTION 67
K	Restore the CD_Frame 61 Restriction 7
Kinematics Parameters of General Positioner (A05B-2600-H874) 13	RESTRICTIONS AND GUIDELINES 19 RESTRICTIONS OF COORDINATED MOTION 6

INDEX B-83484EN/03

Rotary Axis 3

S

Save the CD Frame 60
SELECTING CD_PAIRS 20
Setting CD Jogging Output 78
SETTING DYNAMIC UFRAME 90
SETTING UP COORDINATED PAIRS 19
SETTING UP COORDINATED PAIRS OVERVIEW 19
SETUP SCREEN OF MULTIPLE COORD FRAMES 59
SETUP STEPS 5
SPEED DEFINITION 85
SUPPORTED OPTIONS 6
SWITCHING THE CD_FRAME BY KAREL PROGRAM 63

T

TERMINOLOGY 2
TROUBLESHOOTING 97
TROUBLESHOOTING OVERVIEW 97

U

Unknown Point Calibration for a Linear Axis 48 Unknown Point Calibration for a Rotary Axis 42 UNKNOWN POINT CALIBRATION FOR POSITIONERS (INCLUDING GENERAL POSITIONERS) 33

\mathbf{W}

World Frame of FANUC Positioners 26

REVISION RECORD

REVISION RECORD

Edition	Date	Contents
03	Jul., 2022	 Changed chapter structure. Added new feature "1.8 COORD-MOTION/HIGH SPEED MOTION ADD-ON" Added new feature "5 MULTIPLE COORD FRAMES FOR ONE CD_PAIR"
02	Oct., 2013	 Applied to R-30iB Mate Modify the description of Unknown point calibration. Add the description of setting iRCalibration Multi-Group.
01	Oct., 2012	

B-83484EN/03

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