FANUC America Corporation SYSTEM R-30*i*B Controller Coordinated Motion Setup and Operations Manual

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Applies to software version 8.10 and higher.

About This Manual

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Patents

One or more of the following U.S. patents might be related to the FANUC America products described in this manual.

FRA Patent List

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VersaBell, ServoBell and SpeedDock Patents Pending.

Conventions

This manual includes information essential to the safety of personnel, equipment, software, and data. This information is indicated by headings and boxes in the text.

Warning

Information appearing under WARNING concerns the protection of personnel. It is boxed and in bold type to set it apart from other text.

Caution

Information appearing under **CAUTION** concerns the protection of equipment, software, and data. It is boxed to set it apart from other text.

Note Information appearing next to **NOTE** concerns related information or useful hints.

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Safety

FANUC America Corporation is not and does not represent itself as an expert in safety systems, safety equipment, or the specific safety aspects of your company and/or its work force. It is the responsibility of the owner, employer, or user to take all necessary steps to guarantee the safety of all personnel in the workplace.

The appropriate level of safety for your application and installation can best be determined by safety system professionals. FANUC America Corporation therefore, recommends that each customer consult with such professionals in order to provide a workplace that allows for the safe application, use, and operation of FANUC America Corporation systems.

According to the industry standard ANSI/RIA R15-06, the owner or user is advised to consult the standards to ensure compliance with its requests for Robotics System design, usability, operation, maintenance, and service. Additionally, as the owner, employer, or user of a robotic system, it is your responsibility to arrange for the training of the operator of a robot system to recognize and respond to known hazards associated with your robotic system and to be aware of the recommended operating procedures for your particular application and robot installation.

Ensure that the robot being used is appropriate for the application. Robots used in classified (hazardous) locations must be certified for this use.

FANUC America Corporation therefore, recommends that all personnel who intend to operate, program, repair, or otherwise use the robotics system be trained in an approved FANUC America Corporation training course and become familiar with the proper operation of the system. Persons responsible for programming the system-including the design, implementation, and debugging of application programs-must be familiar with the recommended programming procedures for your application and robot installation.

The following guidelines are provided to emphasize the importance of safety in the workplace.

CONSIDERING SAFETY FOR YOUR ROBOT INSTALLATION

Safety is essential whenever robots are used. Keep in mind the following factors with regard to safety:

- The safety of people and equipment
- Use of safety enhancing devices
- Techniques for safe teaching and manual operation of the robot(s)
- Techniques for safe automatic operation of the robot(s)
- Regular scheduled inspection of the robot and workcell
- Proper maintenance of the robot

Keeping People Safe

The safety of people is always of primary importance in any situation. When applying safety measures to your robotic system, consider the following:

- External devices
- Robot(s)
- Tooling
- Workpiece

Using Safety Enhancing Devices

Always give appropriate attention to the work area that surrounds the robot. The safety of the work area can be enhanced by the installation of some or all of the following devices:

- Safety fences, barriers, or chains
- Light curtains
- Interlocks
- Pressure mats
- Floor markings
- Warning lights
- Mechanical stops
- EMERGENCY STOP buttons
- DEADMAN switches

Setting Up a Safe Workcell

A safe workcell is essential to protect people and equipment. Observe the following guidelines to ensure that the workcell is set up safely. These suggestions are intended to supplement and **not** replace existing federal, state, and local laws, regulations, and guidelines that pertain to safety.

- Sponsor your personnel for training in approved FANUC America Corporation training course(s) related to your application. Never permit untrained personnel to operate the robots.
- Install a lockout device that uses an access code to prevent unauthorized persons from operating the robot.
- Use anti-tie-down logic to prevent the operator from bypassing safety measures.
- Arrange the workcell so the operator faces the workcell and can see what is going on inside the cell.

- Clearly identify the work envelope of each robot in the system with floor markings, signs, and special barriers. The work envelope is the area defined by the maximum motion range of the robot, including any tooling attached to the wrist flange that extend this range.
- Position all controllers outside the robot work envelope.
- Never rely on software or firmware based controllers as the primary safety element unless they comply with applicable current robot safety standards.
- Mount an adequate number of EMERGENCY STOP buttons or switches within easy reach of the operator and at critical points inside and around the outside of the workcell.
- Install flashing lights and/or audible warning devices that activate whenever the robot is operating, that is, whenever power is applied to the servo drive system. Audible warning devices shall exceed the ambient noise level at the end-use application.
- Wherever possible, install safety fences to protect against unauthorized entry by personnel into the work envelope.
- Install special guarding that prevents the operator from reaching into restricted areas of the work envelope.
- Use interlocks.
- Use presence or proximity sensing devices such as light curtains, mats, and capacitance and vision systems to enhance safety.
- Periodically check the safety joints or safety clutches that can be optionally installed between the robot wrist flange and tooling. If the tooling strikes an object, these devices dislodge, remove power from the system, and help to minimize damage to the tooling and robot.
- Make sure all external devices are properly filtered, grounded, shielded, and suppressed to prevent hazardous motion due to the effects of electro-magnetic interference (EMI), radio frequency interference (RFI), and electro-static discharge (ESD).
- Make provisions for power lockout/tagout at the controller.
- Eliminate *pinch points* . Pinch points are areas where personnel could get trapped between a moving robot and other equipment.
- Provide enough room inside the workcell to permit personnel to teach the robot and perform maintenance safely.
- Program the robot to load and unload material safely.
- If high voltage electrostatics are present, be sure to provide appropriate interlocks, warning, and beacons.
- If materials are being applied at dangerously high pressure, provide electrical interlocks for lockout of material flow and pressure.

Staying Safe While Teaching or Manually Operating the Robot

Advise all personnel who must teach the robot or otherwise manually operate the robot to observe the following rules:

- Never wear watches, rings, neckties, scarves, or loose clothing that could get caught in moving machinery.
- Know whether or not you are using an intrinsically safe teach pendant if you are working in a hazardous environment.
- Before teaching, visually inspect the robot and *work envelope* to make sure that no potentially hazardous conditions exist. The work envelope is the area defined by the maximum motion range of the robot. These include tooling attached to the wrist flange that extends this range.
- The area near the robot must be clean and free of oil, water, or debris. Immediately report unsafe working conditions to the supervisor or safety department.
- FANUC America Corporation recommends that no one enter the work envelope of a robot that is on, except for robot teaching operations. However, if you must enter the work envelope, be sure all safeguards are in place, check the teach pendant DEADMAN switch for proper operation, and place the robot in teach mode. Take the teach pendant with you, turn it on, and be prepared to release the DEADMAN switch. Only the person with the teach pendant should be in the work envelope.

> **Warning**
>
> **Never bypass, strap, or otherwise deactivate a safety device, such as a limit switch, for any operational convenience. Deactivating a safety device is known to have resulted in serious injury and death.**

- Know the path that can be used to escape from a moving robot; make sure the escape path is never blocked.
- Isolate the robot from all remote control signals that can cause motion while data is being taught.
- Test any program being run for the first time in the following manner:

> **Warning**
>
> **Stay outside the robot work envelope whenever a program is being run. Failure to do so can result in injury.**

  — Using a low motion speed, single step the program for at least one full cycle.

  — Using a low motion speed, test run the program continuously for at least one full cycle.

  — Using the programmed speed, test run the program continuously for at least one full cycle.

- Make sure all personnel are outside the work envelope before running production.

Staying Safe During Automatic Operation

Advise all personnel who operate the robot during production to observe the following rules:

- Make sure all safety provisions are present and active.
- Know the entire workcell area. The workcell includes the robot and its work envelope, plus the area occupied by all external devices and other equipment with which the robot interacts.
- Understand the complete task the robot is programmed to perform before initiating automatic operation.
- Make sure all personnel are outside the work envelope before operating the robot.
- Never enter or allow others to enter the work envelope during automatic operation of the robot.
- Know the location and status of all switches, sensors, and control signals that could cause the robot to move.
- Know where the EMERGENCY STOP buttons are located on both the robot control and external control devices. Be prepared to press these buttons in an emergency.
- Never assume that a program is complete if the robot is not moving. The robot could be waiting for an input signal that will permit it to continue activity.
- If the robot is running in a pattern, do not assume it will continue to run in the same pattern.
- Never try to stop the robot, or break its motion, with your body. The only way to stop robot motion immediately is to press an EMERGENCY STOP button located on the controller panel, teach pendant, or emergency stop stations around the workcell.

Staying Safe During Inspection

When inspecting the robot, be sure to

- Turn off power at the controller.
- Lock out and tag out the power source at the controller according to the policies of your plant.
- Turn off the compressed air source and relieve the air pressure.
- If robot motion is not needed for inspecting the electrical circuits, press the EMERGENCY STOP button on the operator panel.
- Never wear watches, rings, neckties, scarves, or loose clothing that could get caught in moving machinery.
- If power is needed to check the robot motion or electrical circuits, be prepared to press the EMERGENCY STOP button, in an emergency.
- Be aware that when you remove a servomotor or brake, the associated robot arm will fall if it is not supported or resting on a hard stop. Support the arm on a solid support before you release the brake.

Staying Safe During Maintenance

When performing maintenance on your robot system, observe the following rules:

- Never enter the work envelope while the robot or a program is in operation.
- Before entering the work envelope, visually inspect the workcell to make sure no potentially hazardous conditions exist.
- Never wear watches, rings, neckties, scarves, or loose clothing that could get caught in moving machinery.
- Consider all or any overlapping work envelopes of adjoining robots when standing in a work envelope.
- Test the teach pendant for proper operation before entering the work envelope.
- If it is necessary for you to enter the robot work envelope while power is turned on, you must be sure that you are in control of the robot. Be sure to take the teach pendant with you, press the DEADMAN switch, and turn the teach pendant on. Be prepared to release the DEADMAN switch to turn off servo power to the robot immediately.
- Whenever possible, perform maintenance with the power turned off. Before you open the controller front panel or enter the work envelope, turn off and lock out the 3-phase power source at the controller.
- Be aware that an applicator bell cup can continue to spin at a very high speed even if the robot is idle. Use protective gloves or disable bearing air and turbine air before servicing these items.
- Be aware that when you remove a servomotor or brake, the associated robot arm will fall if it is not supported or resting on a hard stop. Support the arm on a solid support before you release the brake.

Warning

Lethal voltage is present in the controller WHENEVER IT IS CONNECTED to a power source. Be extremely careful to avoid electrical shock. HIGH VOLTAGE IS PRESENT at the input side whenever the controller is connected to a power source. Turning the disconnect or circuit breaker to the OFF position removes power from the output side of the device only.

- Release or block all stored energy. Before working on the pneumatic system, shut off the system air supply and purge the air lines.
- Isolate the robot from all remote control signals. If maintenance must be done when the power is on, make sure the person inside the work envelope has sole control of the robot. The teach pendant must be held by this person.

- Make sure personnel cannot get trapped between the moving robot and other equipment. Know the path that can be used to escape from a moving robot. Make sure the escape route is never blocked.
- Use blocks, mechanical stops, and pins to prevent hazardous movement by the robot. Make sure that such devices do not create pinch points that could trap personnel.

Warning

Do not try to remove any mechanical component from the robot before thoroughly reading and understanding the procedures in the appropriate manual. Doing so can result in serious personal injury and component destruction.

- Be aware that when you remove a servomotor or brake, the associated robot arm will fall if it is not supported or resting on a hard stop. Support the arm on a solid support before you release the brake.
- When replacing or installing components, make sure dirt and debris do not enter the system.
- Use only specified parts for replacement. To avoid fires and damage to parts in the controller, never use nonspecified fuses.
- Before restarting a robot, make sure no one is inside the work envelope; be sure that the robot and all external devices are operating normally.

KEEPING MACHINE TOOLS AND EXTERNAL DEVICES SAFE

Certain programming and mechanical measures are useful in keeping the machine tools and other external devices safe. Some of these measures are outlined below. Make sure you know all associated measures for safe use of such devices.

Programming Safety Precautions

Implement the following programming safety measures to prevent damage to machine tools and other external devices.

- Back-check limit switches in the workcell to make sure they do not fail.
- Implement “failure routines” in programs that will provide appropriate robot actions if an external device or another robot in the workcell fails.
- Use *handshaking* protocol to synchronize robot and external device operations.
- Program the robot to check the condition of all external devices during an operating cycle.

Mechanical Safety Precautions

Implement the following mechanical safety measures to prevent damage to machine tools and other external devices.

- Make sure the workcell is clean and free of oil, water, and debris.
- Use DCS (Dual Check Safety), software limits, limit switches, and mechanical hardstops to prevent undesired movement of the robot into the work area of machine tools and external devices.

KEEPING THE ROBOT SAFE

Observe the following operating and programming guidelines to prevent damage to the robot.

Operating Safety Precautions

The following measures are designed to prevent damage to the robot during operation.

- Use a low override speed to increase your control over the robot when jogging the robot.
- Visualize the movement the robot will make before you press the jog keys on the teach pendant.
- Make sure the work envelope is clean and free of oil, water, or debris.
- Use circuit breakers to guard against electrical overload.

Programming Safety Precautions

The following safety measures are designed to prevent damage to the robot during programming:

- Establish *interference zones* to prevent collisions when two or more robots share a work area.
- Make sure that the program ends with the robot near or at the home position.
- Be aware of signals or other operations that could trigger operation of tooling resulting in personal injury or equipment damage.
- In dispensing applications, be aware of all safety guidelines with respect to the dispensing materials.

Note Any deviation from the methods and safety practices described in this manual must conform to the approved standards of your company. If you have questions, see your supervisor.

ADDITIONAL SAFETY CONSIDERATIONS FOR PAINT ROBOT INSTALLATIONS

Process technicians are sometimes required to enter the paint booth, for example, during daily or routine calibration or while teaching new paths to a robot. Maintenance personal also must work inside the paint booth periodically.

Whenever personnel are working inside the paint booth, ventilation equipment must be used. Instruction on the proper use of ventilating equipment usually is provided by the paint shop supervisor.

Although paint booth hazards have been minimized, potential dangers still exist. Therefore, today's highly automated paint booth requires that process and maintenance personnel have full awareness of the system and its capabilities. They must understand the interaction that occurs between the vehicle moving along the conveyor and the robot(s), hood/deck and door opening devices, and high-voltage electrostatic tools.

Caution

Ensure that all ground cables remain connected. Never operate the paint robot with ground provisions disconnected. Otherwise, you could injure personnel or damage equipment.

Paint robots are operated in three modes:

- Teach or manual mode
- Automatic mode, including automatic and exercise operation
- Diagnostic mode

During both teach and automatic modes, the robots in the paint booth will follow a predetermined pattern of movements. In teach mode, the process technician teaches (programs) paint paths using the teach pendant.

In automatic mode, robot operation is initiated at the System Operator Console (SOC) or Manual Control Panel (MCP), if available, and can be monitored from outside the paint booth. All personnel must remain outside of the booth or in a designated safe area within the booth whenever automatic mode is initiated at the SOC or MCP.

In automatic mode, the robots will execute the path movements they were taught during teach mode, but generally at production speeds.

When process and maintenance personnel run diagnostic routines that require them to remain in the paint booth, they must stay in a designated safe area.

Paint System Safety Features

Process technicians and maintenance personnel must become totally familiar with the equipment and its capabilities. To minimize the risk of injury when working near robots and related equipment, personnel must comply strictly with the procedures in the manuals.

This section provides information about the safety features that are included in the paint system and also explains the way the robot interacts with other equipment in the system.

The paint system includes the following safety features:

- Most paint booths have red warning beacons that illuminate when the robots are armed and ready to paint. Your booth might have other kinds of indicators. Learn what these are.
- Some paint booths have a blue beacon that, when illuminated, indicates that the electrostatic devices are enabled. Your booth might have other kinds of indicators. Learn what these are.
- EMERGENCY STOP buttons are located on the robot controller and teach pendant. Become familiar with the locations of all E-STOP buttons.
- An intrinsically safe teach pendant is used when teaching in hazardous paint atmospheres.
- A DEADMAN switch is located on each teach pendant. When this switch is held in, and the teach pendant is on, power is applied to the robot servo system. If the engaged DEADMAN switch is released during robot operation, power is removed from the servo system, all axis brakes are applied, and the robot comes to an EMERGENCY STOP. Safety interlocks within the system might also E-STOP other robots.

Warning

An EMERGENCY STOP will occur if the DEADMAN switch is released on a bypassed robot.

- Overtravel by robot axes is prevented by software limits. All of the major and minor axes are governed by software limits. DCS (Dual Check Safety), limit switches and hardstops also limit travel by the major axes.
- EMERGENCY STOP limit switches and photoelectric eyes might be part of your system. Limit switches, located on the entrance/exit doors of each booth, will EMERGENCY STOP all equipment in the booth if a door is opened while the system is operating in automatic or manual mode. For some systems, signals to these switches are inactive when the switch on the SOC is

in teach mode.When present, photoelectric eyes are sometimes used to monitor unauthorized intrusion through the entrance/exit silhouette openings.

- System status is monitored by computer. Severe conditions result in automatic system shutdown.

Staying Safe While Operating the Paint Robot

When you work in or near the paint booth, observe the following rules, in addition to all rules for safe operation that apply to all robot systems.

Warning

Observe all safety rules and guidelines to avoid injury.

Warning

Never bypass, strap, or otherwise deactivate a safety device, such as a limit switch, for any operational convenience. Deactivating a safety device is known to have resulted in serious injury and death.

Warning

Enclosures shall not be opened unless the area is known to be nonhazardous or all power has been removed from devices within the enclosure. Power shall not be restored after the enclosure has been opened until all combustible dusts have been removed from the interior of the enclosure and the enclosure purged. Refer to the Purge chapter for the required purge time.

- Know the work area of the entire paint station (workcell).
- Know the work envelope of the robot and hood/deck and door opening devices.
- Be aware of overlapping work envelopes of adjacent robots.
- Know where all red, mushroom-shaped EMERGENCY STOP buttons are located.
- Know the location and status of all switches, sensors, and/or control signals that might cause the robot, conveyor, and opening devices to move.
- Make sure that the work area near the robot is clean and free of water, oil, and debris. Report unsafe conditions to your supervisor.
- Become familiar with the complete task the robot will perform BEFORE starting automatic mode.

- Make sure all personnel are outside the paint booth before you turn on power to the robot servo system.
- Never enter the work envelope or paint booth before you turn off power to the robot servo system.
- Never enter the work envelope during automatic operation unless a safe area has been designated.
- Never wear watches, rings, neckties, scarves, or loose clothing that could get caught in moving machinery.
- Remove all metallic objects, such as rings, watches, and belts, before entering a booth when the electrostatic devices are enabled.
- Stay out of areas where you might get trapped between a moving robot, conveyor, or opening device and another object.
- Be aware of signals and/or operations that could result in the triggering of guns or bells.
- Be aware of all safety precautions when dispensing of paint is required.
- Follow the procedures described in this manual.

Special Precautions for Combustible Dusts (powder paint)

When the robot is used in a location where combustible dusts are found, such as the application of powder paint, the following special precautions are required to insure that there are no combustible dusts inside the robot.

- Purge maintenance air should be maintained at all times, even when the robot power is off. This will insure that dust can not enter the robot.
- A purge cycle will not remove accumulated dusts. Therefore, if the robot is exposed to dust when maintenance air is not present, it will be necessary to remove the covers and clean out any accumulated dust. Do not energize the robot until you have performed the following steps.

1. Before covers are removed, the exterior of the robot should be cleaned to remove accumulated dust.
2. When cleaning and removing accumulated dust, either on the outside or inside of the robot, be sure to use methods appropriate for the type of dust that exists. Usually lint free rags dampened with water are acceptable. Do not use a vacuum cleaner to remove dust as it can generate static electricity and cause an explosion unless special precautions are taken.
3. Thoroughly clean the interior of the robot with a lint free rag to remove any accumulated dust.
4. When the dust has been removed, the covers must be replaced immediately.
5. Immediately after the covers are replaced, run a complete purge cycle. The robot can now be energized.

Staying Safe While Operating Paint Application Equipment

When you work with paint application equipment, observe the following rules, in addition to all rules for safe operation that apply to all robot systems.

> **Warning**
>
> **When working with electrostatic paint equipment, follow all national and local codes as well as all safety guidelines within your organization. Also reference the following standards: *NFPA 33 Standards for Spray Application Using Flammable or Combustible Materials* , and *NFPA 70 National Electrical Code* .**

- **Grounding**: All electrically conductive objects in the spray area must be grounded. This includes the spray booth, robots, conveyors, workstations, part carriers, hooks, paint pressure pots, as well as solvent containers. Grounding is defined as the object or objects shall be electrically connected to ground with a resistance of not more than 1 megohms.
- **High Voltage**: High voltage should only be on during actual spray operations. Voltage should be off when the painting process is completed. Never leave high voltage on during a cap cleaning process.
- Avoid any accumulation of combustible vapors or coating matter.
- Follow all manufacturer recommended cleaning procedures.
- Make sure all interlocks are operational.
- No smoking.
- Post all warning signs regarding the electrostatic equipment and operation of electrostatic equipment according to NFPA 33 Standard for Spray Application Using Flammable or Combustible Material.
- Disable all air and paint pressure to bell.
- Verify that the lines are not under pressure.

Staying Safe During Maintenance

When you perform maintenance on the painter system, observe the following rules, and all other maintenance safety rules that apply to all robot installations. Only qualified, trained service or maintenance personnel should perform repair work on a robot.

- Paint robots operate in a potentially explosive environment. Use caution when working with electric tools.
- When a maintenance technician is repairing or adjusting a robot, the work area is under the control of that technician. All personnel not participating in the maintenance must stay out of the area.

- For some maintenance procedures, station a second person at the control panel within reach of the EMERGENCY STOP button. This person must understand the robot and associated potential hazards.
- Be sure all covers and inspection plates are in good repair and in place.
- Always return the robot to the ‘‘home’’ position before you disarm it.
- Never use machine power to aid in removing any component from the robot.
- During robot operations, be aware of the robot’s movements. Excess vibration, unusual sounds, and so forth, can alert you to potential problems.
- Whenever possible, turn off the main electrical disconnect before you clean the robot.
- When using vinyl resin observe the following:
  - — Wear eye protection and protective gloves during application and removal
  - — Adequate ventilation is required. Overexposure could cause drowsiness or skin and eye irritation.
  - — If there is contact with the skin, wash with water.
  - — Follow the Original Equipment Manufacturer’s Material Safety Data Sheets.
- When using paint remover observe the following:
  - — Eye protection, protective rubber gloves, boots, and apron are required during booth cleaning.
  - — Adequate ventilation is required. Overexposure could cause drowsiness.
  - — If there is contact with the skin or eyes, rinse with water for at least 15 minutes. Then, seek medical attention as soon as possible.
  - — Follow the Original Equipment Manufacturer’s Material Safety Data Sheets.

Chapter 1

OVERVIEW

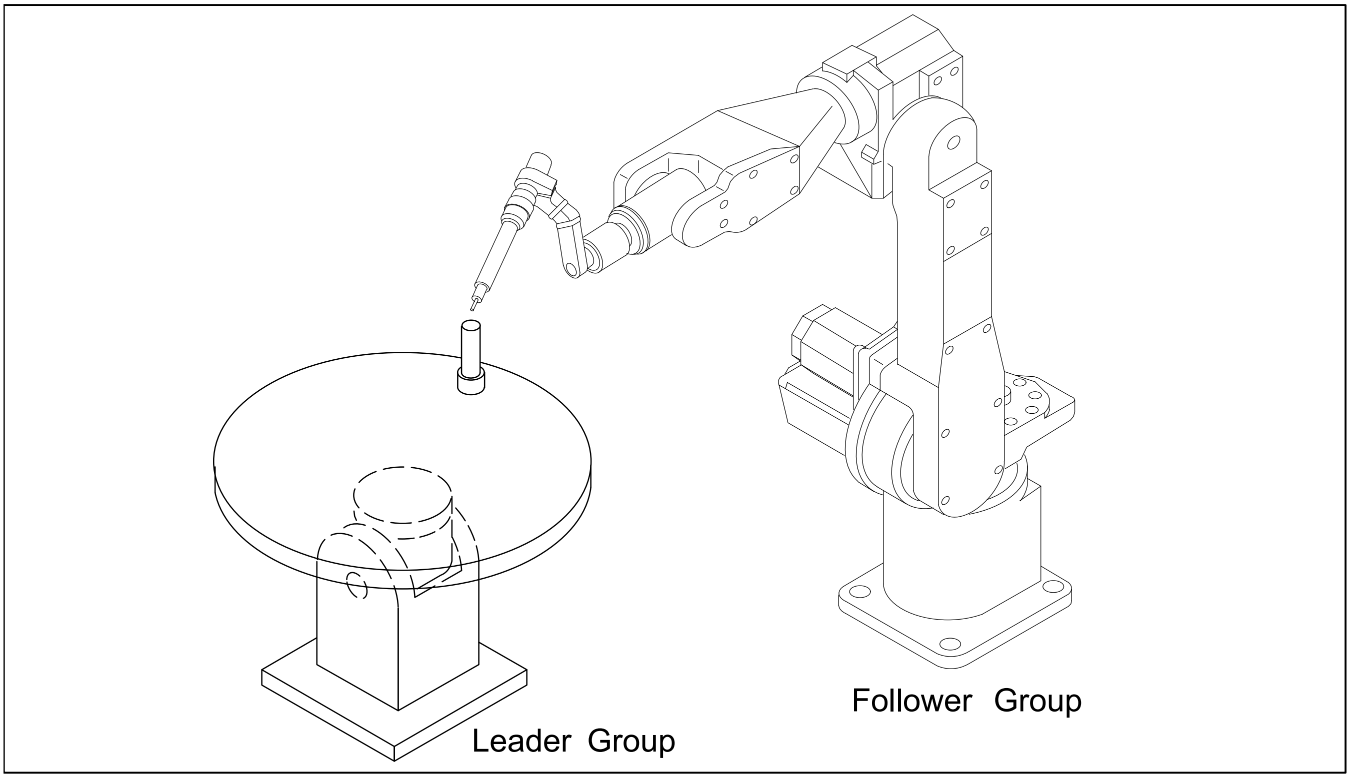
Contents

1.1 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 1–1 .

Figure 1–1. Coordinated Motion Overview



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.

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.
- 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.

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 America Corporation 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*. FANUC America Corporation supports a standard positioner (AMHS500), and a generic type positioner. The positioner can consist of 1-6 axes that can be linear, rotary, or a combination of both. The General Positioner is an extended version of the Positioner. Unlike the Positioner, the axes of a general positioner can be set up at any angle.

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)

1.2 TERMINOLOGY

1.2.1 Overview

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.

1.2.2 Motion Group

A motion group defines a set of motors and axes that are combined to accomplish a motion task. FANUC America Corporation 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 additional motion group can have

- Up to six motors
- Up to three extended axes

Up to four full kinematics devices (robot mechanical units) are supported on one controller

You cannot exceed nine axes per robot motion group; you cannot exceed four axes per non-robot motion group.

- Up to four non-robot motion groups can be defined. The maximum number includes extended axes. This includes General Positioner, Basic Positioner, and Independent Axis devices.
- One to three extended axes can be added to a motion group. The axes cannot be used independently of the motion group.
- Each extended axis adds a position data field (E1, E2, E3) to the motion group data.
- The Index axis device is one axes by definition and the Arc Positioner device is a two-axis motion group device. Neither of these can have additional axes installed.

Note The limitation of a maximum of two Index Devices has been removed

When you use coordinated motion, the "coordination" that is performed is between two motion groups.

1.2.3 Leader Group

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

1.2.4 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.

There are cases where multiple robot followers will be present in a robot program. If the part paths are identical or mirrored (ie. 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.)

1.2.5 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.

1.2.6 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.

1.2.7 Axis Offset

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. The offsets are calculated automatically when unknown kinematic calibration is performed.

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

1.2.8 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.

1.2.9 Follower UFRAME

The follower UFRAME 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 (user frame) 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 Leader Frame Setup section of the *Coordinated Motion Setup and Operations Manual* 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.

1.2.10 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* for more information.

Use the 6-point method to define UTOOL. Ensure that you have defined the UTOOL correctly prior to CD_pair calibration or programming.

1.2.11 Leader UTOOL

The leader UTOOL currently has no function in coordinated motion.

1.2.12 Leader UFRAME

The leader UFRAME currently has no function in coordinated motion.

1.2.13 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 1.2.8 for more information.

1.3 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 AMHS500) have data files supplied for automatic setup. Refer to Chapter 2 *INSTALLATION* for more information.
3. Install the multi-group motion software option.

   Refer to the *Software Installation Manual* for more information.
4. Install the coordinated motion software option.

   Refer to Chapter 2 *INSTALLATION* .

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* 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 5 *JOGGING* .
10. Create coordinated motion teach pendant programs.

    Refer to Chapter 6 *PROGRAMMING* .
11. Test coordinated motion programs.

    Refer to the appropriate application-specific *FANUC America Corporation Setup and Operations Manual.*
12. Run production with coordinated motion programs.

    Refer to the appropriate application-specific *FANUC America Corporation Setup and Operations Manual.*
13. Troubleshoot any problems.

    Refer to Chapter 7 *TROUBLESHOOTING* .

Chapter 2

INSTALLATION

Contents

2.1 OVERVIEW

Before you can set up or use coordinated motion, you must install coordinated motion software and hardware. This chapter describes how to install the software necessary to use coordinated motion.

Refer to the *FANUC America Software Installation Manual* for information on how to install the hardware associated with motion groups and extended axes when you use coordinated motion.

Note If your robotic system has extended axes on Group 1, they must start at the next axis following the robot (this is typically axis 7) and before any multi-group axes. Similarly, if an extended axis is to be added to Group 2, it should be added sequentially after group 2, and before any group 3 axes have been added, and so forth.

2.2 INSTALLATION CONCEPTS

2.2.1 Overview

In order to perform a proper installation, you must make several selections to define the axes of the leader group. This section contains descriptions of some of the key concepts you must understand to define the axes properly during installation:

For Standard Positioners:

- Kinematics type
- Axis arrangement, direction, assignment
- Axis offsets for known kinematics types
- Illegal axis configurations

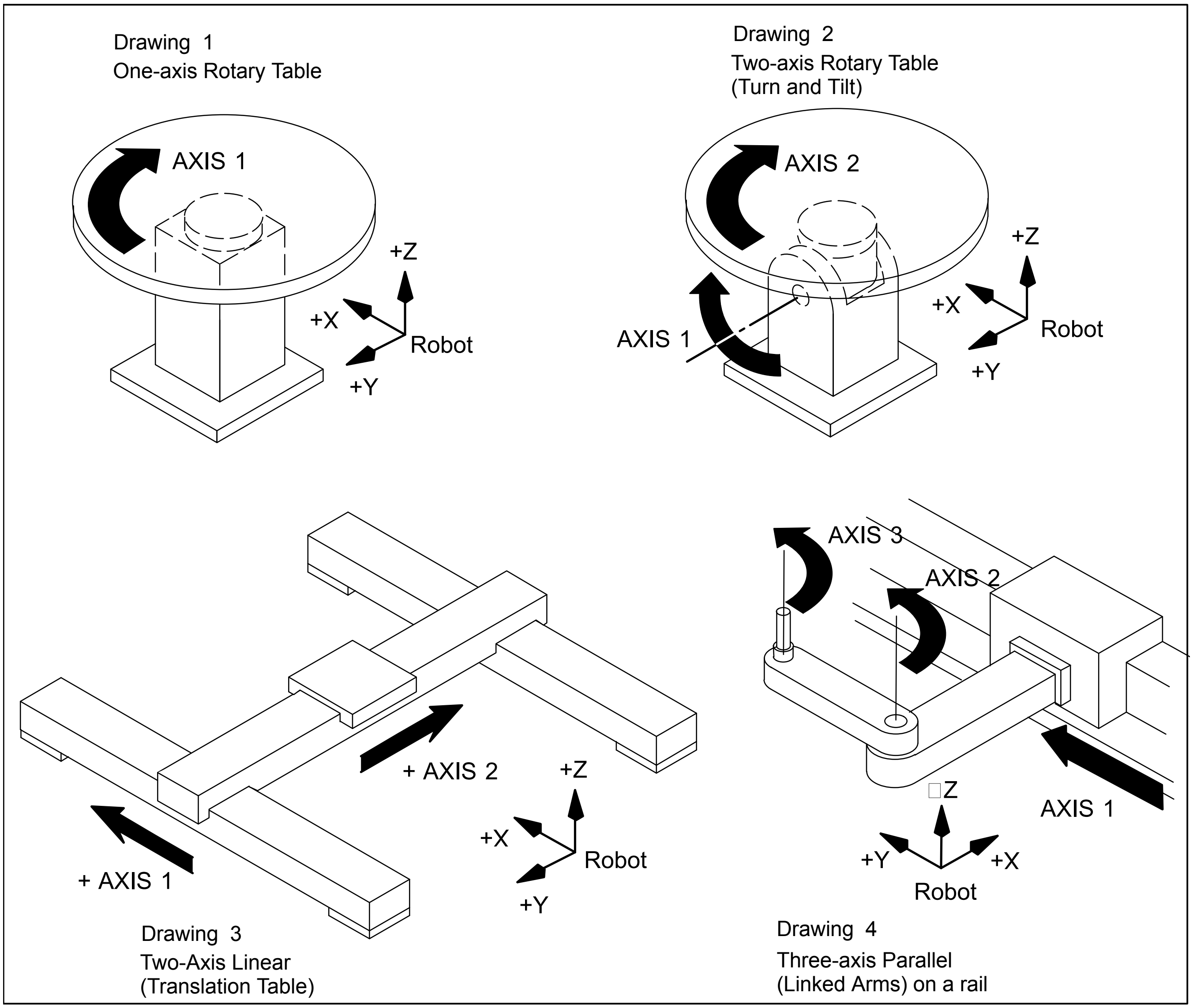
For General Positioners:

- Kinematics type
- D-H (Denavit-Hartenberg) parameters for known kinematics types

  Note For general positioners, you should always use unknown kinematics type unless you need to restore backed up calibration data.

Figure 2–1 contains examples of leader devices you might install. Note that the "Robot" axes demonstrate one possible robot location. Choose the robot location based on your positioner and application.

Figure 2–1. Leader Device Examples



2.2.2 Kinematics Type

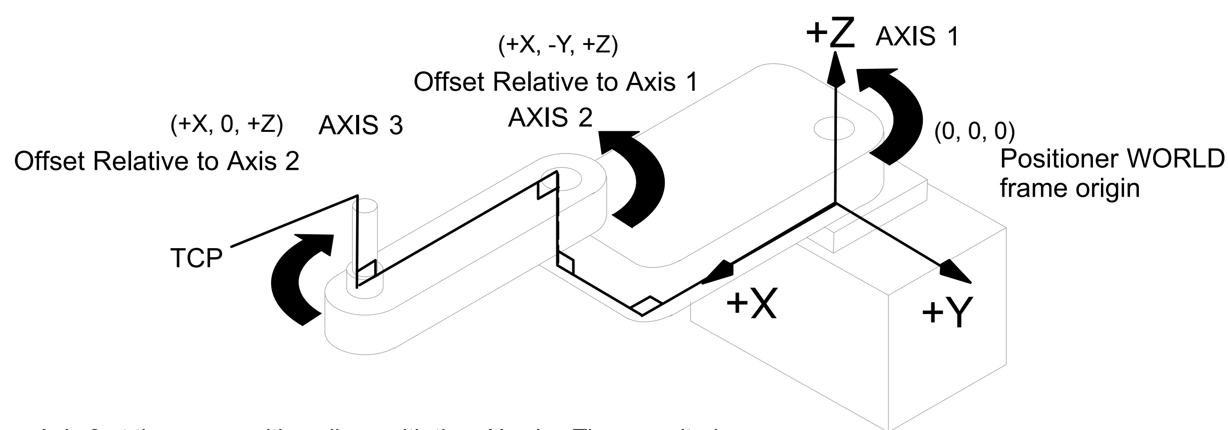
Kinematics defines how a positioner or a general positioner will move in Cartesian space (x, y, and z) when the motors (axes) are turned. This is determined by the Cartesian offset information of each axis to the next axis, and the gear ratios supplied during positioner axis installation.

During installation, you must select the kinematics type. You can perform two kinds of setup, depending on whether the kinematic information is known accurately:

- For a **known kinematics type**, the dimensions of the positioner axes are known exactly. In this case, the offset information will be requested during axis setup. For general positioners, D-H parameters are needed during axis setup. This also includes the case of setting up a system in which calibration data is already known, such as when you upgrade software.
- For an **unknown kinematics type**, the dimensions of the positioner axes are not known. In this case, the offset information will be calculated in the calibration procedure. This is the most common case.

See Figure 2–2 for a description of the offset information involved in determining whether the kinematics type is known or unknown. In Figure 2–2 , x, y, and z are in the frame of the positioner and all axes are at their 0°positions.

Figure 2–2. Known Kinematics Type and Offsets



Note: Axis 2 at the zero position aligns with the +X axis. The magnitude of the offsets and direction are relative to the leader (positioner) frame. This device has three motors and axis 3 rotates.

Note The location of the positioner (0,0,0) WORLD frame must be known relative to the robot WORLD origin.

Note Assign axes and axes direction (+/-) in the most convenient manner for your hardware and application setup and operation.

2.2.3 Axis Arrangement, Direction, and Assignment

During installation of a positioner, you must define the axis arrangement, direction, and assignment of the leader group axes. The positioner (leader) frame is not dependent on the location and orientation of the robot (follower) WORLD frame. The transformation from the robot frame to the positioner frame is determined during CD_pair calibration.

Note Axis arrangement, direction, and assignment is necessary for existing positioners only, not general positioners.

You must assign an axis and direction (x, y, z, -x, -y, or -z) to each positioner axis. Assigning an axis of the positioner frame to the positioner physical axis determines how motion of the follower will be coordinated to the leader motion. In this installation, you must

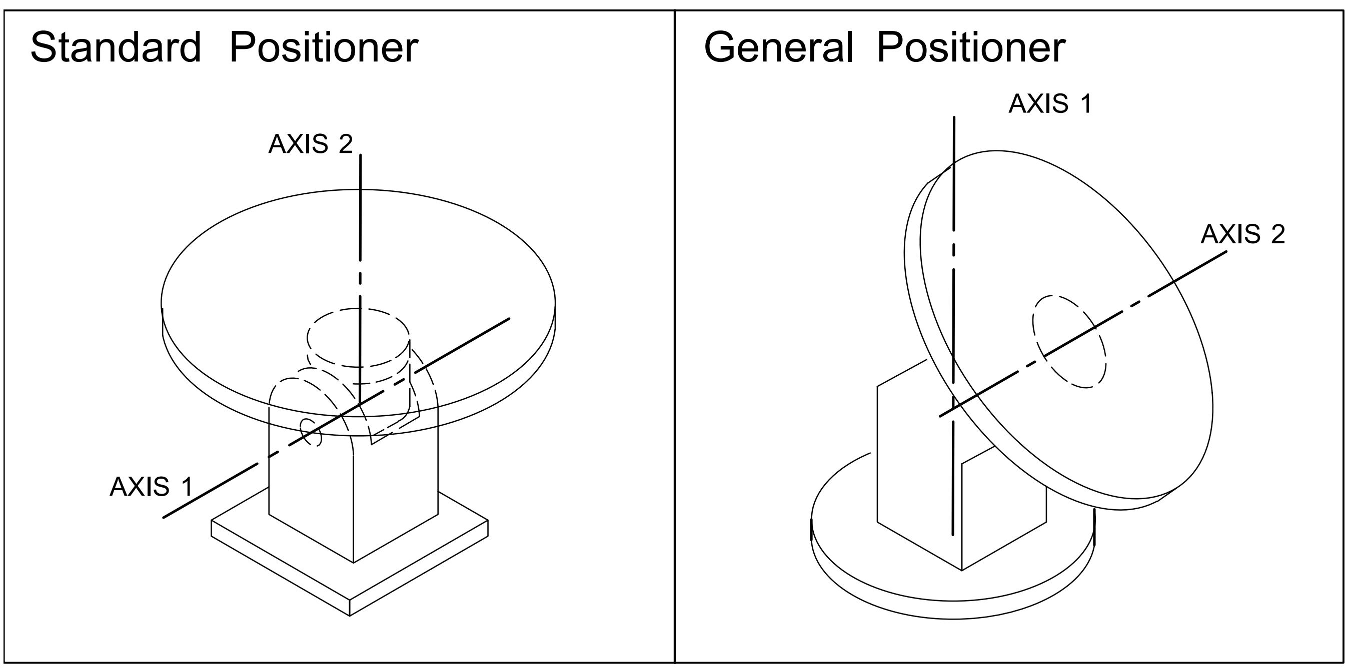
- Make sure you have a positioner with a valid axis arrangement
- Determine the positive direction of each motion axis
- Assign the leader frame axes to the positioner hardware axes

Axis Arrangement

Standard positioner axes must be either parallel or perpendicular to the other axes in the positioner. General positioners can have non-orthogonal axes. See Figure 2–3 .

Axis assignment is arbitrary for single axis positioners. Choose the most convenient axis assignment for your configuration. Axes are usually assigned according to the robot axes to which they are most closely parallel.

Figure 2–3. Alignment of the Leader Frame



Axis Direction

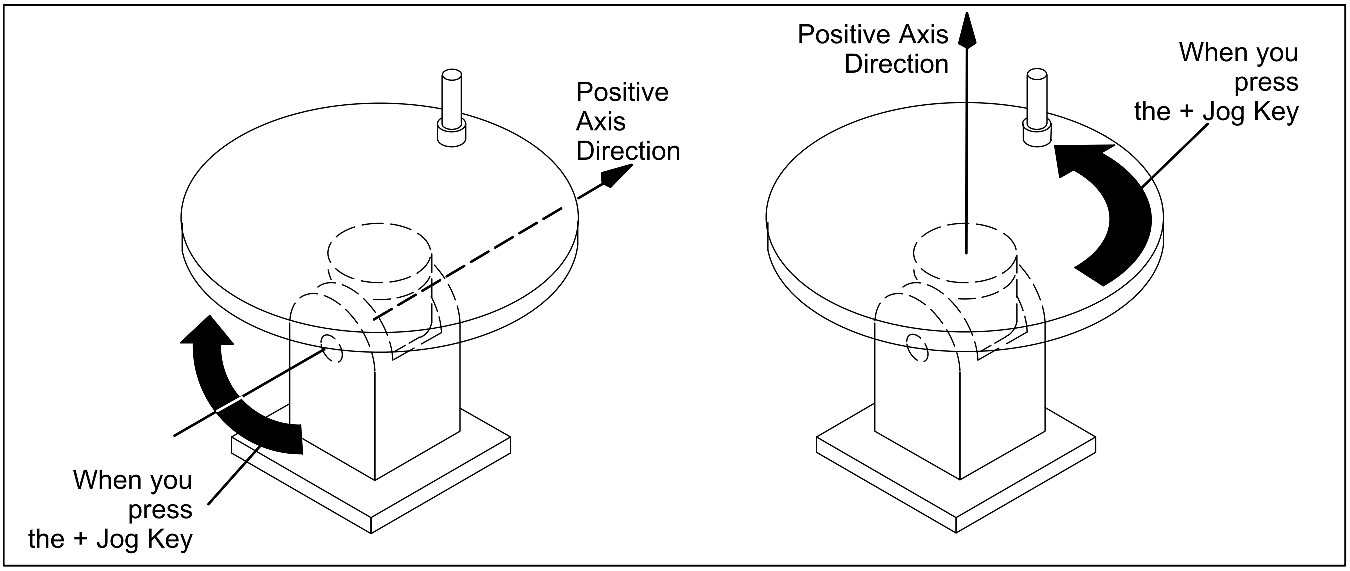
You determine the positive direction of an axis differently for linear and rotary axes. The positive direction of an axis is defined as the motion that occurs when the "+" jog key is pressed for the axis.

For a **rotary axis** , the right hand rule for electrical current is applied to determine the positive direction of the rotary axis, as illustrated in Figure 2–4 .

For **linear axes** , the positive direction is evident by which direction the axis moves when the "+" jog key is pressed.

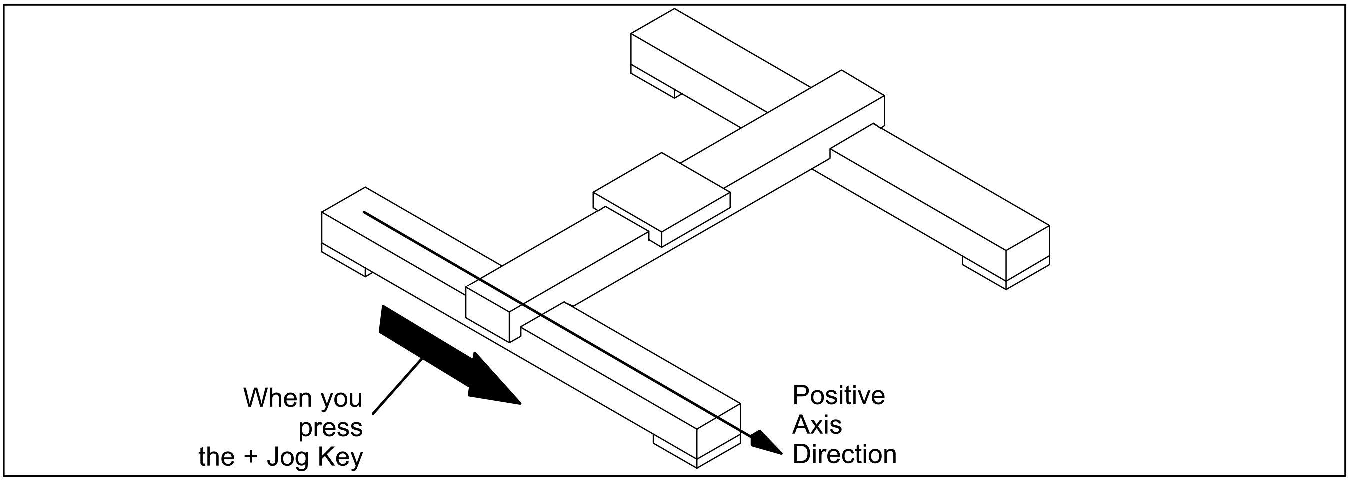
Usually, a positive leader frame axis (+x, +y, +z, for example) is assigned a positioner axis positive direction. The choice of x, y, or z for the first axis is arbitrary. Select the direction of linear or rotary motion relative to the frame you want to establish for the positioner device. The positioner frame is not necessarily aligned with the robot world frame.

Figure 2–4. Rotary Axis Selection



For a **linear axis** , see Figure 2–5 .

Figure 2–5. Linear Axis Selection



Axis Assignment

When you assign an axis, you must decide whether it will be x, y, or z of the leader (positioner) frame. It might be more convenient to align the leader frame (positioner) axis with axes in one of the following robot frames:

- World
- Tool
- User
- Jog

Note There might be a reason to assign -x, -y, or -z to the positive direction of rotation or linear motion of the leader axis. This is permitted.

If the positive jog key direction needs to move the axis in the opposite direction, complete the following steps:

1. Perform a Controlled start (START CTRL).
2. Press MENU.
3. Select MAINTENANCE, Group 2.
4. Press MANUAL.
5. Modify the axis sign to the opposite: from TRUE to FALSE, or from FALSE to TRUE for any axis that needs to be reversed.

Example Assignment

This example describes axis assignment as illustrated in Figure 2–1 and Figure 2–2 . Refer to Figure 2–1 and Figure 2–2 as you read the descriptions in this example. Note that the robot placement in Figure 2–1 and Figure 2–2 is arbitrary. The "typical" assignment is based on the shown robot location.

For **Figure 2–1 , drawing 1**, the axis assignment is arbitrary (x, y, z, -x, -y, or -z). In typical applications, this axis would be assigned -z.

For **Figure 2–1 , drawing 2**, select axis 1 arbitrarily (x, y, z, -x, -y, or -z). Axis 2 must not be the same as axis 1 or its negative. In this drawing, a typical assignment is axis 1 as -y and axis 2 as -z.

For **Figure 2–1 , drawing 3**, select axis 1 arbitrarily (x, y, z, -x, -y, or -z). Axis 2 must not be the same as axis 1 or its negative. A typical assignment would be axis 1 as +x and axis 2 as -y.

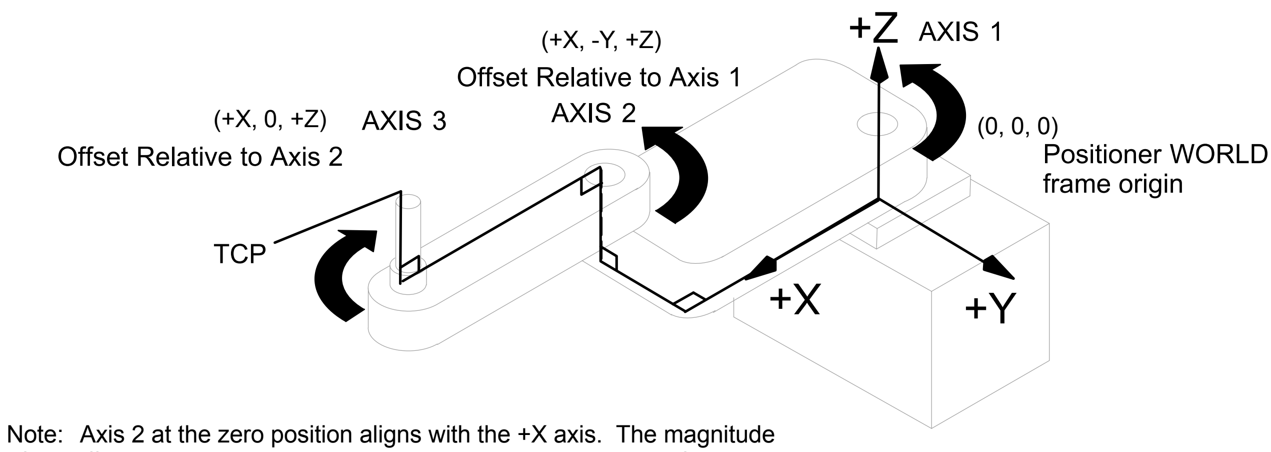
For **Figure 2–1 , drawing 4**, select axis 1 arbitrarily (x, y, z, -x, -y, or -z). Select axis 2 and axis 3 in the same direction as each other, but not the same direction as axis 1 or its negative. A typical assignment would be axis 1 as +y, axis 2 as +z, and axis 3 as +z.

For **Figure 2–2** , axis 1 and axis 2 must be the same axis assignment and in the same direction, and axis 3 must be the same axis assignment but in the opposite direction. A typical assignment would be axis 1 as +z, axis 2 as +z, and axis 3 as -z.

2.2.4 Offsets for Known Kinematics Types

During installation, if you selected a known kinematics type, you must enter offset information. See Figure 2–6 .

Figure 2–6. Axis Offset for Known Kinematics Types



Note: Axis 2 at the zero position aligns with the +X axis. The magnitude of the offsets and direction are relative to the leader (positioner) frame. This device has three motors and axis 3 rotates.

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

- Offset Axis1.X = 0
- Offset Axis1.Y = 0
- Offset Axis1.Z = 0

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

- Offset Axis2.X = a
- Offset Axis2.Y = -b
- Offset Axis2.Z = c

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

- Offset Axis3.X = d
- Offset Axis3.Y = 0
- Offset Axis3.Z = e

Note Offset values a and d are parallel.

Note Each axis is at 0°. Also, in the leader frame, the leader TCP is:

- X = a + d
- Y = -b
- Z = c + e

2.3 INSTALLATION PROCEDURES

Use Procedure 2-1 to install coordinated motion and options. This procedure assumes no prior configuration.

Procedure 2-1 Installing Coordinated Motion

Conditions

- You have reviewed Section 1.3 .
- Group 1 (robot motion group for follower) is installed and executed correctly.
- The hardware for the leader group (positioner) is installed correctly.
- The appropriate application-specific software is installed.

Note Motion axes of the basic positioner must be perpendicular or parallel to the other axes of the basic positioner.

Note Motion axes of the General positioner do not have to be perpendicular or parallel to the other axes of the general positioner. Use UNKNOWN KINEMATICS for this group setup.

Note Coordinated motion is not supported for Independent Axes devices or Index devices.

Note You must install all axes of multiple-axis positioners in order, starting at the base axis and finishing with the table top axis. Start with the first hardware number following Group 1. For example, with a six-axis robot and a two-axis positioner, Group 2 would begin with hardware start number 7. If a more complex positioner is to be used for a total of more than 8 axes, the extra axis control board should be used, starting with Group 2 at hardware start number 9, and installing the axes sequentially.

Note Depending on how the robot software was ordered, the coordinated motion option and the positioner configuration might have already been automatically installed. If not, or if the installation was not completed or needs to be modified, this can be done at controlled start.

Initializing Positioner Groups

1. **If the controller is already in Controlled start mode** , go to Step 2 . Otherwise, complete the following steps.

a. **If the controller is turned on**, turn the power disconnect circuit breaker to OFF.

b. Press and hold the PREV and NEXT keys on the teach pendant. While holding these keys, turn the power disconnect circuit breaker to ON. You will see a screen similar to the following.

```
---------- CONFIGURATION MENU ---------
1 Hot start
2 Cold start
3 Controlled start
4 Maintenance
```

c. Select Controlled start and press ENTER. You will see a screen similar to the following.

```
ARCTOOL SETUP
1  F number          F000000
  Equipment:         1
2  Manufacturer:     General Purpose
3  Model:            MIG (Volts, WFS)
```

2. Press MENU.

3. Select S/W INSTALL and press ENTER. You will see a screen similar to the following.

```
S/W INSTALL
Application: ArcTool
  1   Controller ID
  2   Robot Library
  3   Option
  4   Update
  5   Customization
```

Setting Robot Library Information

4. Select Robot Library and press ENTER. You will see a screen similar to the following.

Note The following screen lists the robots that have been defined for your system.

```
Robot Library
Group 1 of 1 Groups
  1   M-6i (ARCMate 100i)
  2   M-16i (ARCMate 120i)
  3   M-16iL (ARCMate 120iL)
  4   M-410i Floor Mnt
  5   S-430iW Floor Mnt
  6   S-500
  7   AM-HS500 Headstock
  8   Independent Axes
  9   POSITIONER
```

Caution

Be sure to answer the robot configuration questions correctly. If you answer a question incorrectly you will not be notified by the system and your software will operate incorrectly.

5. Insert the memory card into the memory card interface.
6. **To change the display from TITLE to ORDER NUMBER** , press F3, ORD NO. You will see a screen similar to the following.

```
Group 1 of 1 Groups
  1   A05B-2400-xxxx
  2   A05B-2400-xxxx
```

7. **To change the display from ORDER NUMBER to TITLE** , press F3, TITLE.

Note If you want to install a positioner, you must add another group to your system (F5, ADD GRP) and then change to that group (F4, CHG GRP) before you can set up the new information.

Caution

If you add or delete a group, the change will not be active until you perform a cold start. However, do not perform a cold start until you have added or deleted all necessary groups in your system. If you turn the controller off before cold start is completed, your controller’s software will be corrupted, and you will have to re-load the controller.

Caution

Do not add **and** delete groups during the same controlled start; if you do, the system will be corrupted and you will have to reload the controller.

Note The robot will re-execute a controlled start which will give you an opportunity to verify your changes before you perform a cold start.

8. To set up, add, change, and delete robot libraries that have been purchased separately from the application software, refer to Table 2–1 .

Table 2–1. Authorizing, Installing and Setting Up Options

Step Order	To do this	You must do this
1.	Add a group and Install a robot library(e.g. Positioner)	1. Press F5, ADD GRP. 2. Press F1, INSTALL. 3. Insert the specified memory card in the memory card interface. 4. Select the positioner you want to install from the list of robots. 5. If a data file exists on your controller for that positio ner, the positioner will be set up automatically. If a data file does not exist for that positioner, you must answer positioner configuration questions. Refer to Appendix B in the *FANUC America Corporation ArcTool Software Installation Manual* for a list of the questions. If you want to add the new robot to an additional motion group, press F5 to add the group. 6. When you have finished, press FCTN and then select START (COLD) so that the new settings can take effect. **NOTE:** When you add a group, the teach pendant scr een might go blank for approximately 60 to 90 seconds for each group in the system.
2.	Delete a group	1. Press >, NEXT. 2. Press F1, DEL GRP.

Table 2–1. Authorizing, Installing and Setting Up Options (Cont'd)

Step Order	To do this	You must do this
3.	**Re-Install a robot library** (e.g. Positioner)	1. Press F1, INSTALL. 2. Insert the specified memory card into the memory card interface. 3. Select the positioner you want to install from the list of robots. 5. If a data file exists on your controller for that positio ner, the positioner will be set up automatically. If a data file does not exist for that positioner, you must answer positioner configuration questions. Refer to Appendix B in the *FANUC America Corporation ArcTool Software Installation Manual* for a list of the questions.If you want to add the new robot to an additional motion group, press F5 to add the group. 6. When you have finished, press FCTN and then select START (COLD) so that the new settings can take effect. **NOTE:** When you add a group, the teach pendant scr een might go blank for approximately 60 to 90 seconds for each group in the system.
4.	Perform a Cold start	1. Press PREV to display the Configuration Menu. 2. Select Cold start and press ENTER.

Installing Coordinated Motion Options

9. Make sure that the controller is in a controlled start. If not, perform Step 1 then continue to Step 10 .
10. Press MENU.
11. Select S/W INSTALL. You will see a screen similar to the following.

```
S/W INSTALL
Application: ArcTool
  1   Controller ID
  2   Robot Library
  3   Option
  4   Update
  5   Customization
```

12. Move the cursor to Option and press ENTER. You will see a screen similar to the following.

```
OPTION
1  KAREL Cmd. Language        Installed
2  AccuPath                   Authorized
3  Auto Normal Utility        Authorized
4  Auto TCP
5  CE Mark                    Authorized
6  MH Collision Guard         Installed
7  Continuous Turn
8  Control Reliable
9  Coordinated Motion         Authorized
10  CRT/Keyboard Manager      Authorized
```

13. Insert the memory card into the memory card interface (PCMCIA port).

14. **To change the display from TITLE to ORDER NUMBER,** move the cursor to the item you want to change and press F3, ORD NO. You will see a screen similar to the following.

```
1       A05B-2400-xxxx
  2       A05B-2400-xxxx      INSTALLED
  3      A05B-2400-xxxx
```

15. **To change the display from ORDER NUMBER to TITLE,** press F3, TITLE.

16. Install the Coordinated Motion option and the Multi-Group Motion option.

Note When you install the Coordinated Motion option, the Multi-Gr oup option is automatically installed if it is not already installed. The Multi-Group Motion status will not show the change until you perform a controlled start.

Note If this option was purchased with the application software and is a requirement for your application , the PAC code will already be available and the option will be authorized, installed and set up. The option status will be Installed. You do not need to do anything more to install or set up this option.

Note If this option has not yet been authorized for installation it will have an empty option status.

17. To authorize, install and set up additional options that have been purchased separately from the application software refer to Table 2–2 .

Table 2–2. Authorizing, Installing and Setting Up Options

Step Order	To do this	You must do this
1.	**Obtain the PAC code**	The Product Authorization Codes (PAC) for each option you have purchased and want to install are available from FANUC America Corporation America.
2.	Authorize	1. Move the cursor to the name of the option you want to install. 2. Press F4, AUTH. 3. Type the PAC code for the option and press ENTER. 4. Press PREV to display the S/W INSTALL screen. The option status will be Authorized. 5. Go to Install to install the option.
3.	Install or Re-Install	1. Make sure the memory card is in the memory card interface. 2 Move the cursor to the name of the option you want to install. 3. Press F1, INSTALL. The software will install automatically. 4. When it is finished, the S/W INSTALL menu will be displayed. **NOTE** You will be notified if you need to insert a different memory card. **NOTE** Some options will display the setup program automatically. Refer to the appropriate section to set up the option.
4.	Setup (optional) Some options have user-settable parameters. The setup function restores these parameters to their default values.	1. Move the cursor to the name of the option you want to set up. 2. Press F2, SETUP. 3. When the option setup has finished, the S/W INSTALL screen will be displayed.

18. Make sure that the controller is in a Controlled start. If not, perform Step 1 then continue to Step 19 .

19. Press MENU.

20. Select MAINTENANCE. You will see a screen similar to the following.

```
ROBOT MAINTENANCE
Setup Robot System Variables
Group  Robot Library/Option   Ext Axes
  1   M-16iL (ARCMate\120iL)  0
  2   POSITIONER                0
            Extended Axis Control
```

21. **To change the display from TITLE to ORDER NUMBER** , press F2, ORD NO. You will see a screen similar to the following.

```
Group   Robot Library/Option      Ext Axes
  1    A05B-2400-XXXX        0
       A05B-2400-XXXX
```

22. **To change the display from ORDER NUMBER to TITLE** , press F2, ORD NO.
23. Move the cursor to the title or order number of the robot library you want to modify.
24. Decide whether you want to perform AUTO setup or MANUAL setup. Refer to Table 2–3 .

Table 2–3. Auto and Manual Robot Library Setup

ITEM	DESCRIPTION
AUTO	This item allows you to set up the robot library or option automatically using default values for each setup item.
MANUAL	This item allows you to set up the robot library or option manually by allowing you to answer each setup question individually. Manual setup records your answers as the new default values.

25. **To modify your setup**,
    a. Move the cursor to the order number or title of the item you want to modify.
    b. **To perform an automatic setup**, press F2, AUTO. The robot library questions will be answered automatically and will be displayed quickly on the screen.
    c. **To perform a manual setup**, press F3, MANUAL. The questions, if they exist, will be displayed on the screen and you will have to answer them. The default value for each question will be displayed. You can either accept the default or change it.

- To set up a **positioner** manually, go to **Modifying the Positioner Setup Manually.**

26. Make sure that a positioner axis has been installed on your controller. Refer to **Initializing Positioner Groups** (Step 1 through Step 8).

Note The following steps assume that you have just completed **Performing Robot Library and Option Maintenance** (Step 18 through Step 25), and that you have selected the positioner that you want to set up.

27. Press F4, MANUAL.

28. Answer the questions in Table 2–4 .

Table 2–4. Positioner Setup Configuration Information

You Must Answer These Questions	You Have These Choices	Comments	Write Your Answer Here
Hardware Start Axis Setting	Hardware Start Axis (1..16)	Type the hardware starting number for the first axis of the positioner. For example, if a two-axis positioner is added to an M-6i (without any additional axes in the follower group) the hardware start number of the positioner is seven, because the M-6i has six axes. For more complex arrangements of axes and groups, you must determine the amplifier and axis numbers based on the hardware installed in your system. **NOTE** The positioner setup requires that all axes of multiple-axis positioners be installed in order sequentially, starting from the base axis and going to the table top axis. The axis of the positioner that contains the workpiece, fixture, or work surface of the positioner must be assigned last. The hardware installation must reflect this.	
Kinematics Type	Known kinematics Unknown kinematics	Type 1 if the relationship between neighboring axes is known accurately. Type 2 if the relationship between axes is unknown.	

29. When you have finished setting up the items in Table 2–4 , you will see a screen similar to the following.

```
*** Group 2 Total POSITIONER Axes = 0 ***
1. Display/Modify POSITIONER Axes 1->6
2. Add POSITIONER Axis
3. Delete POSITIONER Axis
4. EXIT
```

30. Type 2, Add POSITIONER Axis, or 3, Delete POSITIONER Axis, and press ENTER.

31. The axes will be numbered automatically as you add them. The first axis is axis one. Refer to Table 2–5 .

Table 2–5. Positioner and General Positioner Setup Configuration Information

You Must Answer These Questions	You Have These Choices	Comments	Write Your Answer Here
Alpha Motor Size	Refer to Table 2–7 for valid motor and amp combinations.	**NOTE** If the motor combination you specify is not supported, the message, "Motor type not found," will be displayed. The system will ask for the motor information again. Refer to the *FANUC AC Servo Motor Digital Series Descriptions Manual,* the *FANUC AC Servo Motor Alpha Series Descriptions Manual,* or the *FANUC AC Servo Motor Beta Series Descriptions Manual* for more information.	
Motor Type	Refer to Table 2–7 for valid motor and amp combinations.		
Current Limit for Amplifier	Refer to Table 2–7 for valid motor and amp combinations.	**NOTE** If the motor combination you specified is not supported, the message, "Motor type not found," will be displayed. The system will ask for the motor information again.	
Amplifier Number Setting	Amplifier Number (1->16)	The six-axis amplifier is assigned as amplifier 1, by default. The positioner axes typically begin on amplifier 2.	
Amplifier Type Setting	1. A06B-6100 series 6 axes amplifier2. A06B-6093 Beta series (FSSB)	Normally choose the Beta series.	
Axis Type Setting	1. Linear Axis 2. Rotary Axis		

Table 2–5. Positioner and General Positioner Setup Configuration Information (Cont'd)

You Must Answer These Questions	You Have These Choices	Comments	Write Your Answer Here
Direction Setting(Positioners only)	1: +X 3: +Y 5: +Z2: -X 4: -Y 6: -Z	Select the direction of linear or rotary motion relative to the frame you want to establish for the positioner device; this is not necessarily aligned with the robot WORLD frame. For example, the first axis of the positioner could be defined as +Z, but could be aligned with the robot x-axis.	
Offset Setting(Positioners only) only if known kinematics is used	Enter Offset X (mm)?Enter Offset Y (mm)?Enter Offset Z (mm)?	**NOTE** Axis 1 has a value of 0 for the x, y, and z offsets. Each of axes 2, 3, and so forth will have non-zero offset values.	
D-H Parameter Setting(General Positioners only) only if known kinematics is used	Enter A[i] (mm)?Enter ALPHA[i] (deg)?For rotary axis: Enter D[i] (mm)?For linear axis: Enter THETA[i] (deg)?where i is the index of axis.	The default value is displayed. For one-axis general positioners, set a value of 0 for all D-H parameters.	

Table 2–5. Positioner and General Positioner Setup Configuration Information (Cont'd)

You Must Answer These Questions	You Have These Choices	Comments	Write Your Answer Here
Gear Ratio Setting	Gear Ratio (mot-rev/axs-rev)	**The gear ratio for linear axes** is the number of millimeters traveled for one rotation of the motor. For example, if a 50mm pinion on the motor is directly coupled to the rack, and the radius of the pinion is 25mm, the gear ratio is 2(pi)(25) = 157.08. If the axis has a gear box between the motor and pinion, divide the number by the gear ratio. For example, if the motor is connected to a 5:1 gear box and a 50mm pinion, the gear ratio is (2)(pi)(25)/5 = 31.416. **The gear ratio for rotary axes** is in motor turns per single rotation of the rotary axes. The ratio is ng2:ng1, where ng is the number of teeth on a gear. ng1 is attached to the motor and ng2 is attached to the axis. For example, if gear 1 has 25 teeth and gear 2 has 50 teeth, the ratio would be 2:1. Commercial gear drives are generally labeled for items such as gear ratio, maximum RPM, and torque maximum. Look at tags or labels on the equipment for this information.	
Maximum Speed Setting	Suggested Speed = 200.040 mm/sec(Calculated with Max Motor Speed)(1:Change, 2:No Change)	**Note** The maximum joint velocity is automatically calculated based on the gear ratio and the maximum gear ratio and the maximum RPM of the motor chosen. This value can be used or you can lower it. **Warning** **Do not increase the value of the maximum joint velocity; otherwise, the maximum motor RPM will be exceeded. This could injure personnel or damage equipment.**	

Table 2–5. Positioner and General Positioner Setup Configuration Information (Cont'd)

You Must Answer These Questions	You Have These Choices	Comments	Write Your Answer Here
Motion Sign Setting	Current value = TRUE(1: TRUE, 2: FALSE)	The direction determines which way the motor turns when the positive jog key is pressed, and should be consistent with axis alignment. TRUE indicates that the motor will turn counterclockwise when looking at the motor shaft from the front. **NOTE** If the rotation is incorrect, you can modify it by performing a controlled start.	
Upper Limit Setting	Enter the upper limit.	Set the upper software limit of the axis to a value smaller than the hard stop.	
Lower Limit Setting	Enter the lower limit	Set the lower software limit of the axis to a value smaller than the hard stop. This is usually 0 or a negative number.	
Master Position	Enter the master position.		
Accel Time 1 Setting	Current value = 384 msec(1:Change, 2:No Change)	The sum of acc_time_1 and acc_time_2 is the time, in milliseconds, it will take for the axis to reach full joint speed. The min_acctime value is used for acceleration/deceleration if the distance between the two points is short enough that the axis cannot reach full speed.	
Accel Time 2 Setting	Current value = 192 msec(1:Change, 2:No Change)		
Exponential Filter Setting	Exp Filter Valid = TRUE(1: TRUE, 2: FALSE)		
Exponential Accel Time Setting	Current value = 20 msec(1: Change, 2: No Change)		
Minimum Accel Time Setting	Current value = 384 msec(1: Change, 2: No Change)		

Table 2–5. Positioner and General Positioner Setup Configuration Information (Cont'd)

You Must Answer These Questions	You Have These Choices	Comments	Write Your Answer Here
Load Ratio Setting	Load Ratio is:Load Inertia (Kg*cm*s**2) Motor Inertia (Kg*cm*s**2)Load ratio? (0:None 1~5:Valid)	The load ratio adjusts the gain of the axis based on the load inertia and the motor inertia. A value of 0 continues the program without adjusting the gain. Refer to the *FANUC AC Servo Motor Digital Series Descriptions Manual* or the *FANUC AC Servo Motor Beta Series Descriptions Manual* for more information.	
Brake Number Setting	Type the brake number (2 - 4)	The robot is always assigned to Brake 1. The remaining brakes are controlled by the robot 6–axis amplifier via a cable connected to the brake control board. Typically, brake numbers are assigned to match the amplifier number. **Warning** **Make sure that the brake number is assigned and is connected correctly; otherwise, improper operation will result.**	
Servo Off Setting	Current value = TRUE(1: TRUE, 2: FALSE)	If enabled, SERVO OFF allows the brakes to hold the axis and drop servo power after the specified time.	
Servo Off Time Setting Displayed if Servo Timeout is Enabled.	Servo Off Time (0..30 sec)		

Refer toTable 2–6 for valid FANUC motor and amp combinations and Table 2–7 for supported Third-Party Motor and Amp Combinations.

Table 2–6. Supported Motor and Amp Combinations

Motor Name	Direct Entry Motor Selection	Standard and Enhanced Motor Selection		
	Motor ID (DEC)	Size	RPM	Current
α*i*S2/5000 20A	15562	60	12	10
α*i*S2/5000 40A	15557	60	12	5
α*i*S2/6000 20A	15578	60	13	10
α*i*S4/5000 20A	15818	61	12	10
α*i*S4/5000 40A	15813	61	12	5
α*i*S8/4000 40A	16053	62	11	5
α*i*S8/4000 80A	16055	62	11	7
α*i*S8/6000 80A	16087	62	13	7
α*i*S12/4000 80A	16311	63	11	7
α*i*S22/4000 160A	16572	64	11	12
α*i*S22/4000 80A	16567	64	11	7
α*i*S30/3000 80A	16679	65	2	7
α*i*S30/4000 160A	16828	65	11	12
α*i*S40/4000 160A	17084	66	11	12
β*i*S0.2/5000 4A	20674	80	12	2
β*i*S0.3/5000 4A	20930	81	12	2
β*i*S0.4/5000 20A	21194	82	12	10
β*i*S0.5/6000 20A	21466	83	13	10
β*i*S1/6000 20A	21722	84	13	10
β*i*S2/4000 20A	21946	85	11	10
β*i*S2/4000 40A	21941	85	11	5
β*i*S4/4000 20A	22202	86	11	10
β*i*S4/4000 40A	22197	86	11	5
β*i*S8/3000 20A	22314	87	2	10
β*i*S8/3000 40A	22309	87	2	5

Table 2–6. Supported Motor and Amp Combinations (Cont'd)

Motor Name	Direct Entry Motor Selection	Standard and Enhanced Motor Selection		
	Motor ID (DEC)	Size	RPM	Current
β*i*S12/2000 20A	22554	88	1	10
β*i*S12/2000 40A	22549	88	1	5
β*i*S12/3000 40A	22565	88	2	5
β*i*S22/2000 40A	22805	89	1	5
α*i*F1/5000 20A	25802	100	12	10
α*i*F1/5000 40A	25797	100	12	5
α*i*F2/5000 20A	26058	101	12	10
α*i*F2/5000 40A	26053	101	12	5
α*i*F4/4000 40A	26293	102	11	5
α*i*F4/4000 80A	26295	102	11	7
α*i*F8/3000 40A	26405	103	2	5
α*i*F8/3000 80A	26407	103	2	7
α*i*F12/3000 80A	26663	104	2	7
α*i*F22/3000 80A	26919	105	2	7
α*i*F30/3000 160A	27180	106	2	12
α*i*F40/3000 160A	27436	107	2	12

Table 2–7. Supported Third-Party Motor and Amp Combinations

Motor Name	Direct Entry Motor Selection	Standard and Enhanced Motor Selection		
	Motor ID (DEC)	Size	RPM	Current
NIMAK 40A	40485	158	2	5
BAUTZ/3300 80A	40743	159	2	7
ARO/3000(6Pole) 80A	40999	160	2	7
ARO/3000 40A	41253	161	2	5
ARO/3000(4Pole) 80A	41255	161	2	7
ARO 3G 40A	43301	169	2	5
ARO 3G 80A	43303	169	2	7
Tolmtc HT12/4000 40A	41653	162	11	5
Tolmtc HT23/4000 40A	41909	163	11	5
EXLAR GSX40/3000i 40A	42069	164	5	5
EXLAR GSX30 20A	43098	168	5	10
Tolmtc SW44/4000 40A	42421	165	11	5
Tolmtc SW44/4000 80A	42423	165	11	7

Table 2–7. Supported Third-Party Motor and Amp Combinations (Cont'd)

Motor Name	Direct Entry Motor Selection	Standard and Enhanced Motor Selection		
	Motor ID (DEC)	Size	RPM	Current
TolmtcGSWA101 40A	42677	166	11	5
TolmtcGSWA101 80A	42679	166	11	7
TolmtcGSWA102/3 40A	42933	167	11	5
TolmtcGSWA102/3 80A	42935	167	11	7
TolmtcGSWA301/2 20A	43706	170	11	10
TolmtcGSWA301/2 40A	43701	170	11	5
TS4817N4930E239 80A	38583	150	11	7
TS4817N4930E235 40A	38837	151	11	5
TS4817N4930E235 80A	38839	151	11	7
DENYOU KRM-32198 40A	39717	155	2	5
DENYOU KRM-32198 80A	39719	155	2	7

32. When you have finished answering all the questions in Table 2–5 , you will see a screen similar to the following.

```
*** Group 2 Total GENERAL POS Axes = 0 ***
1. Display/Modify GENERAL POS Axes 1->6
2. Add GENERAL POS Axis
3. Delete GENERAL POS Axis
4. EXIT
```

33. You can either continue adding or deleting axes, or exit.

If you want to add/delete other axes , type 2, Add/delete POSITIONER Axes and repeat Step 29 through Step 32 .

If you are finished , type 4, Exit. You will see a screen similar to the following.

```
ARCTOOL SETUP
1  F number                  F000000
Equipment:                 1
2  Manufacturer             General Purpose
3  Model:                   MIG (Volts, WFS)
```

34. Press PREV to display the Configuration Menu.

35. Select Cold start and press ENTER.

36. **When the controller is turned on** , master and calibrate the robot. Refer to Chapter 4 *CALIBRATION* .

Coordinated Motion and options are now installed.

Chapter 3

SETTING UP COORDINATED PAIRS

Contents

3.1 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.

Table 3–1. Coordinated Pair Configurations

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

Note Multi-robot systems add additional CD_pair combinations. Refer to the *ArcTool Setup and Operations Manual* , DualARC Section 21, for additional information. 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

Use Procedure 3-1 to select CD_pairs.

Procedure 3-1 Selecting CD_pairs

Steps

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:ATTACHED
Use Leader Frame number:  1
```

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.

Chapter 4

CALIBRATION

Contents

4.1 OVERVIEW

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.

Kinematics Type

The kinematics type is determined when the leader group (positioner) is installed. Kinematics is determined for the leader group through installation parameters. Two kinematics types are available:

- Known
- Unknown

Known kinematics type is applied to leader groups for which the arm length and offsets are known. This information is required at the time the axes of the leader group are installed. This type can also be used when you have existing calibration information that was defined previously for the CD_pair.

Unknown kinematics type is used for leader groups such as turntables or positioners for which the arm length(s) and offset(s) are not known, or are not known accurately. Unknown kinematics type is the most common kinematics type.

The kind of calibration you perform depends on the kinematics type you specified during leader group installation. Refer to Chapter 2 *INSTALLATION* 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

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).

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

4.2 KNOWN FOUR POINT CALIBRATION (Also for Arc Positioner)

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 Coord Independent Axes installation.

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

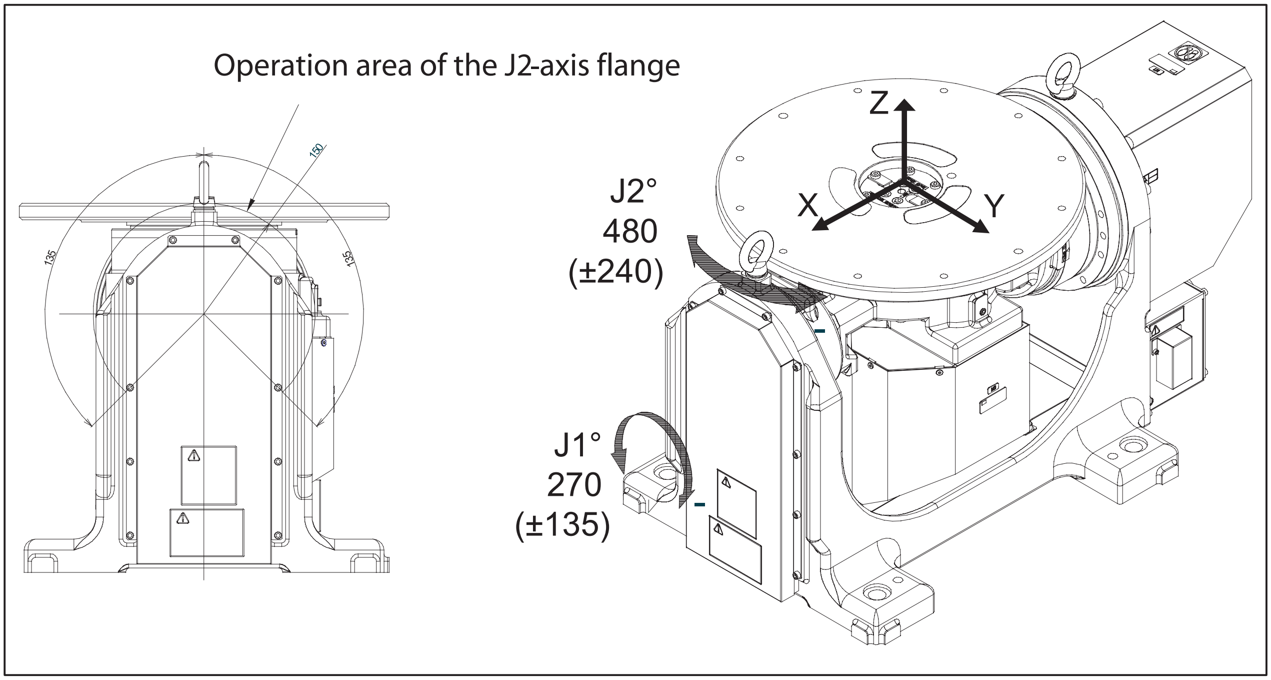
- Leader's TCP.
- Orient origin point, which is a "temporary" origin point that can be located at any position within the follower's working motion range.
- X direction point, which aligns with the position X axis.
- Y direction point, which aligns with the position Y axis.

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.

ARC Positioner (H871)

The ARC Positioner has known kinematics. Therefore, Known Four Point Calibration should be used when an ARC Positioner is used as a leader group. Figure 4–1 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 4–1. Arc Positioner TCP Frame



Guidelines

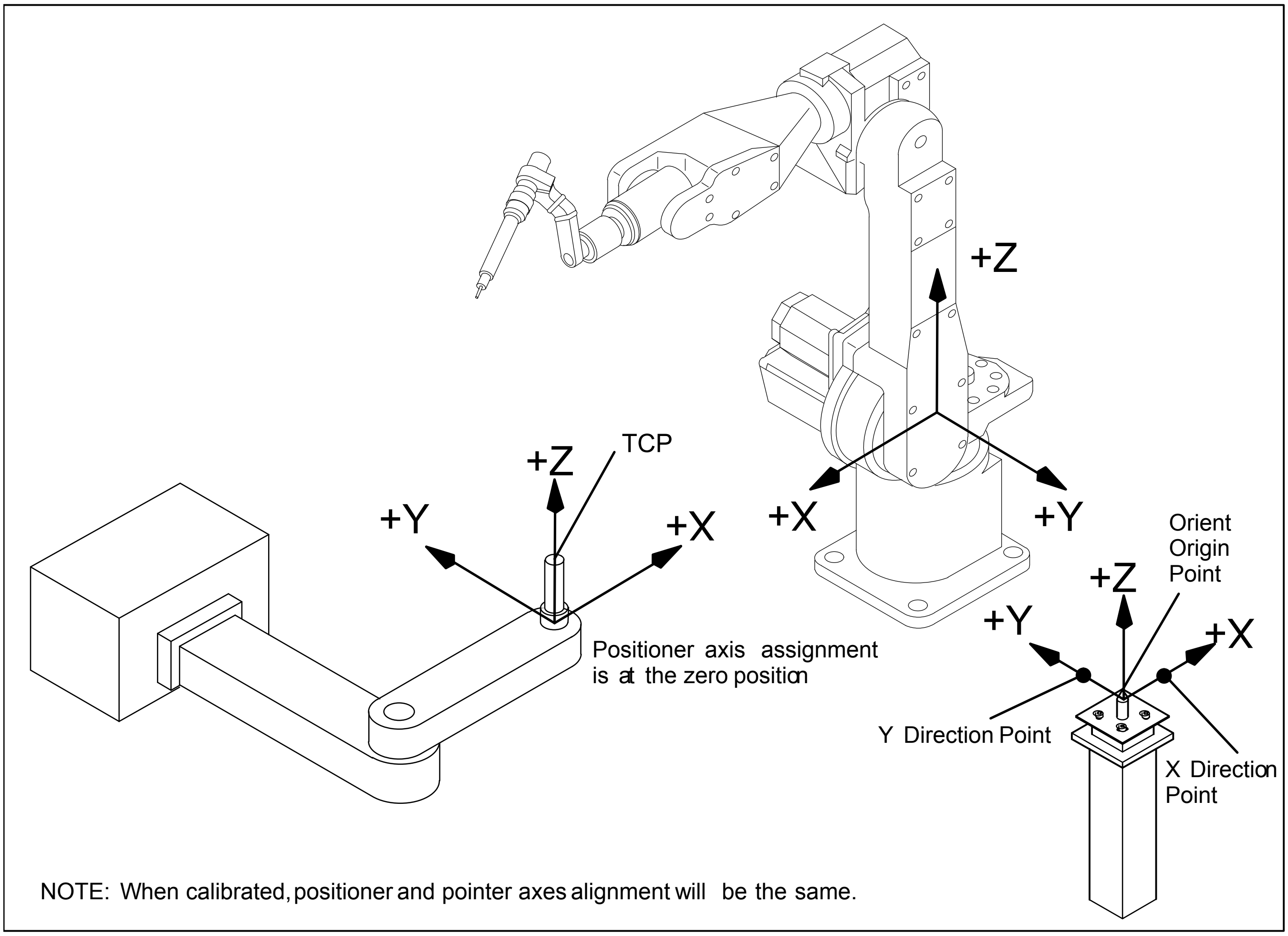
When you perform known four point calibration, use the following guidelines:

- 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 .

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

Figure 4–2. 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.

If you do not align these positions carefully, the calibration frame will be incorrect, but a calibration frame will be calculated. In this case, the coordinated motion will not be accurate.

Use Procedure 4-1 to perform known four point calibration.

Procedure 4-1 Known Four Point Calibration

Conditions

- The follower group and leader group have been mastered and calibrated. (Refer to the appropriate application-specific *Setup and Operations Manual* .)
- Axes in the leader group must be either parallel or perpendicular to each other. (Figure 2–1)
- The selection of "axis direction" for the multiple-axis devices must be consistent with the right-hand rule. (Chapter 2 *INSTALLATION*)
- The CD_pair has been set up (Chapter 3 *SETTING UP COORDINATED PAIRS*).

Steps

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.

```
SETUP Coord
 Known type calibration     Coord Pair: 1
 Group Number Leader: 3          Follower: 1
  X: ******** Y: ******** Z: ********
  W: ******** P: ******** R: ********
 Leader's TCP point :    UNINIT
 Orient Origin point :   UNINIT
 X Direction Point :     UNINIT
 Y Direction Point :     UNINIT
```

7. Define the leader's TCP point: (Figure 4–3)

   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. Move the positioner axis (axes) to the zero angle position.On a tabletop, choose a position on the table.

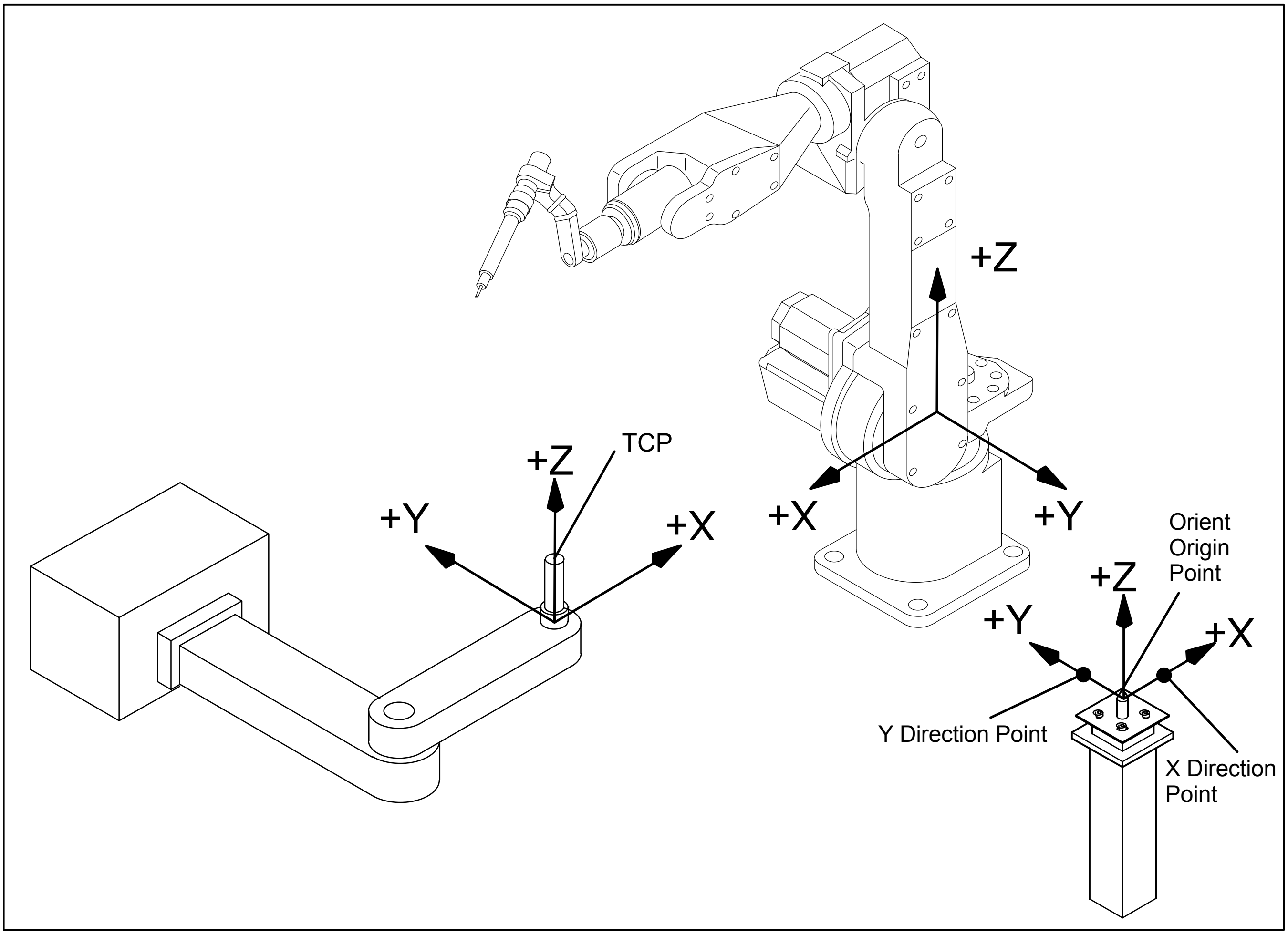
   c. Jog the follower only, and touch the follower TCP to the leader TCP.

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

d. Press and hold SHIFT and press F5, RECORD.

UNINIT is changed to RECORDED.

Figure 4–3. Defining Points



8. Define the orient origin point: (Figure 4–3)

a. Move the cursor to Orient Origin Point.

Note Jog **only** the follower in Step 8b .

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 4–3)

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 9b .

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 4–3)

a. Move the cursor to Y Direction Point.

Note Jog **only** the follower in Step 10b and Step 10c .

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.

UNINIT is changed to RECORDED.

11. Press F3, EXEC, to execute the calibration.

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

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 7–1 in Chapter 7 *TROUBLESHOOTING* .

4.3 KNOWN DIRECT CALIBRATION

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.

Denavit-Hartenberg (D-H) Parameters

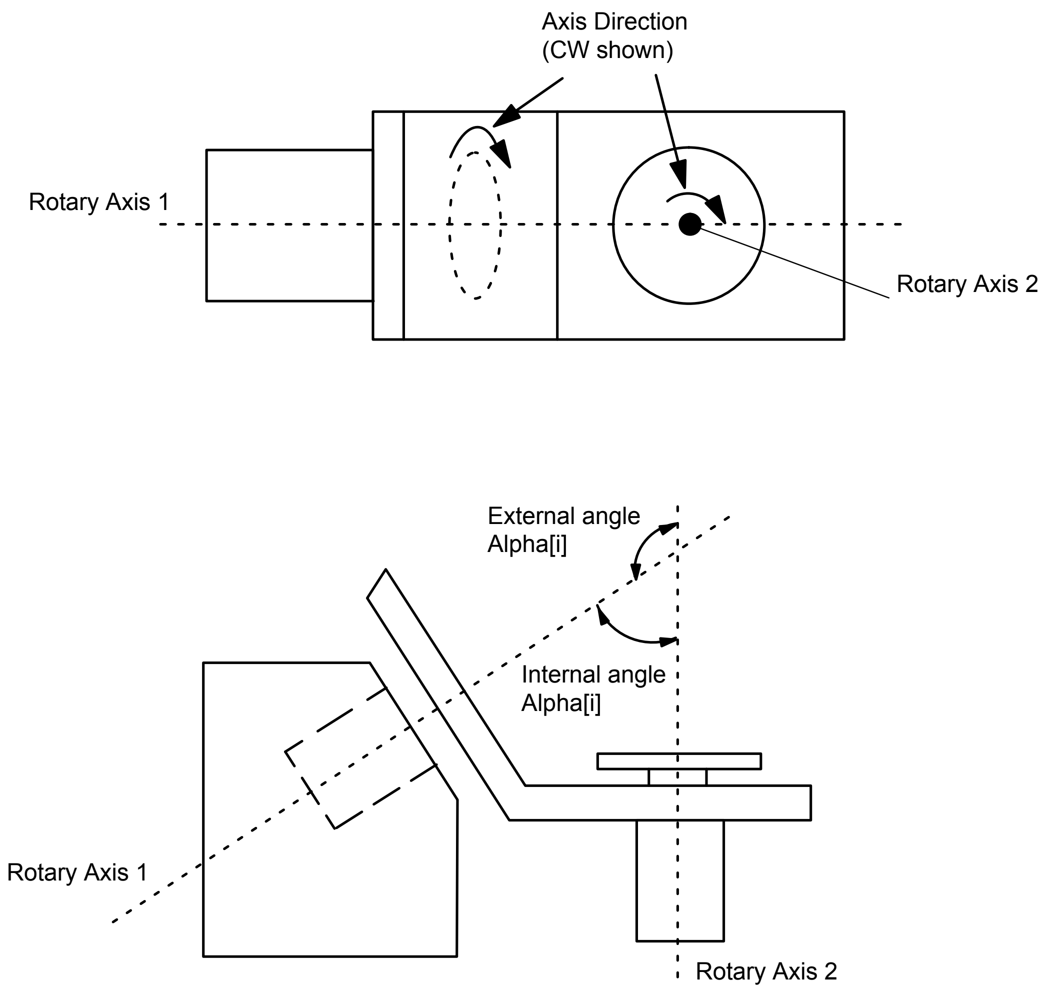
The Denavit-Hartenberg (D-H) parameters define the kinematic model of any positioner that works in coordinated motion with the robot. The common nomenclature that is used to define these parameters for a general device is shown in Figure 4–6 .

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

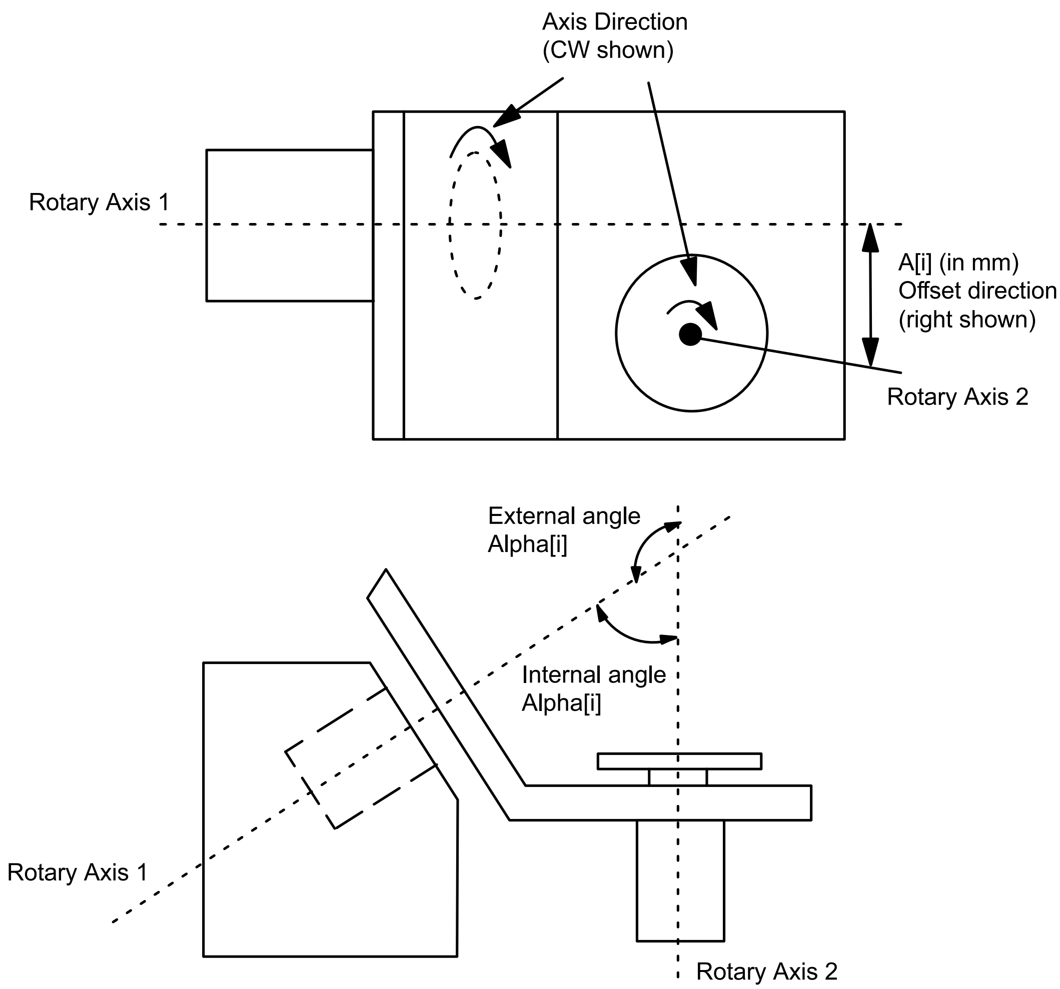
Figure 4–4 and Figure 4–5 show the possible configurations and meanings of the D-H parameters for a two-axis general positioner.

Figure 4–4. Two-Axis General Positioner with Intersecting Axes



Case	Axis 1 Direction	Axis 2 Direction	Alpha[i]	A[i] Dimension
1	CW	CCW	External angle, + degrees	0
2	CW	CW	Internal angle, + degrees	0
3	CCW	CCW	Internal angle, + degrees	0
4	CCW	CW	External angle, + degrees	0

Figure 4–5. Two-Axis General Positioner with Non-Intersecting Axes



Case	Axis 1 Direction	Axis 2 Direction	Alpha[i]	Offset Direction	A[i] Dimension
1	CW	CCW	Ext. angle, + degrees	Left	Offset in mm
2	CW	CCW	Ext. angle, – degrees	Right	Offset in mm
3	CW	CW	Int. angle, – degrees	Left	Offset in mm
4	CW	CW	Int. angle, + degrees	Right	Offset in mm
5	CCW	CCW	Int. angle, – degrees	Left	Offset in mm
6	CCW	CCW	Int. angle, + degrees	Right	Offset in mm
7	CCW	CW	Ext. angle, + degrees	Left	Offset in mm
8	CCW	CW	Ext. angle, – degrees	Right	Offset in mm

Use Procedure 4-2 to perform known direct calibration for positioners. Use Procedure 4-3 to perform known direct calibration for general positioners.

Procedure 4-2 Known Direct Calibration for Positioners

Conditions

- The follower group and leader group have been mastered and calibrated. (Refer to the appropriate application-specific *S etup and Operations Manual* .)
- 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 three-dimensional right hand rule conventions for axis labeling.
- 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.

Steps

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:
   - $SCR_GRP[leader_group].$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:   1
  X:   0.000 Y:   0.000 Z:   0.000
  W:   0.000 P:   0.000 R:   0.000
 X:                         0.0000
 Y:                         0.0000
 Z:                         0.0000
 W:                         0.0000
 P:                         0.0000
 R:                         0.0000
```

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.

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 7–1 in Chapter 7 *TROUBLESHOOTING* .

Procedure 4-3 Known Direct Calibration for General Positioners

Conditions

- The follower group and leader group have been mastered and calibrated. (Refer to the appropriate application-specific *S etup and Operations Manual* .)
- The leader group hardware configuration is correct.
- The CD_pair has been set up (Chapter 3 *SETTING UP COORDINATED PAIRS*).
- 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.

Steps

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 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 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]

   Note See Figure 4–6 for a graphical definition of the D-H parameters.

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:   1
  X:  0.000 Y:  0.000 Z:  0.000
  W:  0.000 P:  0.000 R:  0.000
 X:                          0.0000
 Y:                          0.0000
 Z:                          0.0000
 W:                          0.0000
 P:                          0.0000
 R:                          0.0000
```

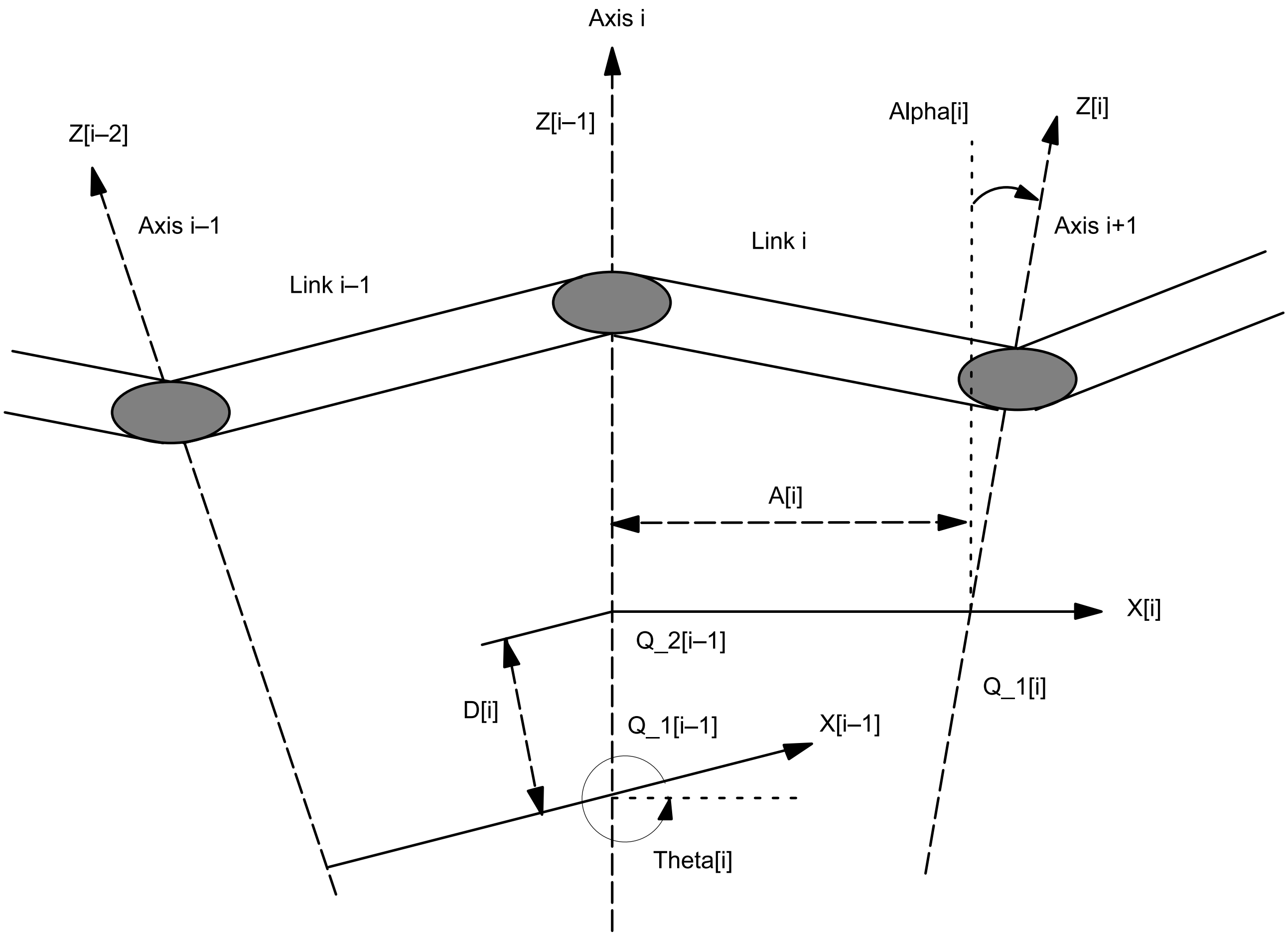
8. Move the cursor to X, type the x value of the leader frame origin point, and press ENTER.
9. Move the cursor to Y, type the y value of the leader frame origin point, and press ENTER.

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.

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 7–1 in Chapter 7 *TROUBLESHOOTING* .

Figure 4–6. Definition of D-H Parameters



A[i] = the distance between Q_1[i] and Q_2[i–1] along the X[i] direction
Alpha[i] = the angle from the Z[i–1] to Z[i] where the positive direction is the same as X[i]

For rotary axis i:
  D[i] = the distance between Q_1[i–1] and Q_2[i–1] along the Z[i–1] direction
For linear axis i:
  Theta[i] = the angle from X[i–1] to X[i] where the positive direction is the same as Z[i–1]

4.4 UNKNOWN POINT CALIBRATION FOR 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 positioners for which arm length(s) and offset(s) 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.

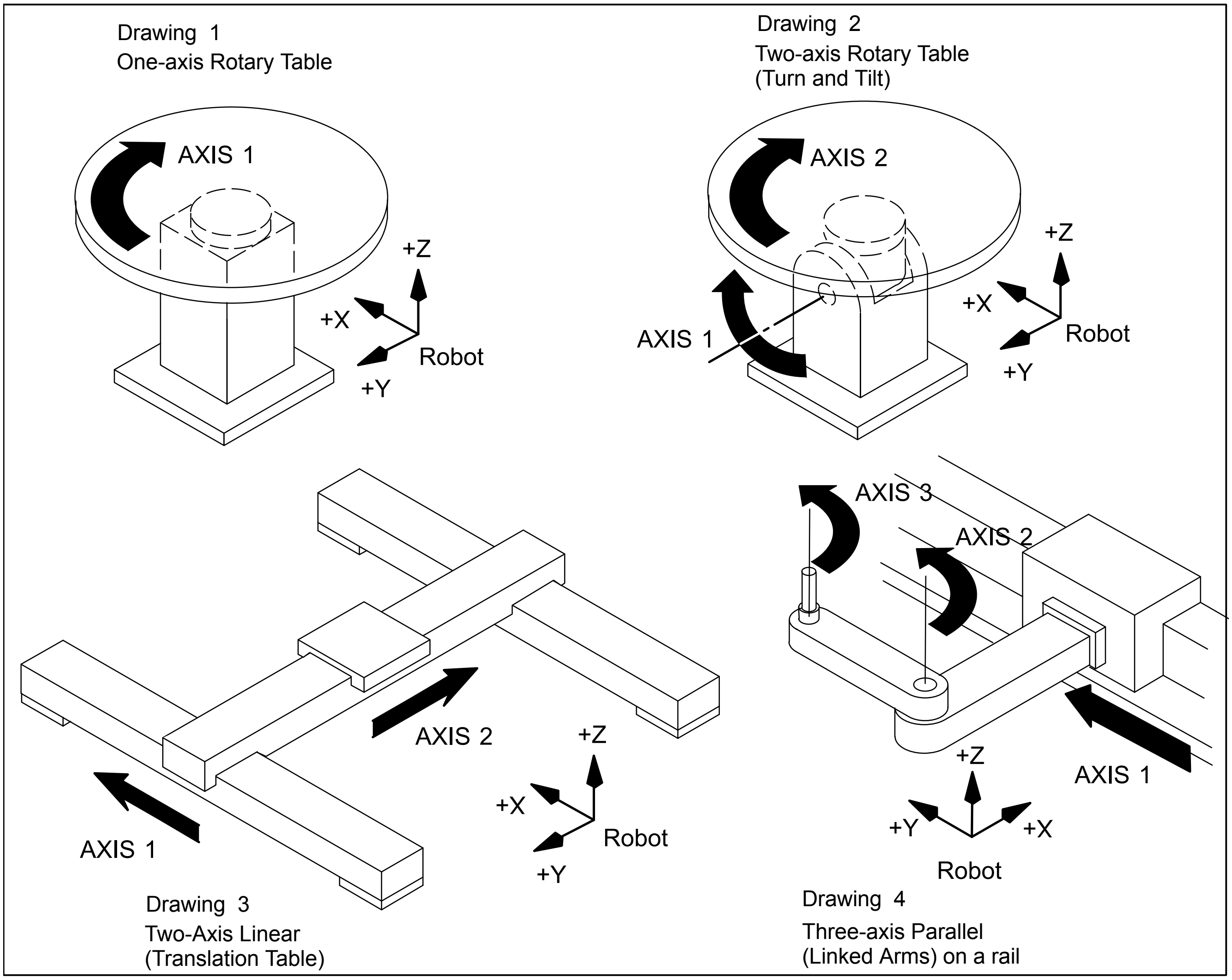
Calibration is required for each axis of an unknown kinematics device:

- 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.

Figure 4–7 shows examples of linear and rotary axis unknown kinematics devices that are used as leaders in coordinated motion.

Note For the ARC POSITIONER (H871), use the "Known Four Point Calibration" method instead, refer to Section 4.2 .

Figure 4–7. Leader Device Examples



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).

  The x, y, or z axis of the leader frame must be aligned with the first motor's axis of rotation or linear axis:

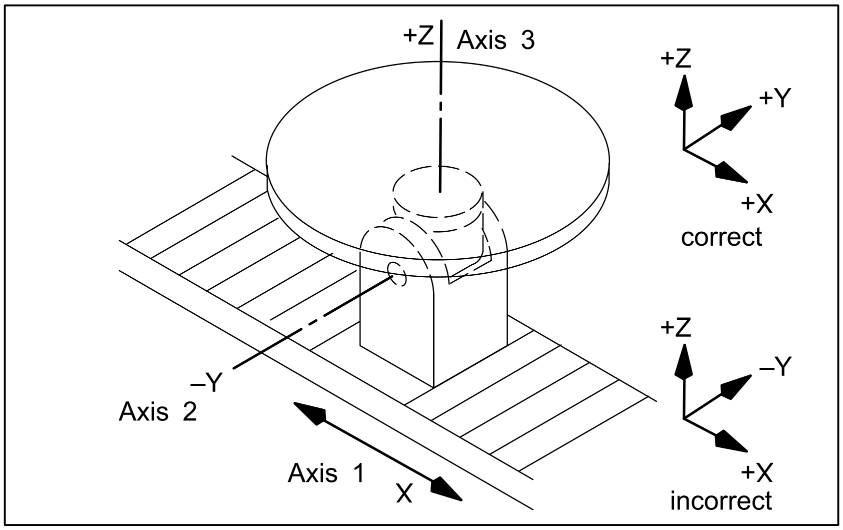
— In a one-axis positioning device, the assignment and the direction of the axis is arbitrary.

— In a two-axis positioning device, the direction of the second axis is not arbitrary. The second axis must align with respect to the first axis by being either parallel or perpendicular to the first axis. The assignment of the leader frame axis (z, y, x) is made with respect to the axis one assignment and the right-hand rule.

— The third motor of a three-axis positioning device must be either parallel or perpendicular to one of the other axes.

In the case of three mutually perpendicular axes, one will be x, one y, and one z. The positive direction of the axes must establish a correct Cartesian space frame. See Figure 4–8 .

Figure 4–8. Correct and Incorrect Axis Alignment



If possible, the alignment should reflect a logical alignment for leader frame x, y and z. Often, it is best to align these with the follower (robot) WORLD axes, or with the UFRAME or UTOOL axes of the follower.

For example, in Figure 4–7 ,

— The one-axis rotary table can be any axis (x, y, z, -x, -y, or -z). See Drawing 1.

— Axis 1 of the two-axis rotary table can be any frame axis, such as y. However, the perpendicular axes cannot be y or -y. See Drawings 2 and 3.

— Parallel axes with the same positive axis direction must be assigned the same. In the three-axis parallel illustration, axis 2 and axis 3 must be defined as, for example, (x and x), (-x and -x), (y and y), or (-y and -y). See Drawing 4.

- 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).

Use Procedure 4-4 to set up the tool frame using the six point method. Use Procedure 4-5 to perform unknown point calibration for a rotary axis. Use Procedure 4-6 to perform unknown point calibration for a linear axis. Use both Procedure 4-5 and Procedure 4-6 for positions with linear and rotary axes.

Procedure 4-4 ArcTool Tool Frame Six Point Method

Conditions

-

> **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.

Steps

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 MultiARM 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     Z:  0.0
    W:    0.0     P:  0.0     R:  0.0
   Comment: ****************
   Approach point 1:          UNINIT
   Approach point 2:          UNINIT
   Approach point 3:          UNINIT
   Orient Origin Point:       UNINIT
   X Direction Point:         UNINIT
   Z Direction Point:         UNINIT
  Active TOOL $MNUTOOLNUM[1]=1
```

Note In this screen, Tool frames are being set for group 1, because the active tool is $MNUTOOLNUM[1]. If the active tool is $MNUTOOLNUM[2], then Tool frames for group 2 will be set.

Note The XZ variation of the six point method is described here. The XY variation is the same except a +y direction point is taught in instead of the +z direction point.

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 14f , 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.

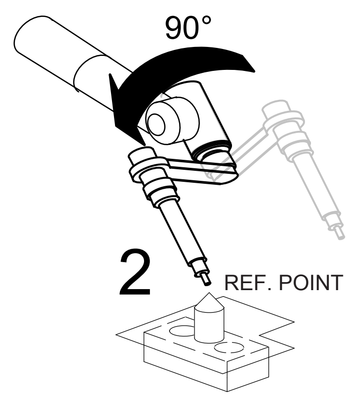
Warning

In Step 15f , 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 4–9):

Figure 4–9. 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° (but no more than 360°) about the z-axis of the 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.

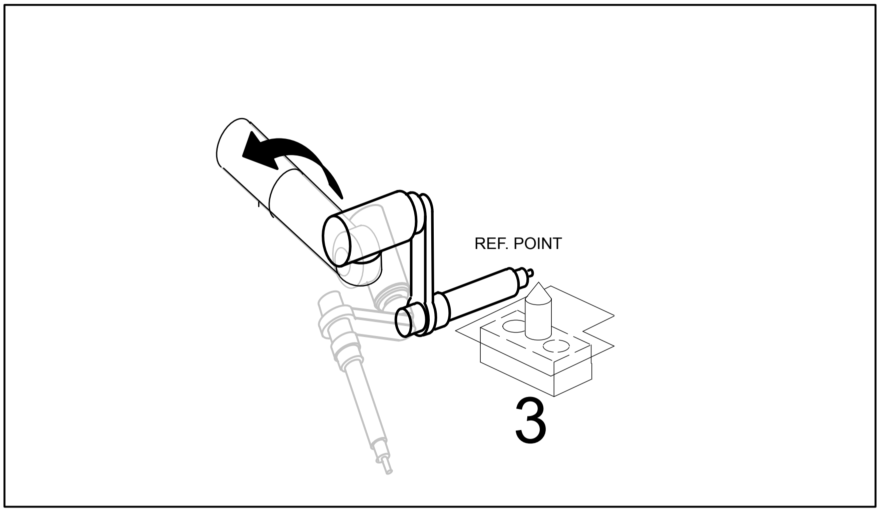
g. Move the cursor to Orient Origin Point.

> **Warning**
>
> **In Step 16h , 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 4–10. 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.

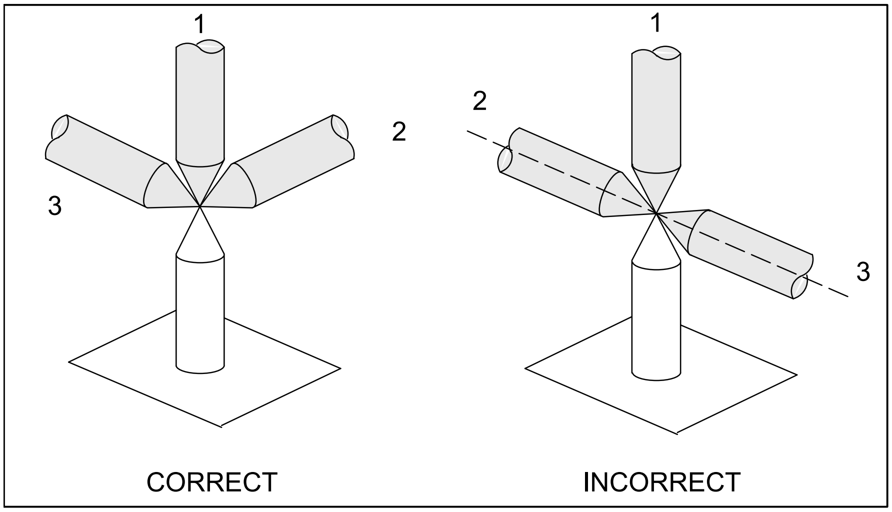
Warning

In Step 17h , 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 4–11 .

Figure 4–11. 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.

```
SETUP Frames
  Tool Frame Setup / Six Point
        X      Y      Z         Comment
  1:    0.0    0.0    0.0     *************
  2:    0.0    0.0    0.0     *************
  3:    0.0    0.0    0.0     *************
  4:    0.0    0.0    0.0     *************
  5:    0.0    0.0    0.0     *************
  6:    0.0    0.0    0.0     *************
  7:    0.0    0.0    0.0     *************
  8:    0.0    0.0    0.0     *************
  9:    0.0    0.0    0.0     *************
  Active TOOL $MNUTOOLNUM[1]=1
```

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.

> **Caution**
>
> 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 save the frames and related system variables to a file**.

23. **To check that the tool frame has been defined properly**:

a. Move the cursor to the Orient Origin Point.

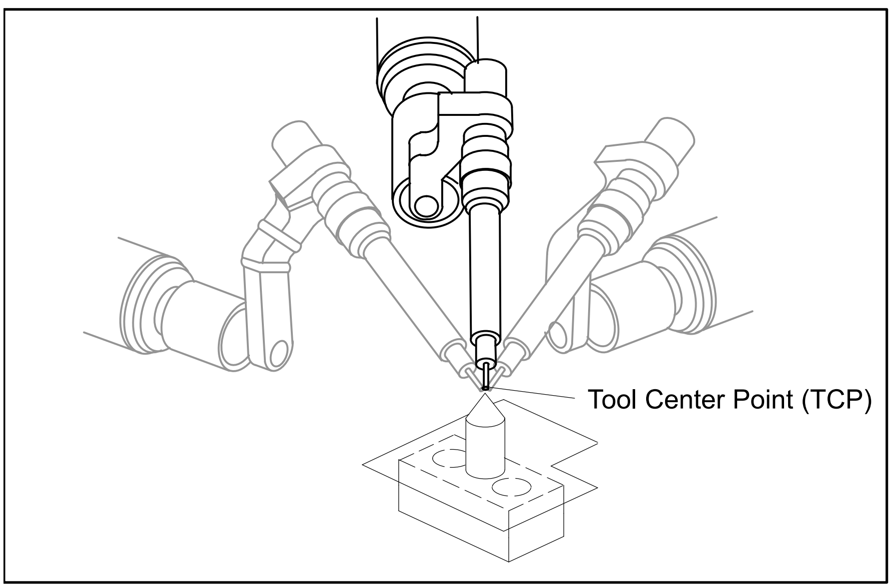
b. Press and hold the SHIFT key and press F4, MOVE_TO, until the TCP has returned back to the touch block pointer tip.

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 4–12 .

Figure 4–12. Verifying the Tool Frame



f. **If the TCP does not remain close to the pointer tip,** repeat Procedure 4-4 to redefine the tool frame.

Procedure 4-5 Unknown Point Calibration for a Rotary Axis

Conditions

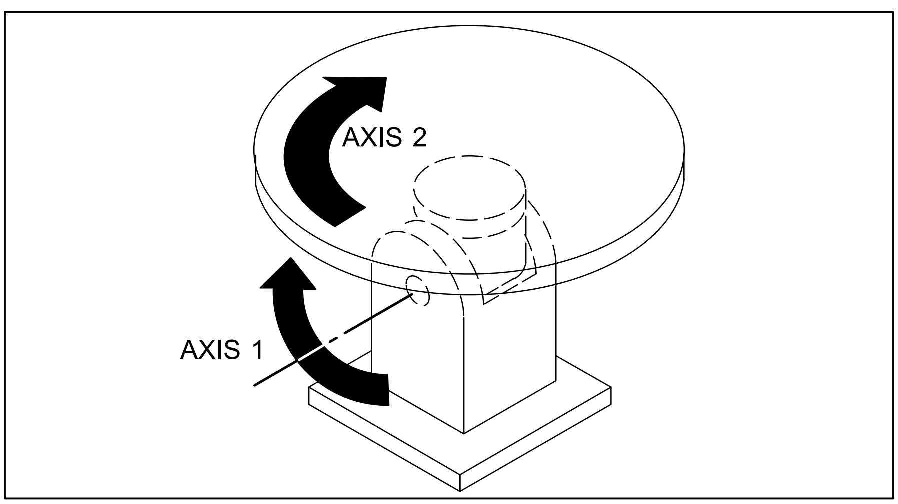
- The number, direction, and order of axes for the leader group is set and known.
- The leader frame alignment has been determined.
- Mastering and calibration of the leader and follower groups has been completed.
- The tool frame and user frame (if applicable) of the follower group have been defined.
- 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 4–13 .

Figure 4–13. Unknown Point Calibration Overview for a Rotary Axis



Steps

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.

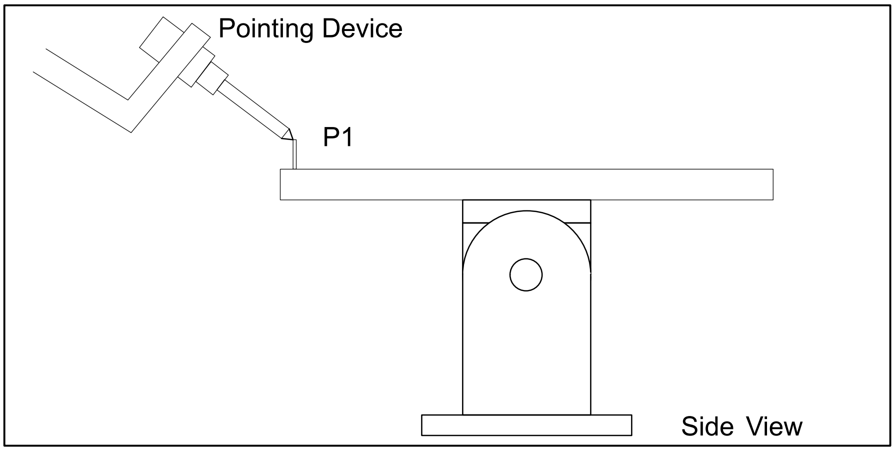
```
SETUP Coord
Unknown type calibration      Coord Pair: 1
 Group Number Leader:  3      Follower:   1
  X:  0.000    Y:  0.000     Z:  0.000
  W:  0.000    P:  0.000     R:  0.000
 Axis Number:              1  (Total:2)
 Axis Type:                ROTARY
 Axis Direction:           +Y
 Point 1:                  UNINIT
 Point 2:                  UNINIT
 Point 3:                  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 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 4–14 .
   c. Press and hold SHIFT and press F5, RECORD.

Figure 4–14. Defining Point 1 for Axis 1



Note For the next two points, if the total positive rotation is less than60°, 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 4–15)

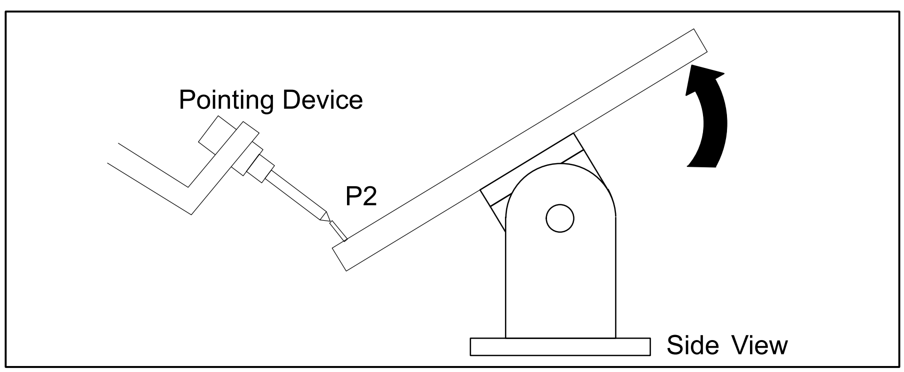
a. Move the cursor to Point 2.

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 4–15. Defining Point 2 for Axis 1



11. Record Point 3: (Figure 4–16)

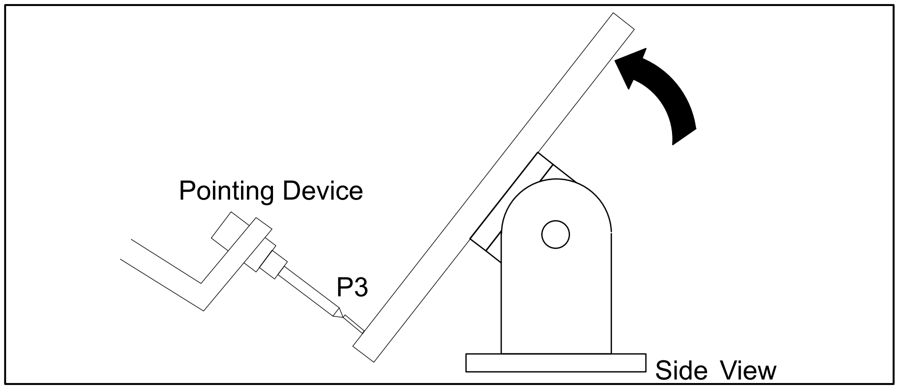
a. Move the cursor to Point 3.

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 4–16. 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.

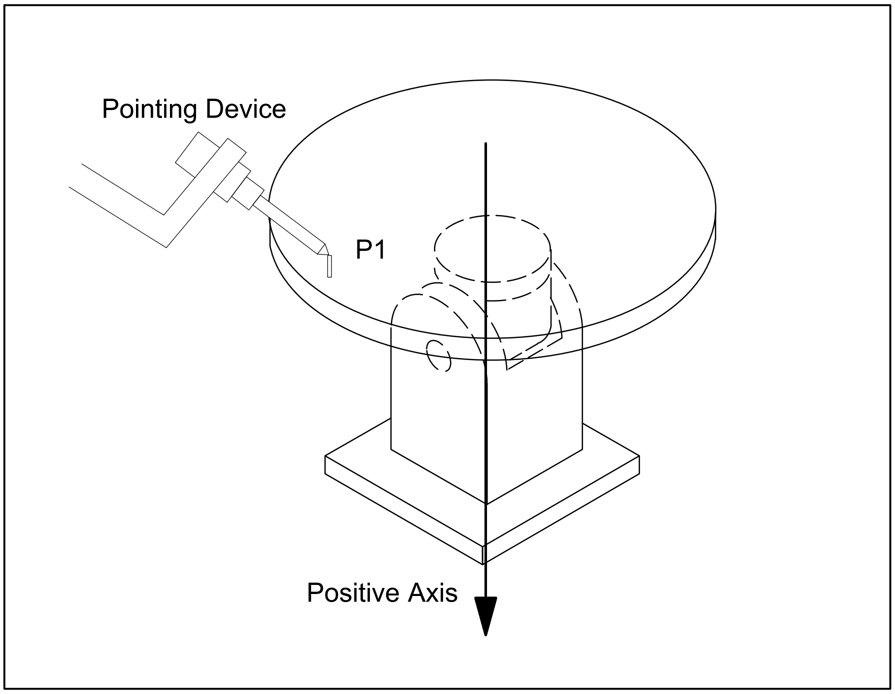
Make sure axes 1 and 2 are each in the zero position. See Figure 4–17 .

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 4–17. Defining Point 1 for Axis 2



14. Record Point 2 (Second Axis): (Figure 4–18)

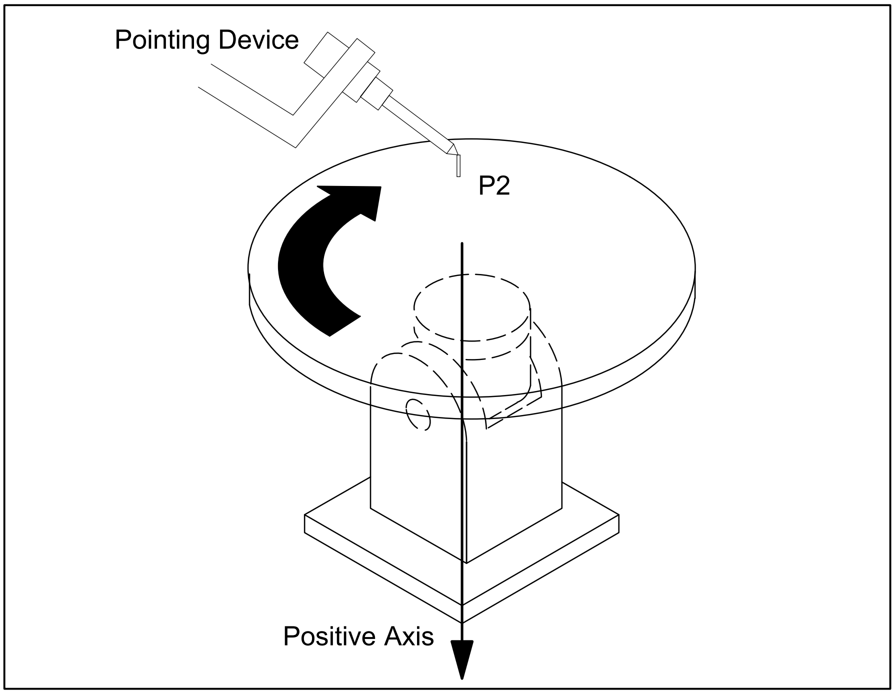
a. Move the cursor to Point 2.

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 4–18. Defining Point 2 for Axis 2



15. Record Point 3 (Second Axis): (Figure 4–19)

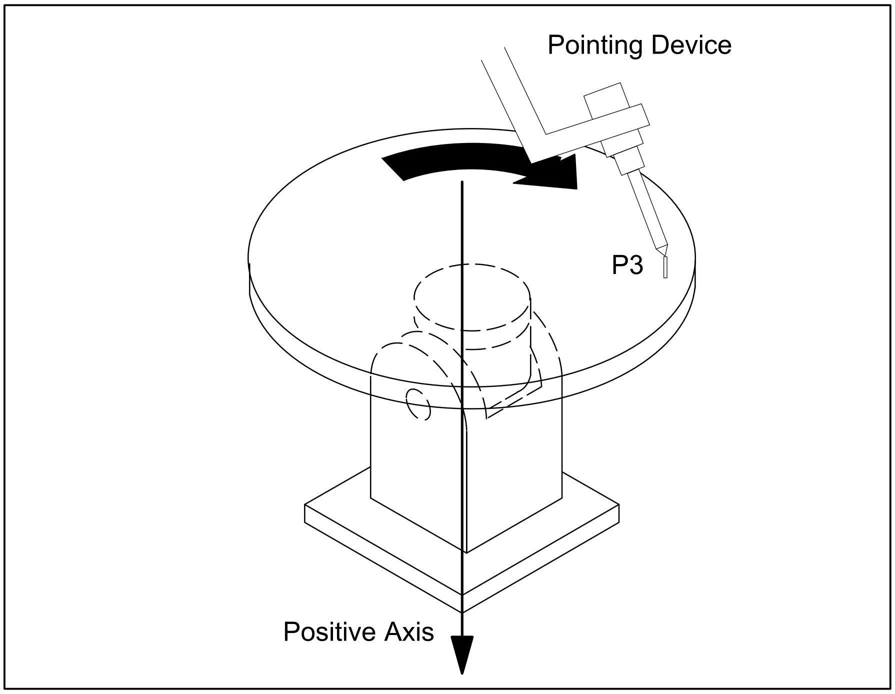
a. Move the cursor to Point 3.

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 4–19. Defining Point 3 for Axis 2



16. Repeat Step 6 through Step 15 for all of the rotary axes of the positioner.
17. Perform Procedure 4-6 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.

    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 7–1 in Chapter 7 *TROUBLESHOOTING* .
19. Turn off the controller and then turn it on again to enable this data for system use.

Procedure 4-6 Unknown Point Calibration for a Linear Axis

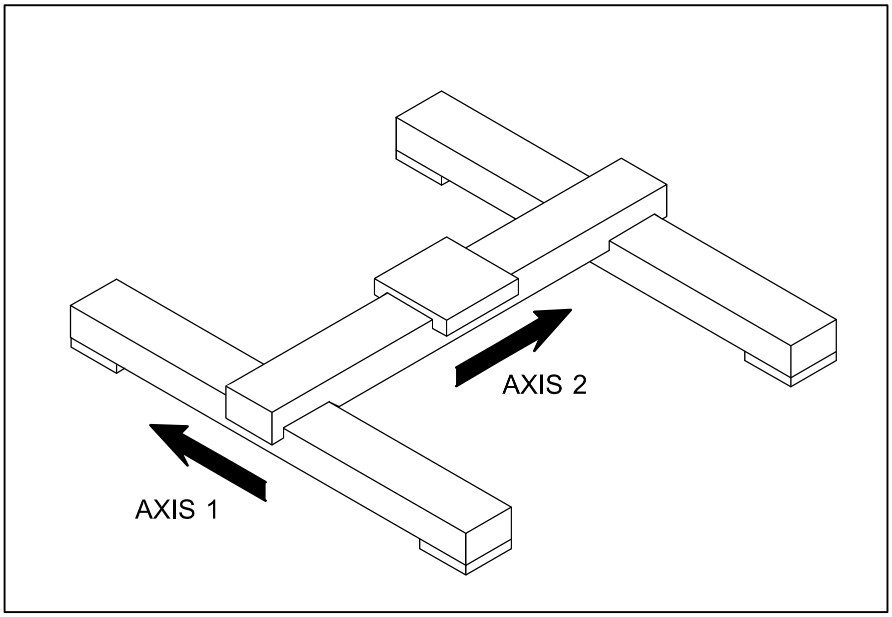
Conditions

- The number, direction, and order of axes for the leader group is set and known.
- The leader frame alignment has been determined.
- 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 positioning device.

- The CD_pair has been set up (Chapter 3 *SETTING UP COORDINATED PAIRS*).

Note When you calibrate axes, you must start at the base axis and finish with the tabletop or work surface axis. See Figure 4–20 .

Figure 4–20. Unknown Point Calibration Overview for a Linear Axis



Steps

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:   1
  X:  0.000    Y:  0.000     Z:  0.000
  W:  0.000    P:  0.000     R:  0.000
 Axis Number:             2  (Total:2)
 Axis Type:               LINEAR
 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.

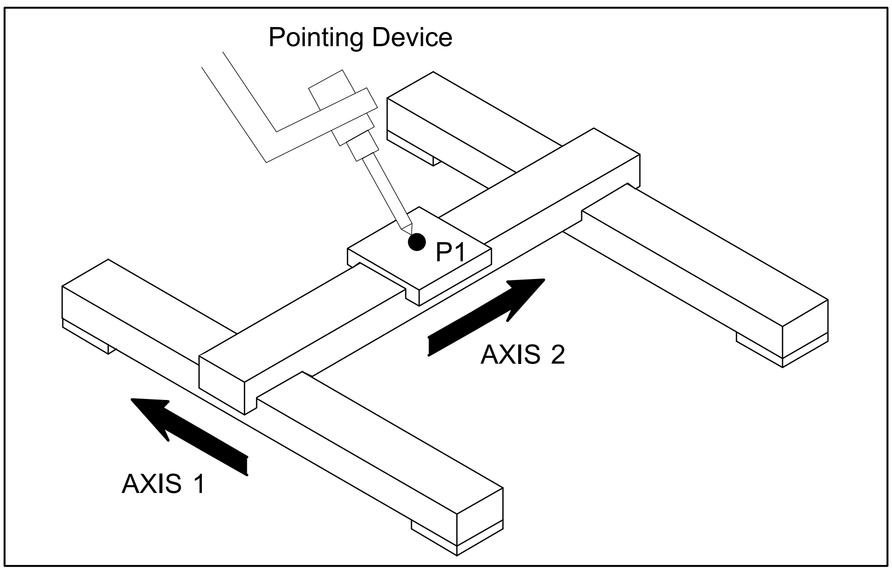
9. Record Point 1:

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 4–21 .

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

Figure 4–21. Defining Point 1 for Axis 1



10. Record Point 2: (Figure 4–22)

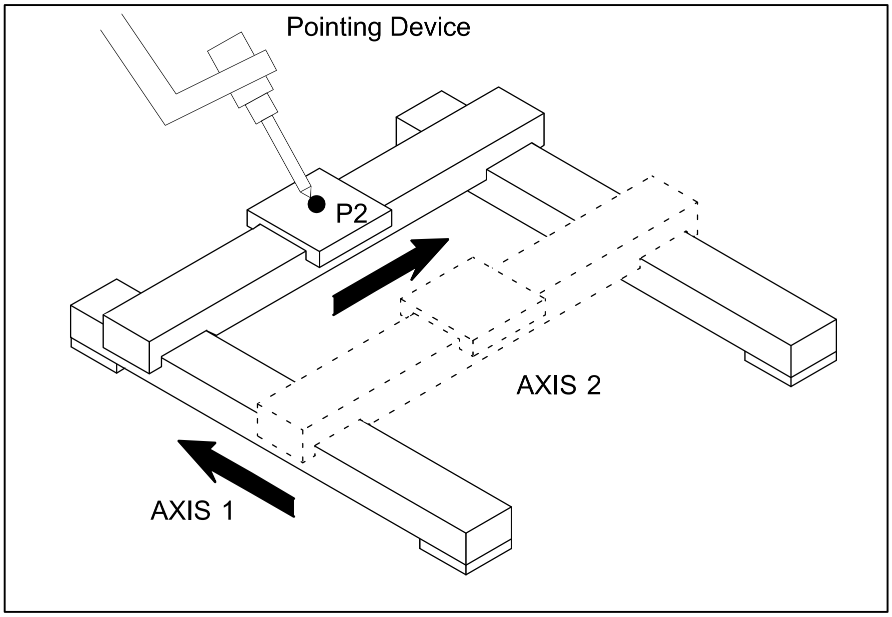
a. Move the cursor to Point 2.

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 4–22. Defining Point 2 for Axis 1



11. Record Point 1 (second axis):

a. Move all axes to their zero positions.

b. Move the cursor to Axis Number and enter the number of the axis you are calibrating (2, for example).

c. Move the cursor to Axis Direction and change it if necessary.

d. Move the cursor to Point 1.

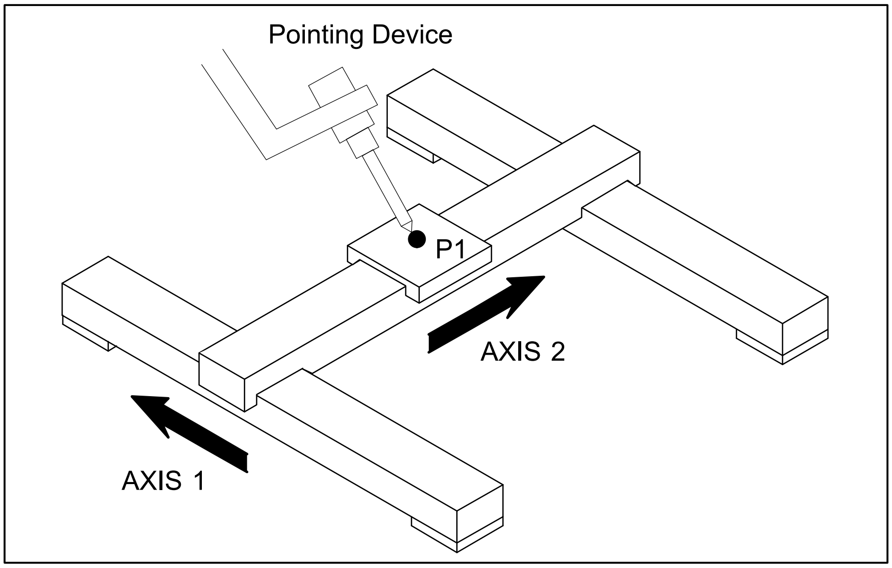
e. Jog the follower (robot) so that the pointing device touches the marked position on the leader. See Figure 4–23 .

f. Press and hold SHIFT and press F5, RECORD.

Note Point 1 for the second axis can be the same as Point 1 for the first axis. Use MOVE_TO to move the robot to Point 1 of the first axis, select the appropriate axis number, and record the position. MOVE_TO will move only one group at a time. To move another group, toggle the group number and press F4, MOVE_TO.

Note Use the same pointer or reference mark for all axes.

Figure 4–23. Defining Point 1 for Axis 2



12. Record Point 2 (second axis): (Figure 4–24)

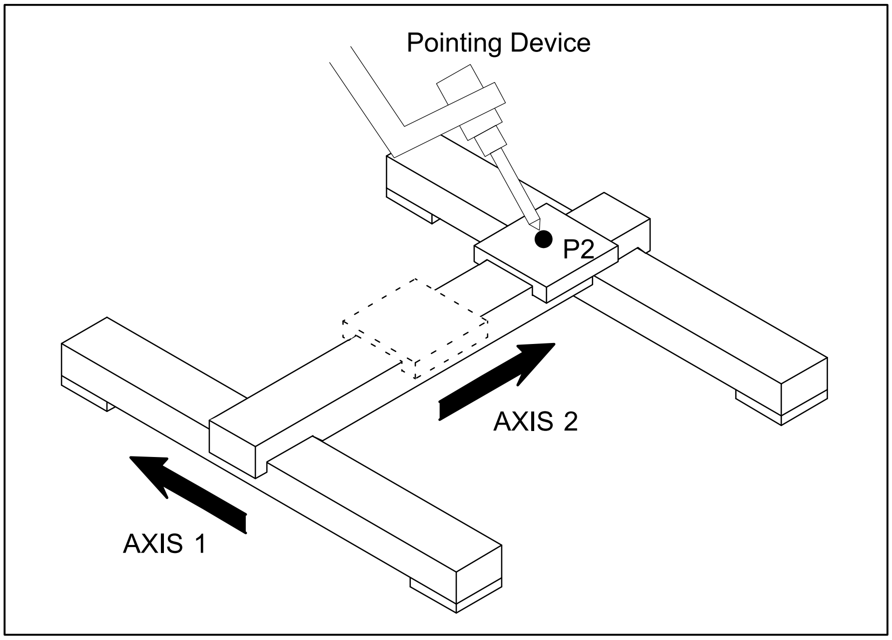
a. Move the cursor to Point 2.

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 4–24. Defining Point 2 for Axis 2



13. Repeat Step 6 through Step 10 for all of the linear axes of the positioner.
14. Perform Procedure 4-5 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.

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

    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 7–1 in Chapter 7 *TROUBLESHOOTING* .
16. Turn off the controller and then turn it on again to enable this data for system use.

4.5 UNKNOWN POINT CALIBRATION FOR 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.

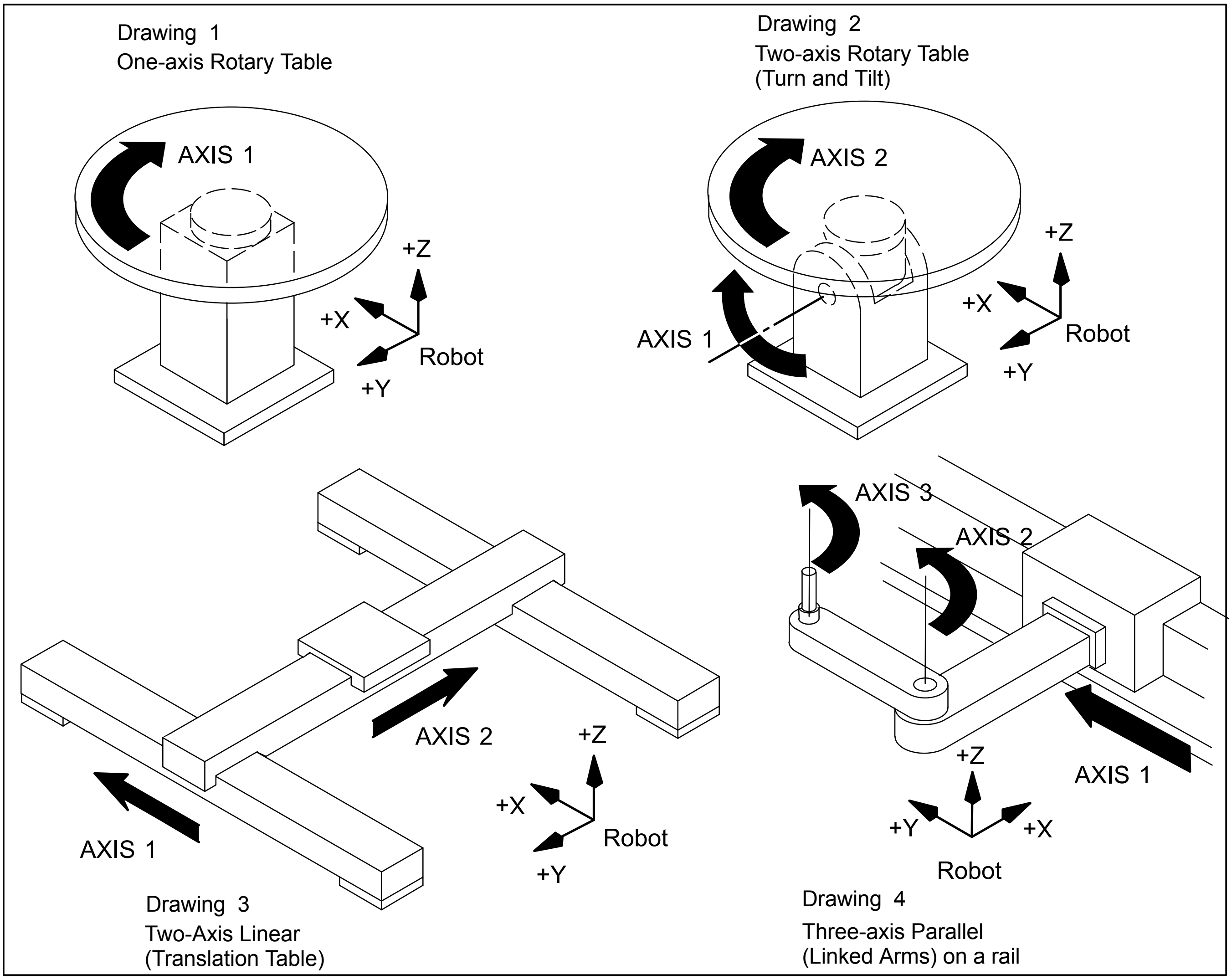
Unknown kinematics type is used for turntables or general positioners for which arm length(s) and D-H parameters are not known, or are not known accurately. Unknown point calibration is typically used for all single-axis tables, multiple-axis tables, and linear or linear/rotary positioners.

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.

Figure 4–25 shows examples of linear and rotary axis unknown kinematics devices that are used as leaders in coordinated motion.

Figure 4–25. Leader Device Examples



Conditions for Calibration

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

- The number of the general positioner and order of axes for the leader group is set and known.
- The leader group hardware configuration is correct.
- 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).

Use Procedure 4-5 to perform unknown point calibration for a rotary axis. Use Procedure 4-6 to perform unknown point calibration for a linear axis. Use both Procedure 4-5 and Procedure 4-6 for general positioners with linear and rotary axes.

Procedure 4-7 Unknown Point Calibration for a Rotary Axis of General Positioners

Conditions

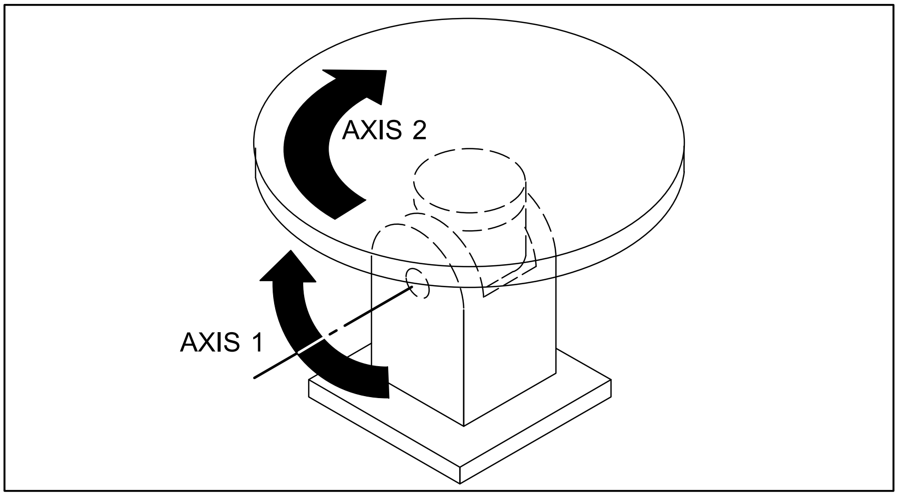
- The number of the general positioner and order of axes for the leader group is set and known.
- Mastering and calibration of the leader and follower groups has been completed.
- The tool frame and user frame (if applicable) of the follower group have been defined.
- A mark or pointer has been placed 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 4–26 .

Figure 4–26. Unknown Point Calibration Overview for a Rotary Axis



Steps

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:   1
  X:  0.000    Y:  0.000     Z:  0.000
  W:  0.000    P:  0.000     R:  0.000
 Axis Number:             1  (Total:2)
 Axis Type:               ROTARY
 Axis Direction:          +Z
 Point 1:                 UNINIT
 Point 2:                 UNINIT
 Point 3:                 UNINIT
```

Note Axis Direction will be determined automatically as the +z direction of an attached frame. This value can not be changed.

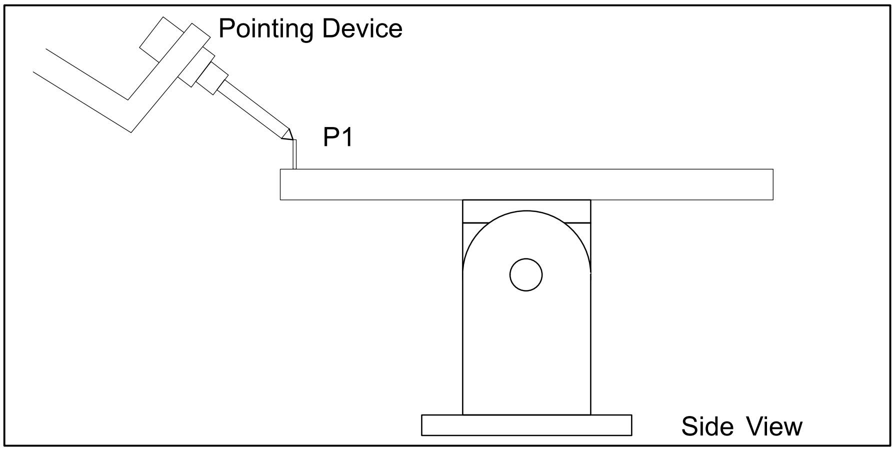
1. Move all axes of the leader to their zero positions.
2. Move the cursor to Axis Number and enter the number of the axis you are calibrating.

3. 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.

4. 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 4–27 .
   c. Press and hold SHIFT and press F5, RECORD.

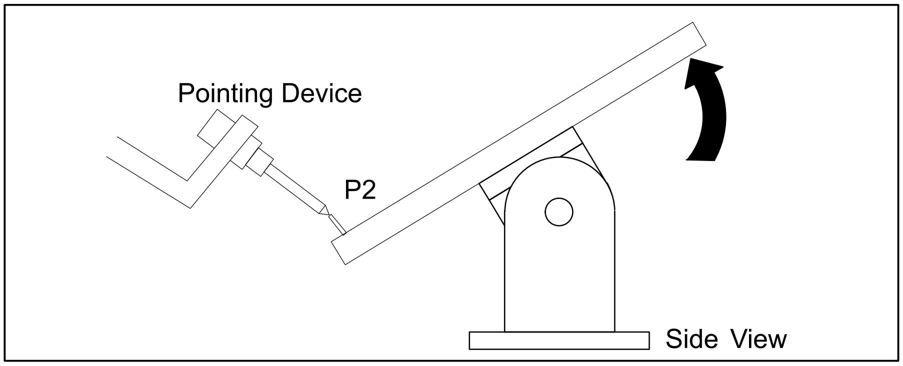
Figure 4–27. Defining Point 1 for Axis 1



Note For the next two points, if the total positive rotation is less than60°, 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.

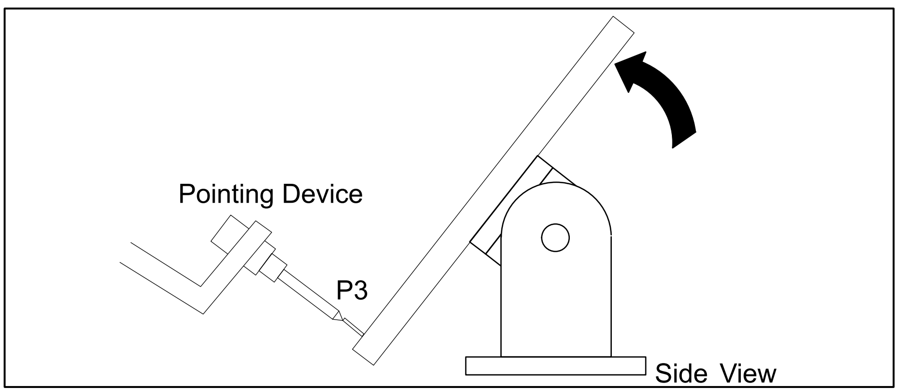
5. Record Point 2: (Figure 4–28)
   a. Move the cursor to Point 2.
   b. Jog the first axis only of the leader from 30 to 90 degrees in the positive direction.
   c. Jog the follower (robot) so that the pointing device touches the marked position on the leader.
   d. Press and hold SHIFT and press F5, RECORD.

Figure 4–28. Defining Point 2 for Axis 1



6. Record Point 3: (Figure 4–29)
   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 4–29. Defining Point 3 for Axis 1



7. **If your positioner has a single axis,** press F3, EXEC, to complete the CD_pair calibration. Otherwise, go to Step 13 .
8. 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.

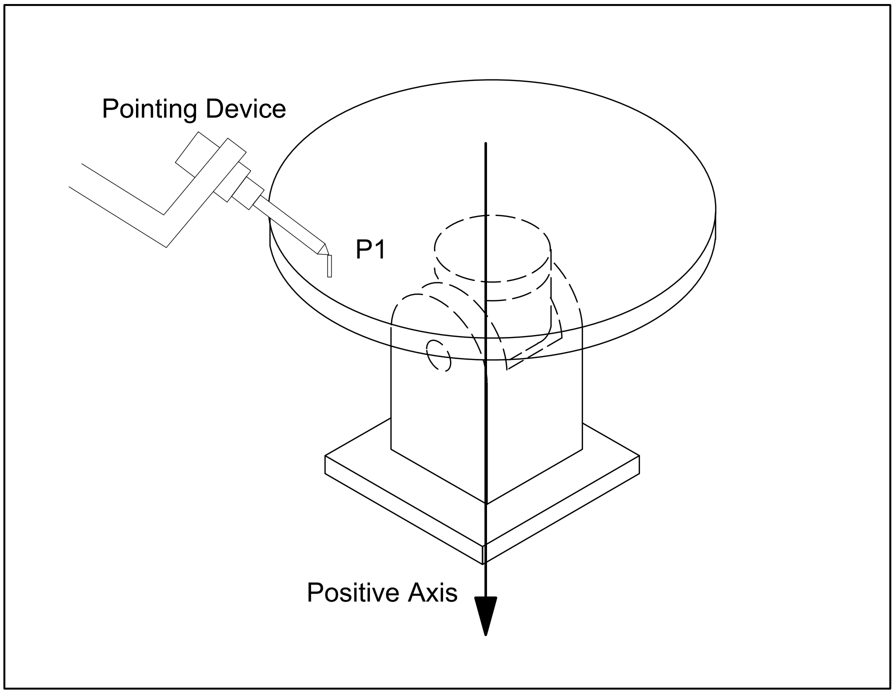
Make sure axes 1 and 2 are each in the zero position. See Figure 4–30 .

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.

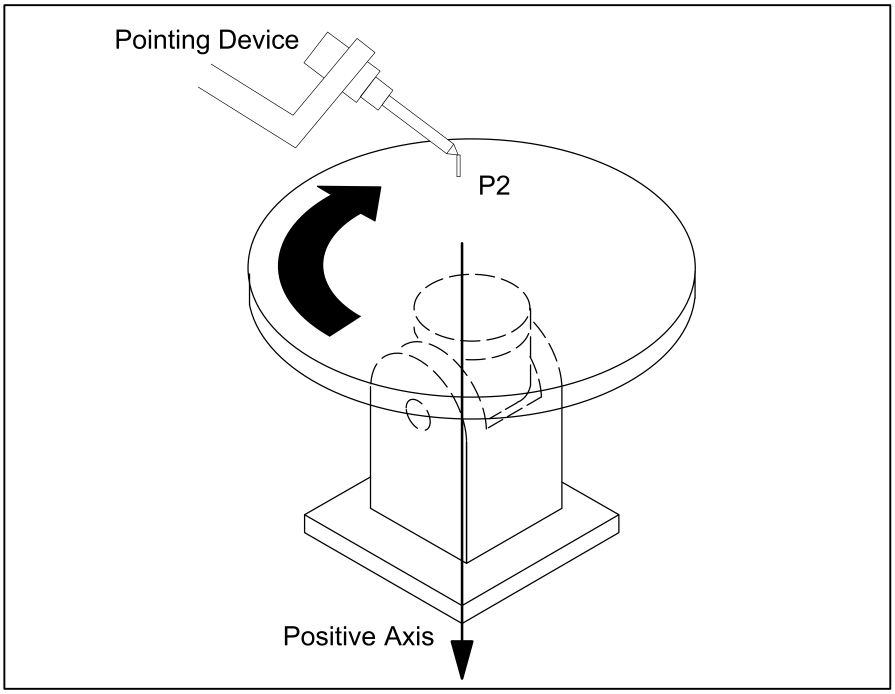
c. Press and hold SHIFT and press F5, RECORD.

Figure 4–30. Defining Point 1 for Axis 2



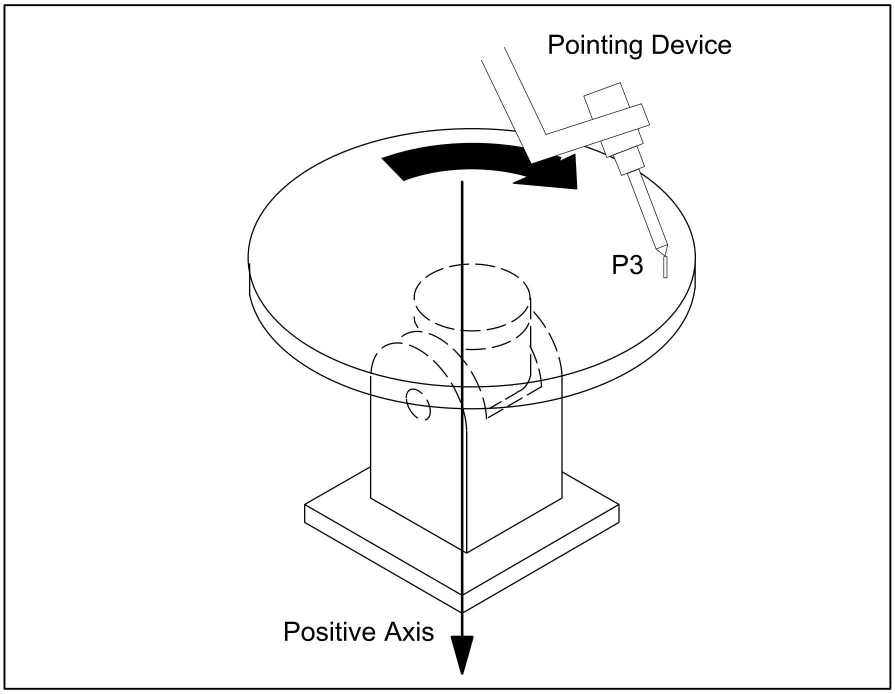
9. Record Point 2 (second axis): (Figure 4–31)
   a. Move the cursor to Point 2.
   b. Jog the second axis only of the leader from 30 to 90 degrees in the positive direction.
   c. Jog the follower (robot) so that the pointing device touches the marked position on the leader.
   d. Press and hold SHIFT and press F5, RECORD.

Figure 4–31. Defining Point 2 for Axis 2



10. Record Point 3 (second axis): (Figure 4–32)
    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 4–32. Defining Point 3 for Axis 2



11. Repeat Step 6 through Step 15 for all of the rotary axes of the positioner.
12. Perform Procedure 4-6 for all of the linear axes of the positioner.
13. **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.

    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 7–1 in Chapter 7 *TROUBLESHOOTING* .
14. Turn off the controller and then turn it on again to enable this data for system use.

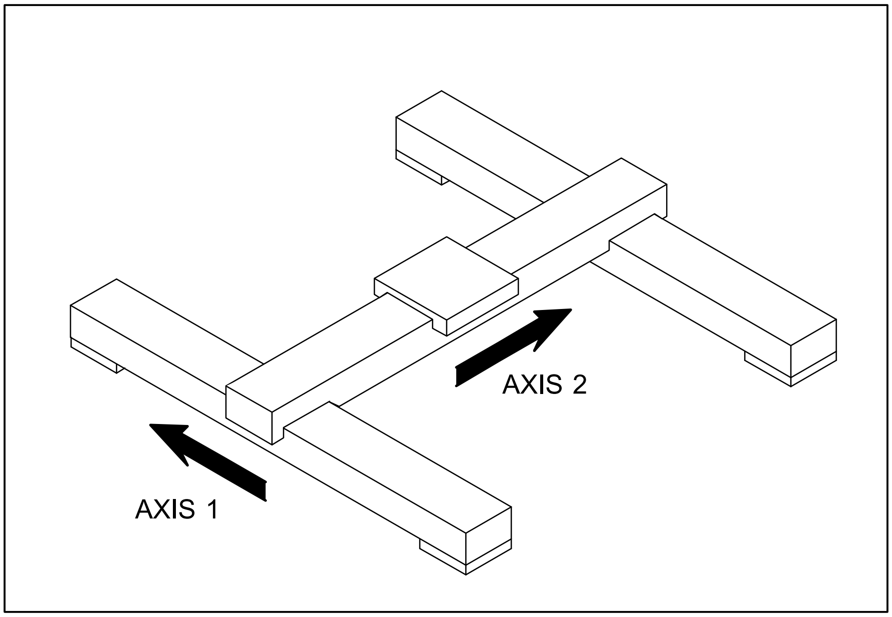
Procedure 4-8 Unknown Point Calibration of a Linear Axis for General Positioners

Conditions

- The number 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 positioning device.
- The CD_pair has been set up (Chapter 3 *SETTING UP COORDINATED PAIRS*).

Note When you calibrate axes, you must start at the base axis and finish with the tabletop or work surface axis. See Figure 4–33 .

Figure 4–33. Unknown Point Calibration Overview for a Linear Axis



Steps

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:   1
  X:  0.000    Y:  0.000     Z:  0.000
  W:  0.000    P:  0.000     R:  0.000
 Axis Number:             2  (Total:2)
 Axis Type:               LINEAR
 Axis Direction:          +Z
 Point 1:                 UNINIT
 Point 2:                 UNINIT
```

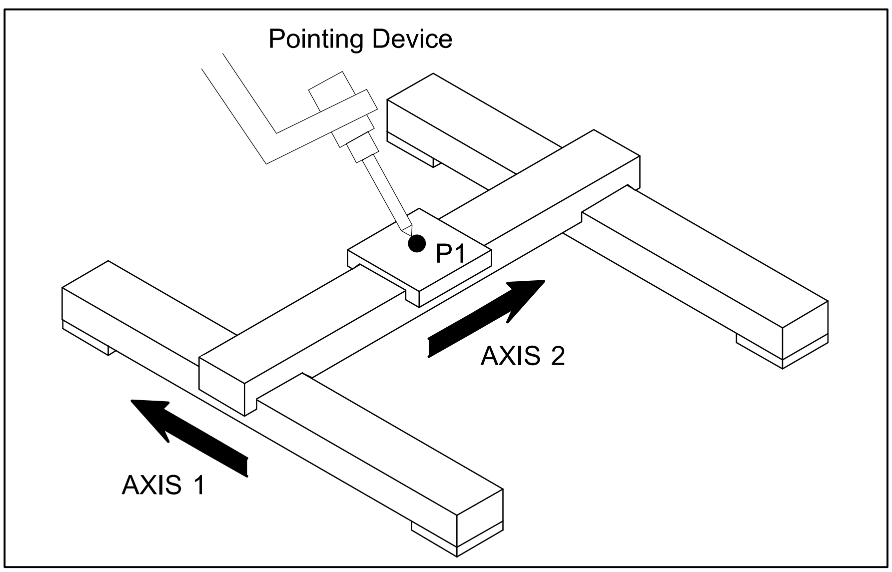
Note Axis Direction will be determined automatically as the +z direction of an attached frame. This value can not be changed.

1. Move all axes of the leader to their zero positions.
2. Move the cursor to Axis Number and enter the number of the axis you are calibrating.
3. 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.

4. 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 4–34 .
   c. Press and hold SHIFT and press F5, RECORD.

Figure 4–34. Defining Point 1 for Axis 1

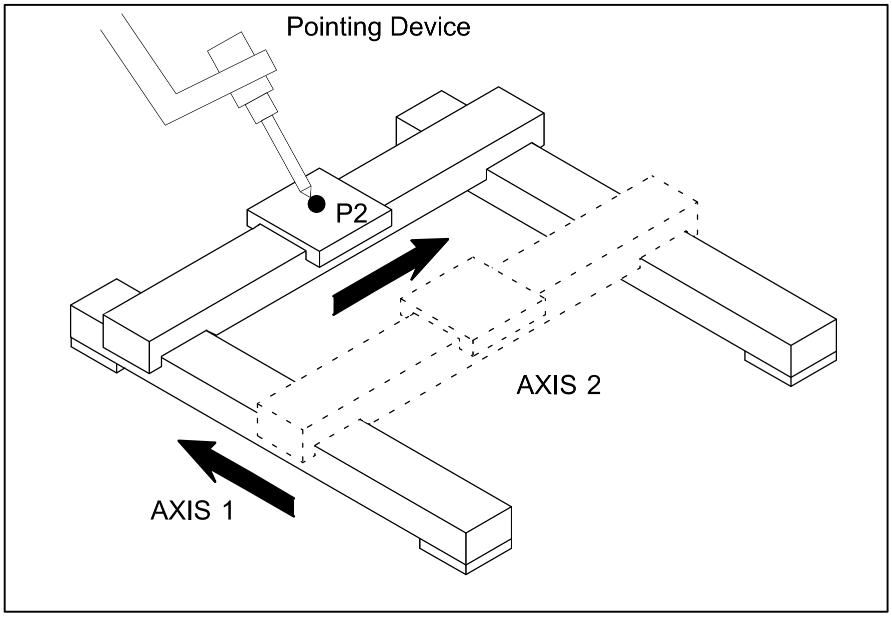


5. Record Point 2: (Figure 4–35)
   a. Move the cursor to Point 2.
   b. Jog the first axis only of the leader 150 mm or more in the positive direction.

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 4–35. Defining Point 2 for Axis 1



6. Record Point 1 (second axis):

a. Move all axes to their zero positions.

b. Move the cursor to Axis Number and enter the number of the axis you are calibrating (2, for example).

c. Move the cursor to Axis Direction and change it if necessary.

d. Move the cursor to Point 1.

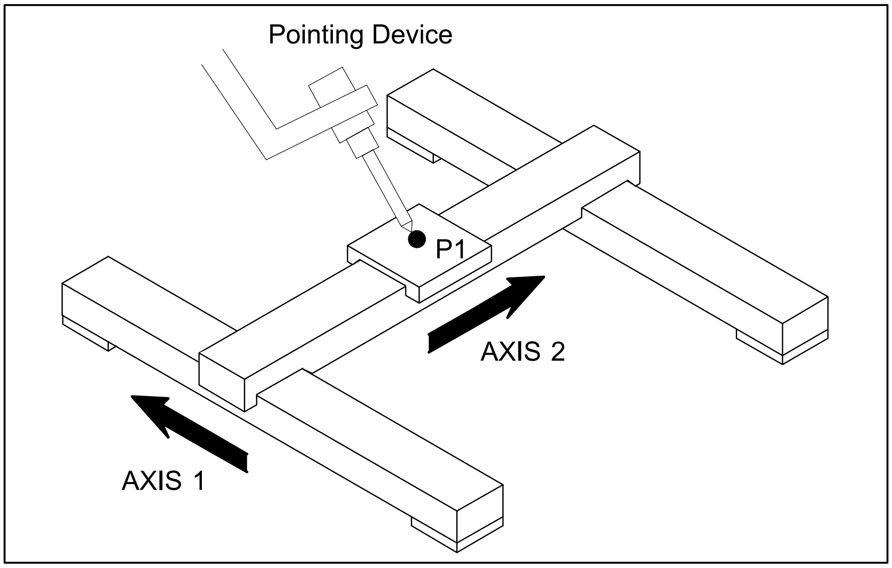
e. Jog the follower (robot) so that the pointing device touches the marked position on the leader. See Figure 4–36 .

f. Press and hold SHIFT and press F5, RECORD.

Note Point 1 for the second axis can be the same as Point 1 for the first axis. Use MOVE_TO to move the robot to Point 1 of the first axis, select the appropriate axis number, and record the position. MOVE_TO will move only one group at a time. To move another group, toggle the group number and press F4, MOVE_TO.

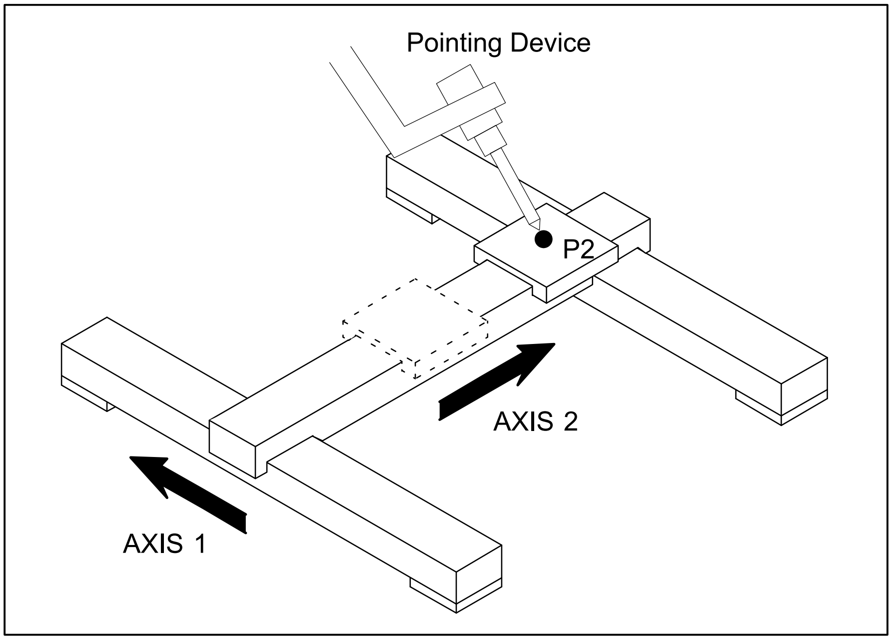
Note Use the same pointer or reference mark for all axes.

Figure 4–36. Defining Point 1 for Axis 2



7. Record Point 2 (second axis): (Figure 4–37)
   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 4–37. Defining Point 2 for Axis 2



8. Repeat Step 6 through Step 10 for all of the linear axes of the positioner.
9. Perform Procedure 4-5 for all of the rotary axes of the positioner.
10. **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.

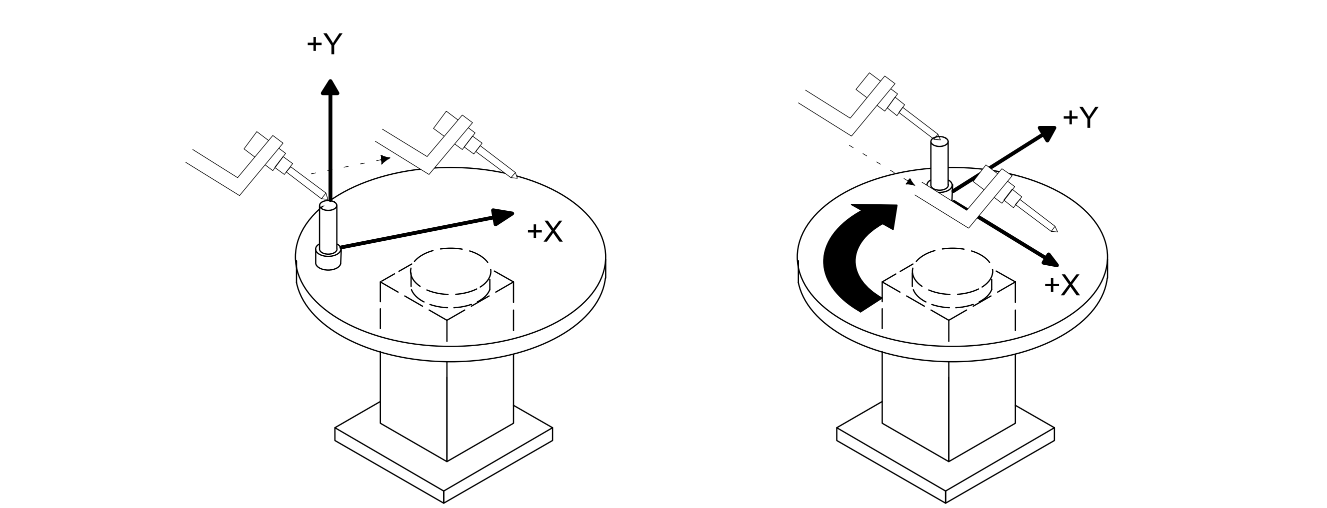
    If the calibration was not successful, or if a calibration message is displayed on the prompt line of the teach pendant screen, refer to Table 7–1 in Chapter 7 *TROUBLESHOOTING* .
11. Turn off the controller and then turn it on again to enable this data for system use.

4.6 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 4–38 .

Figure 4–38. Leader Frame Jogging



Procedure 4-9 Leader Frame Setup

Note In a table top coordination application, the leader is the table. It would be difficult to define this leader frame by moving the leader position; therefore, use the follower to teach the leader frames.

Conditions

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

Steps

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:  1
 Group Number Leader:   2      Follower:    1
 Leader Frame:
  X:  0.000    Y:  0.000     Z:  0.000
  W:  0.000    P:  0.000     R:  0.000
 Leader Frame number:     :       1
 Origin Point:            :  UNINIT
 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.

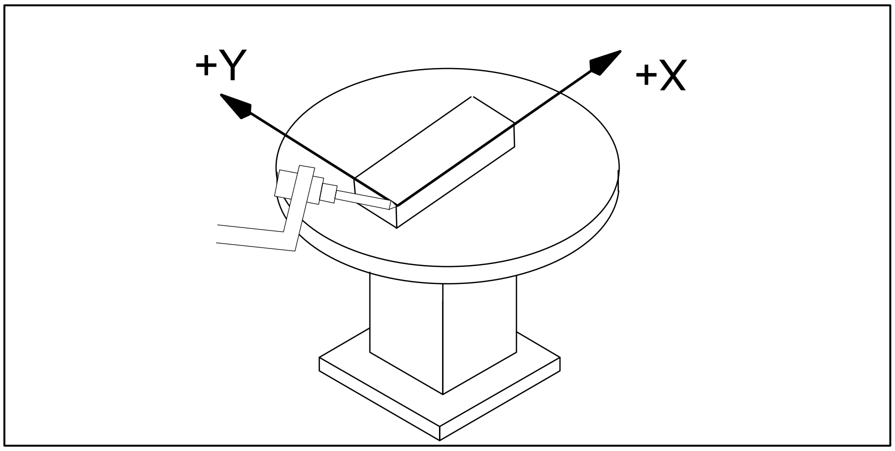
8. Record Origin Point:

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 4–39 .

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

Figure 4–39. Defining the Origin Point



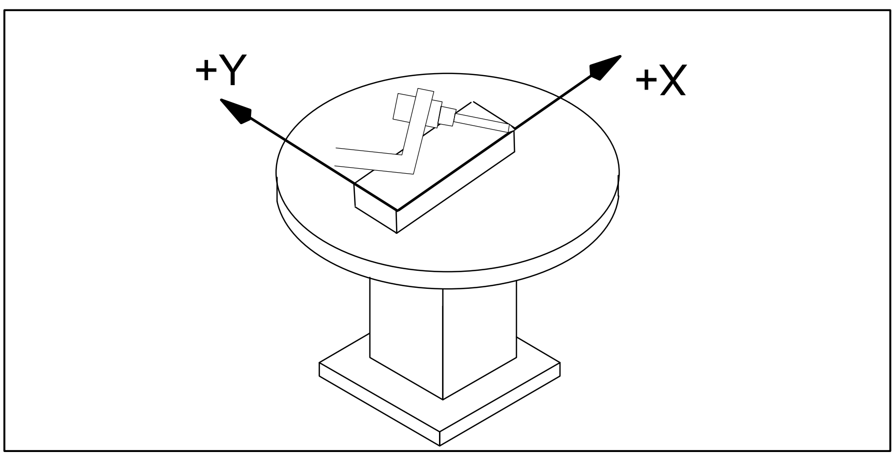
9. Record X Direction Point:

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 4–40

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.

Figure 4–40. Defining the X Direction Point



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

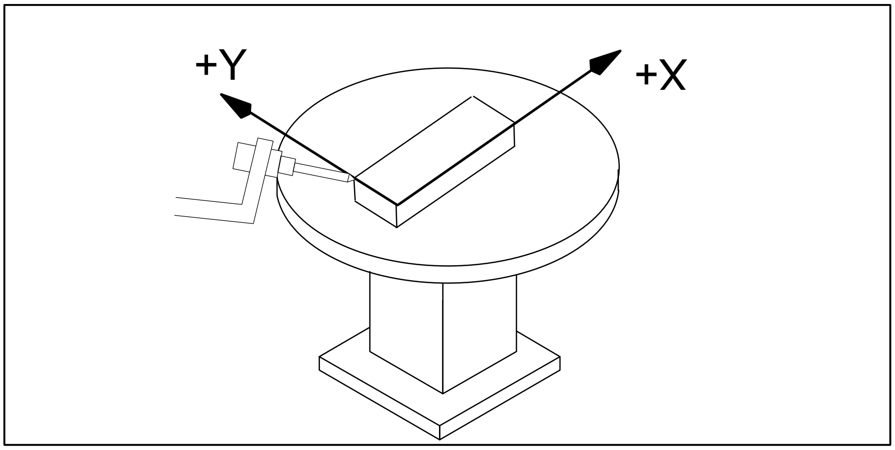
10. Record Y Direction Point:

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 4–41 .

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 4–41. Defining the Y Direction Point



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

11. **To display the new leader frame values,** press and hold SHIFT, and press F3, EXEC.

4.7 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. 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.

Setting

1.

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

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

2. Select “Leader Frame number’. The selected leader frame is with the Follwer Uframe. Use Procedure 4-9 to perform leader frame setup.
3. After setting “Follower Uframe number” and cycling 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.

Programming

On the TPE program, use the Uframe number set as Dynamic UFrame for the position to which you want to apply TPE offset in relative frame. On this TP program, we suppose Leader frame number is 1 and Follower Uframe number is 9. Here, note that the position P[5], P[6], P[7], P[8] and P[9] are follower's TCP position based on the leader frame 1. And other positions are based on the follower's world frame. Since P[5]-P[9] are relative form based on the leader frame 1, i.e. 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 ;
```

Restrictions

This function cannot be used with the following motion.

- Weaving
- Multi-follower programs
- Remote TCP
- Tracking motion (Line Tracking, TAST, etc.)
- Multi-Pass
- Any option that is not supported with Coordinated motion

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.

A new option, CD Dynamic Uframe Arc (R845) has been added in V8.30. It includes the existing option CD Dynamic Uframe (R700). The new option, 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.

Chapter 5

JOGGING

Contents

5.1 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** 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** 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** 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)** 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.**

5.2 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.

Note You will not be able to switch between Coordinated jogging and Fixed orientation coordinated jogging if the Follower Orientation field on the Setup Coord screen is not set to BOTH. Refer to Procedure 5-1 to accomplish this task.

In Figure 5–1 , 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.

Figure 5–1. Coordinated Jogging Display

```
PROGRAM NAME                    C21    JOINT 10%
```

In Figure 5–2 , 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."

Figure 5–2. Coordinated Subgroup Jogging Display

```
PROGRAM NAME                  S21    JOINT 10%
```

In Figure 5–3 , 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."

Figure 5–3. Fixed Orientation Coordinated Jogging Display

```
PROGRAM NAME                  F21    JOINT 10%
```

Table 5–1 lists various jogging designations for a leader group 2 and follower groups 1 and 3.

Table 5–1. 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.

Procedure 5-1 Enabling Toggle Coordinate Orientation

Conditions

- The coordinate pairs must be calibrated.

Steps

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. Move the cursor to Follower orientation.
6. Press F4, [CHOICE], and select BOTH.

5.3 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 5–4 and Figure 5–5 .
- Follower TCP maintains a relative position to the leader in location, but the relative orientation can change. See Figure 5–6 and Figure 5–7 .

Note Before leader group jogging can be used, leader frames must be setup. Refer to Section 4.6 for information on setting up leader frames.

Figure 5–4. Rotary Leader Coordinated Jogging (C21)-Tilt (Attached Orientation)

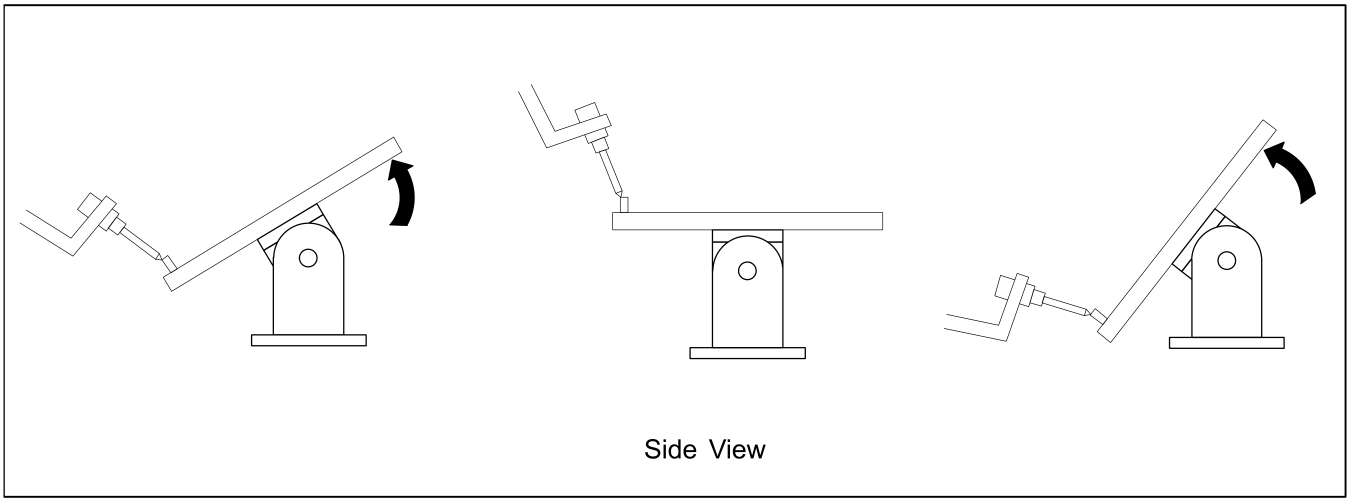


Figure 5–5. Rotary Leader Coordinated Jogging (C21)-Turn (Attached Orientation)

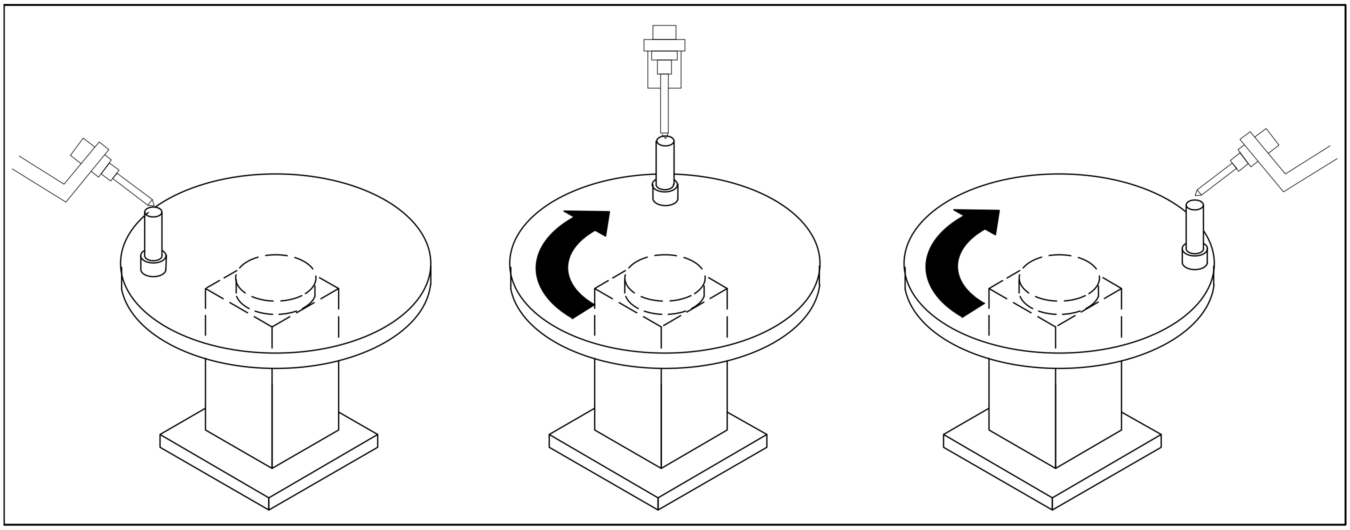


Figure 5–6. Rotary Leader Coordinated Jogging (F21) - Tilt (Fixed Orientation)

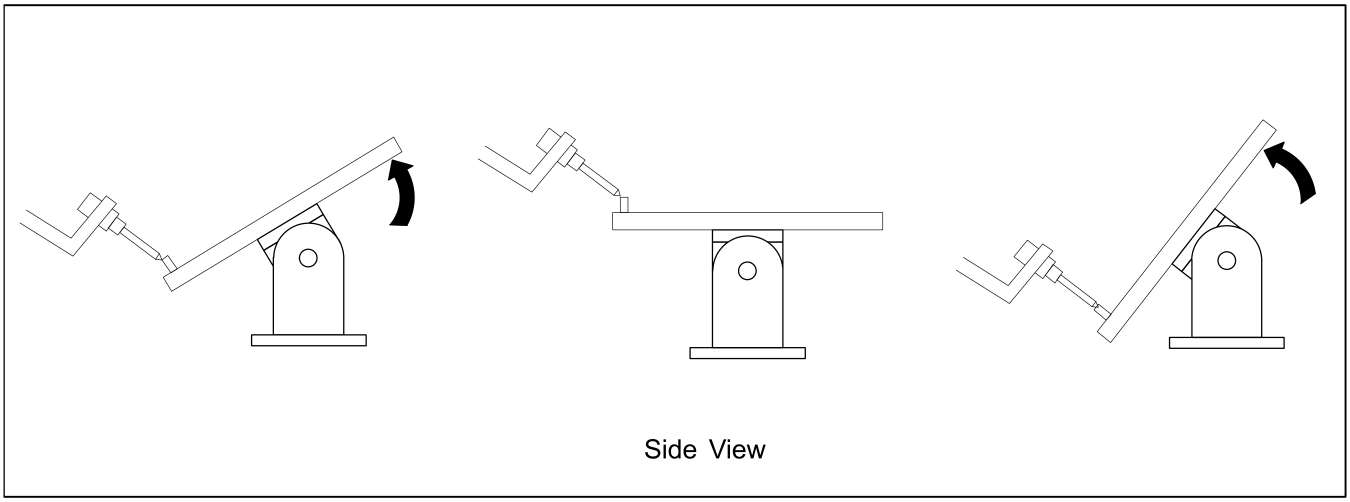
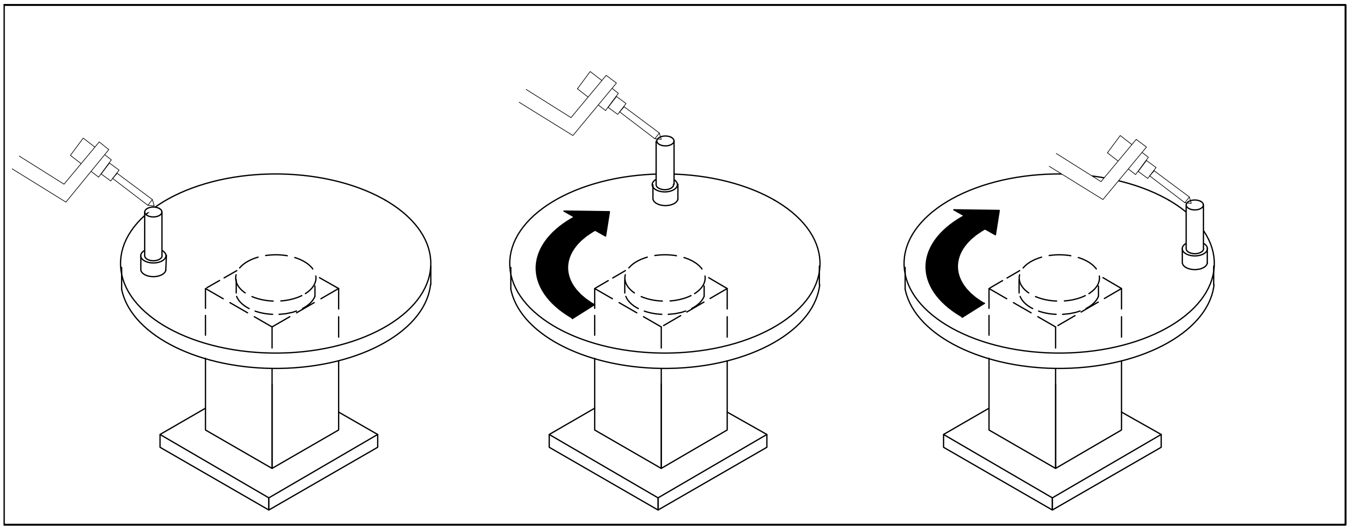


Figure 5–7. Rotary Leader Coordinated Jogging (F21) - Turn (Fixed Orientation)

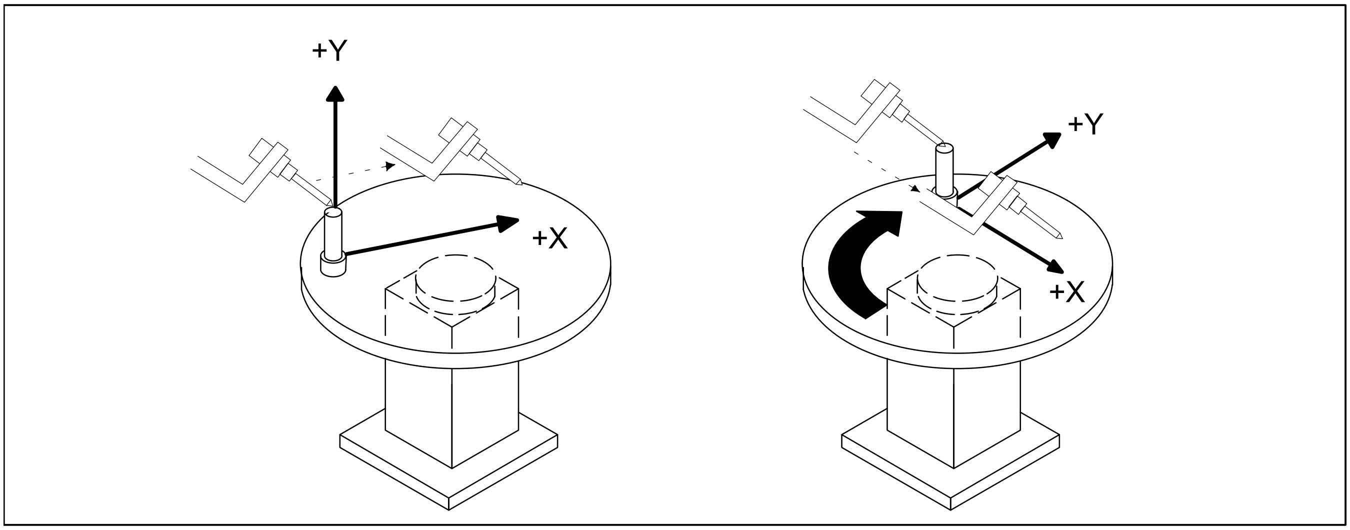


5.3.1 Leader Frame (LDR) Jog Coordinate Mode

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, when the leader (table) is rotated, the follower (robot) TCP will maintain its relative distance and orientation along the current jog path. See Figure 5–8 .

Figure 5–8. 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 5–9 .

Figure 5–9. LDR Jogging Display

```
POSITION              G1              LDR2    50%
```

Note When you select the leader group (robot) to jog, and LDR2 jog is displayed, the jog direction for the TCP is defined in the Leader group WORLD frame. See Figure 5–9 .

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 5.5 for information on jogging the robot.

5.4 JOGGING EXAMPLES

Table 5–2 lists the kinds of coordinated motion jogging that are available.

Table 5–2. 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 Independent Axes
F21	Fixed orientation coordinated group jog	Coordinated frame of the leader moves in JOINT. Follower moves with the coordinated frame without changing relative location in the leader frame, and orientation remains the same	No effect for coordinated Independent Axes
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 Independent Axes
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.

Figure 5–10 , through Figure 5–14 show examples of the effect of coordinated jogging.

Figure 5–10. Linear Leader Coordinated Jogging

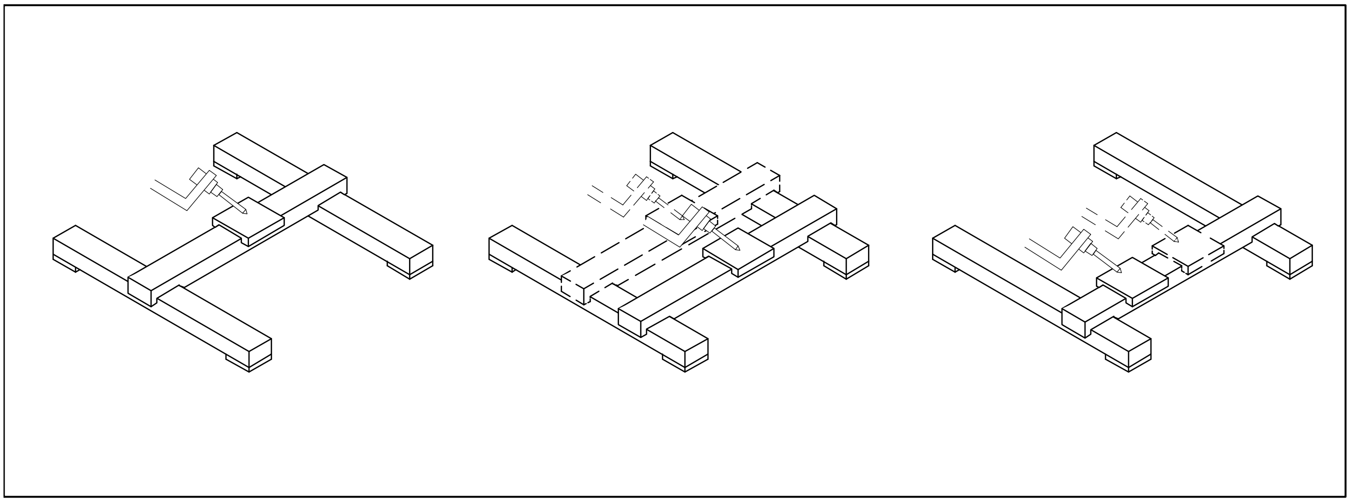


Figure 5–11. Rotary Leader Coordinated Jogging - Tilt (Attached Orientation)

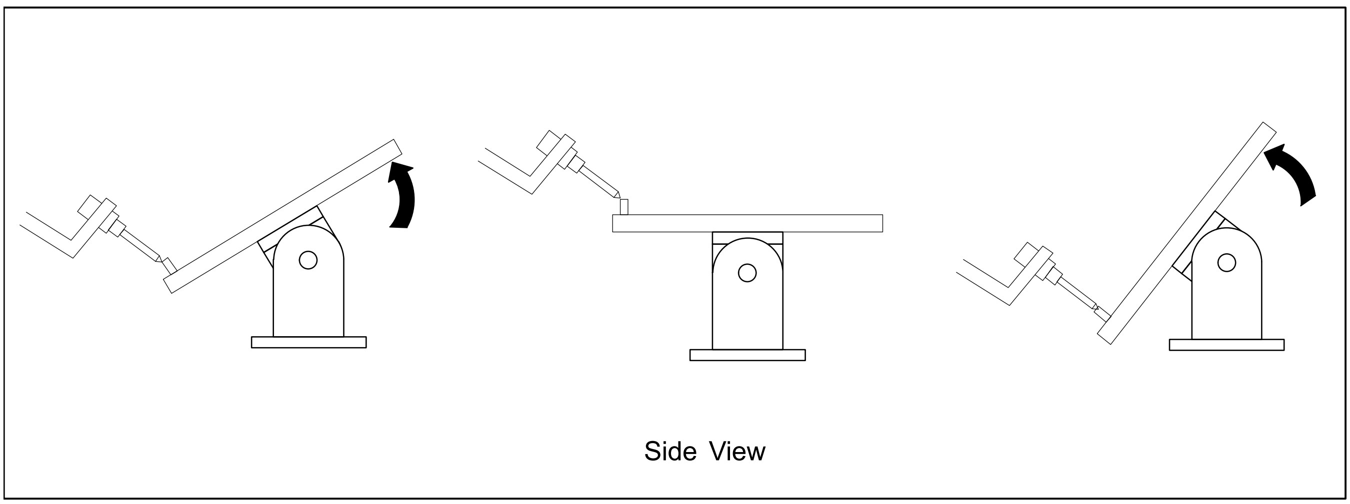
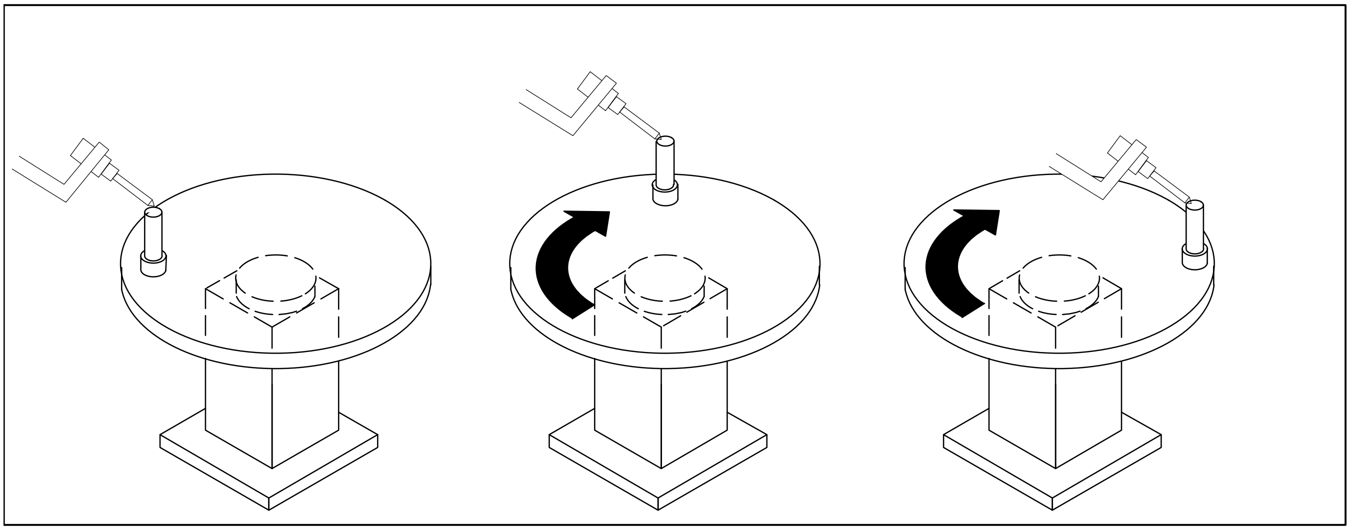
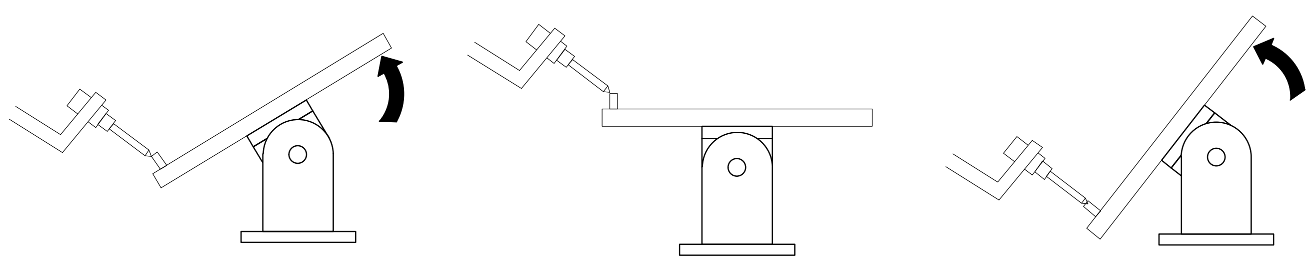


Figure 5–12. Rotary Leader Coordinated Jogging - Turn (Attached Orientation)



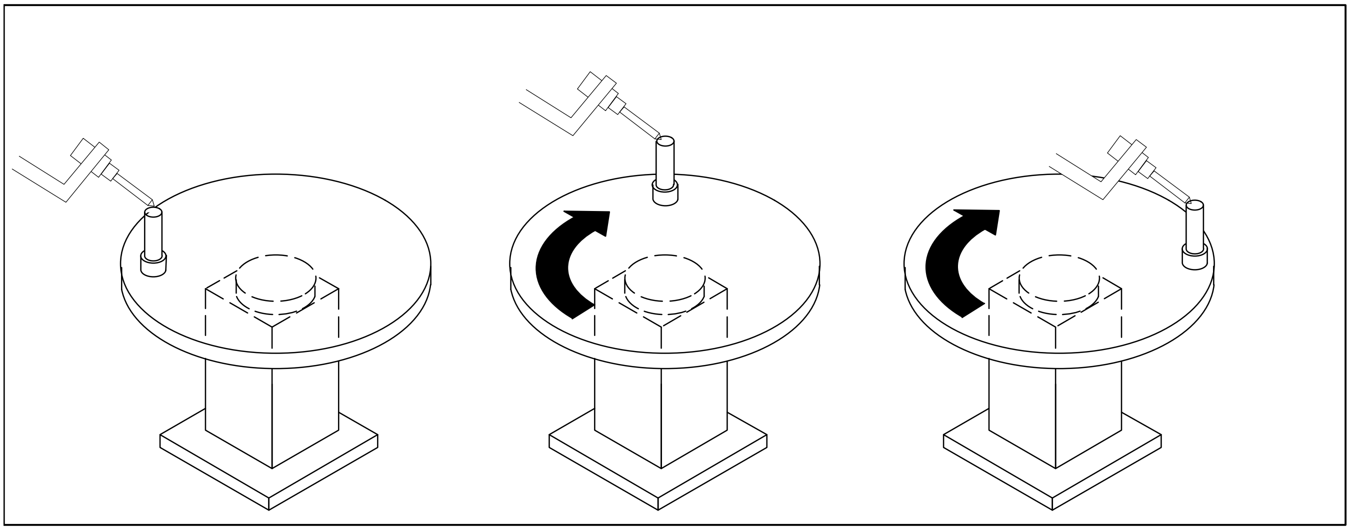
Note The tool orientation remains constant relative to the tabletop during jogging. You can have coordinated motion on more than one axis being jogged at the same time.

Figure 5–13. Rotary Leader Coordinated Jogging - Tilt (Fixed Orientation)



Side View

Figure 5–14. Rotary Leader Coordinated Jogging - Turn (Fixed Orientation)



> **Warning**
>
> **The farther the follower TCP is from the leader rotary 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.**

5.5 JOGGING PROCEDURE

Use Procedure 5-2 to jog the robot using coordinated motion.

Procedure 5-2 Jogging Using Coordinated Motion

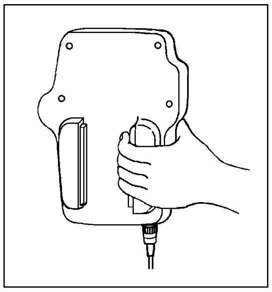
Conditions

- All personnel and unnecessary equipment are out of the workcell.
- All EMERGENCY STOP faults have been cleared.
- All other faults have been cleared and the fault light is not illuminated.

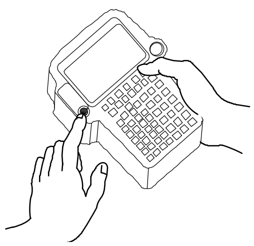
> **Warning**
>
> **Make certain that all safety requirements for your workplace have been followed; otherwise, you could injure personnel or damage equipment.**

Steps

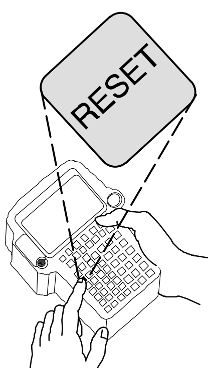
1. Hold the teach pendant and continuously press the DEADMAN switch on the back of the teach pendant.



2. Turn the teach pendant ON/OFF switch to the ON position.



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.



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 5.3 .

Note If there is no follower group, TOGGLE COOR ORNT will not be displayed.

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

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.

4. 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.

Warning

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 ON/OFF switch to OFF, and release the DEADMAN switch.

5.6 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 Procedure 5-3 .

Example

In case of two CD pairs and the assigned output signals as the following, the output will be as shown in Table 5–3 for different jog modes.

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

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

Table 5–3. Output signals in the example case

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

Procedure 5-3 Setting CD jogging output

Steps

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
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.

Chapter 6

PROGRAMMING

Contents

6.1 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.

Benefits of Coordinated Motion Programming

Coordinated motion provides the following program execution enhancements:

- It allows continuous processing on long linear joints while maintaining tool orientation to the workpiece. Path lengths can greatly exceed the maximum useable work envelope of the robot itself.
- It reduces the number of program points that would be required to execute simultaneous motion of a table and robot. Simultaneous motion typically would require a point to be taught for every 6-8 mm. The group of points is reduced to two points with coordinated motion programming for a linear weld.
- It provides better or preferred positions on complex workpieces, especially for leaders (positioners) with two or more axes.
- It reduces the non-productive motion (air cut moves) by use of continuous repositioning of the workpiece, especially for workpieces that have processing on several planes.

Coordinated Motion Program Execution

In the example shown in Coordinated Motion Program Example , G2 is the leader group, G1 is the follower group.

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
```

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.

6.2 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.

You can use only one leader in a teach pendant program. You must indicate the motion groups of the one leader and all followers in the group mask program header information. You must exclude other leader groups not used in the program in the group mask.

For example, for two positioners and one robot, CD_pair 1 = G1+G2 and CD_pair 2 = G1+G3. You cannot have G1, G2, G3 in the header if you intend to use coordinated motion. If G1 and G2 are a CD_pair, and G3 is not included in a CD_pair, then G1, G2, G3 can be included in the program header and coordinated motion will execute.

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 appropriate application-specific *Setup and Operations Manual* for more information on modifying program header information.

6.3 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 only in linear (L) and circular (C) 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 wrist jogging.
- 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 Coordinated Motion Termination Type Example .
- For Coordinated motion RPM and Multipass, the starting position for tracking and replay must be linear and must contain the COORD option.

Coordinated Motion Termination Type Example

```
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
```

6.4 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.

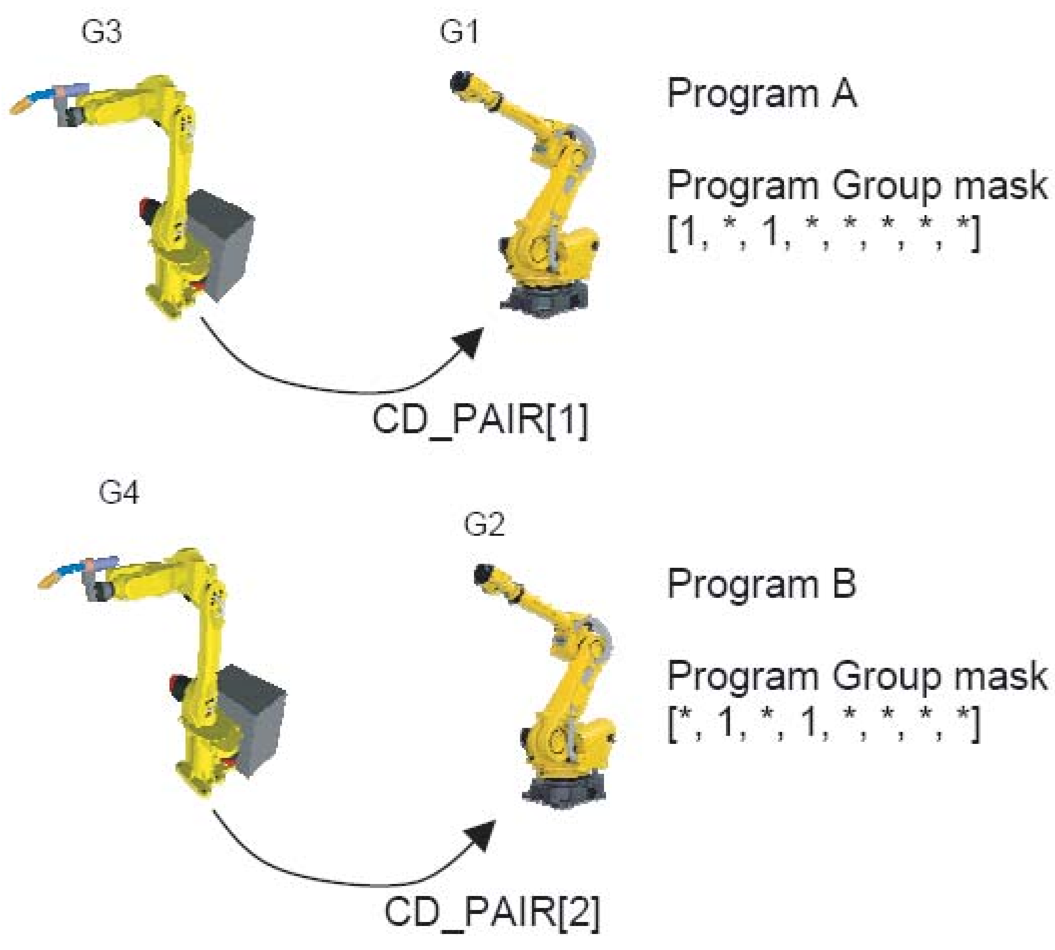
In a multi-arm system, it is possible that one robot could function as a leader at one time, but then function as a follower at another time. If the COORD option is used in a system where the program group mask has more than one “potential leader”, the alarm CD-009 “More than one leader” is posted. An example system shown in Table 6–1 is illustrated in Figure 6–1 and Figure 6–2 .

Table 6–1.

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

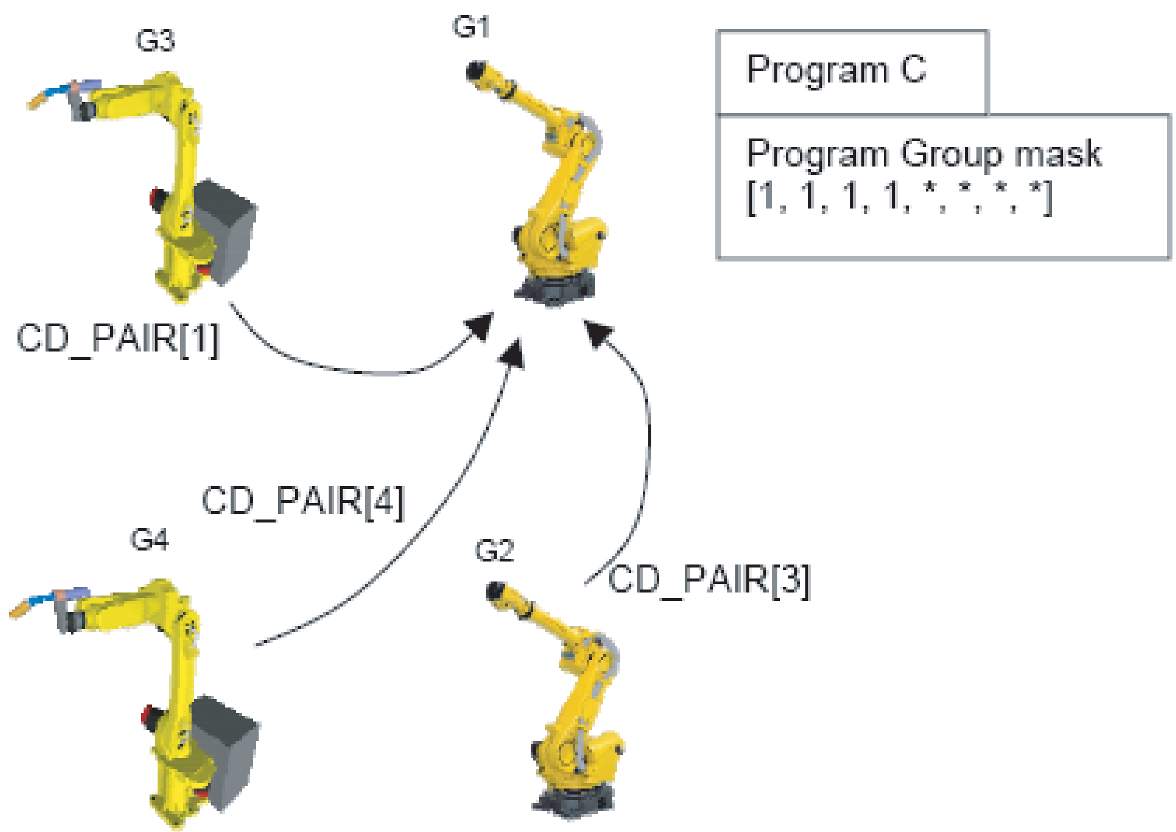
In Figure 6–1 , only one leader is possible for each program.

Figure 6–1. One Possible Leader



In Figure 6–2 , there are two potential leaders. In this case, you could use COORD[1] in Program C to specify group 1 as the leader.

Figure 6–2. Two Possible Leaders



In the following example,

```
L 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

```
L P[1] 25mm/sec CNT100 COORD [ m ]
L P[2] 25mm/sec FINE COORD [ m ]
….
L P[2] 1000mm/sec CNT100           <- reposition moves (non-COORD)
L P[3] 1000mm/sec FINE
L P[4] 25mm/sec CNT100 COORD [ n ]  <- change leader group
L P[5] 25mm/sec FINE COORD [ n ]
```

- 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.

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

6.5 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.

6.6 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.

  Note 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.
- 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.

6.7 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.

Orientation control at the VIA position is also provided in coordinated motion, but the plane in which the circular move executes is determined by the start and end positions.

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.
  - — You use a fast linear coordinated move for an air cut move that might be quicker than a joint air cut move.

  Note You minimize the motion of either the leader or follower group 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.

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.

The (x,y,z) data of the VIA position is not used in the motion path execution, only for planning the circle. The plane of execution of the circle will be determined by the start and end positions. The plane of circular motion during program execution is not changed by re-teaching the VIA position, only by changing the start and end positions.

The plane in which circular motion OCCURS is relative to the tabletop of the positioner. As the positioner moves, the circular motion plane also moves. This will appear as a helical motion.

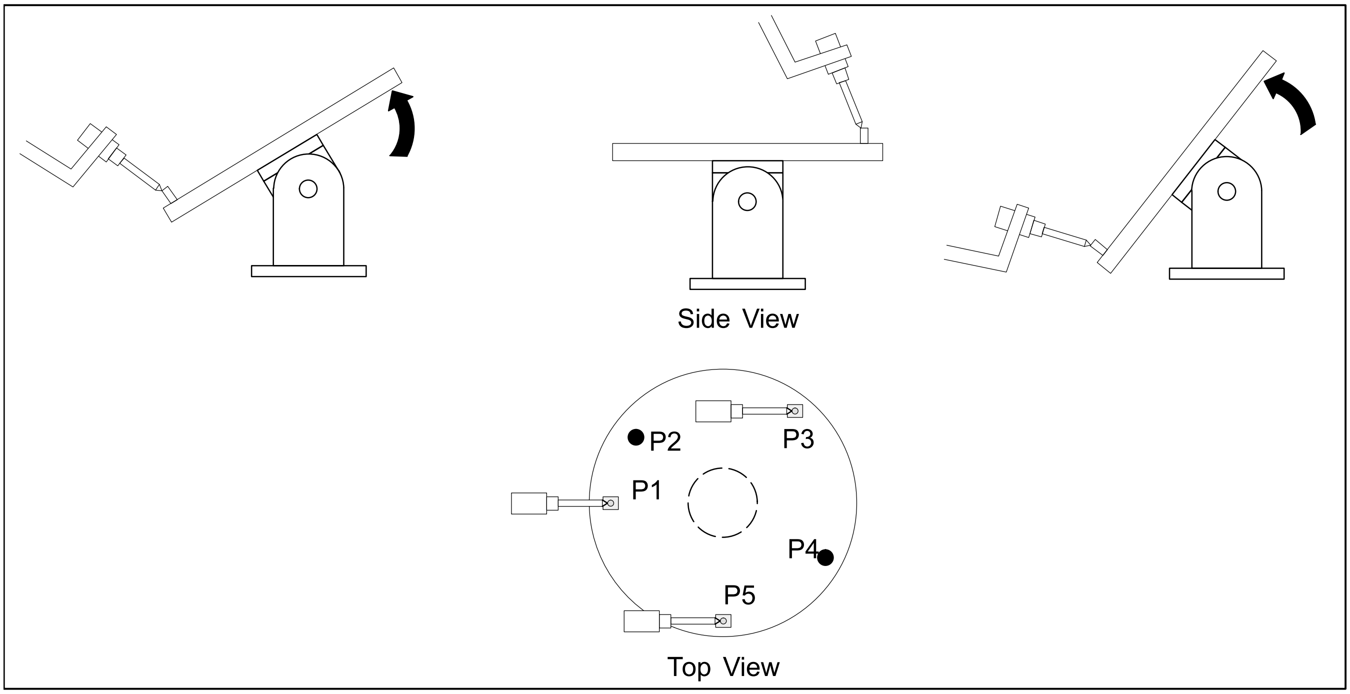
To perform a spiral or helical motion on a headstock-mounted workpiece, use circular motion training positions approximately every 45°of headstock rotation.

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 6–3 , 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 6–3. Coordinated Circular Motion



6.8 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 6–4 . 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 6–4. Relative and Simultaneous Coordinated Motion

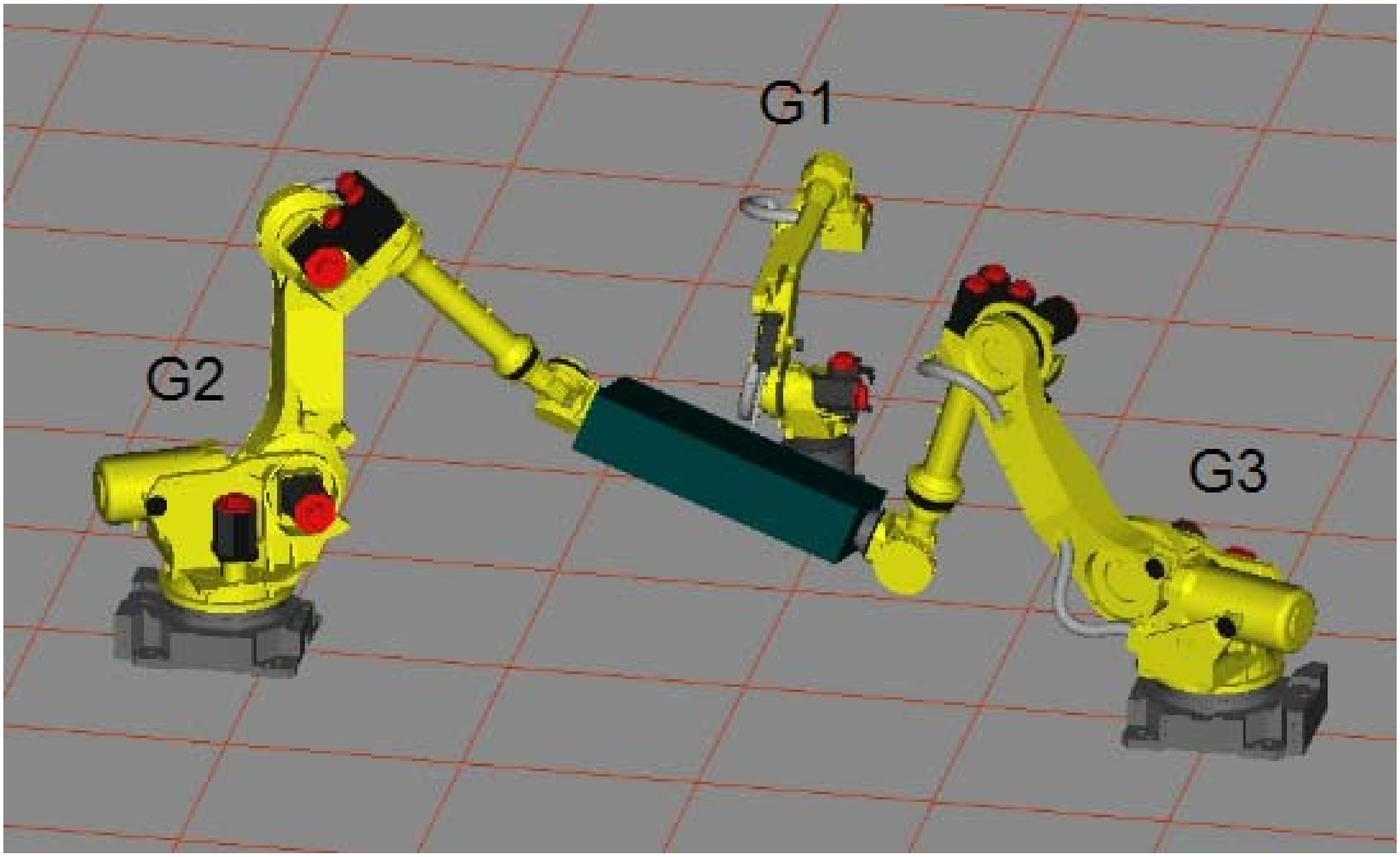


Table 6–2.

	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.
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.

Table 6–2. (Cont'd)

	Relative Motion	Simultaneous Motion
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. ** Since the TCP of the follower does not move with respect to the leader, the motion is a zero distance motion.		

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

1. Calculated the group mask of each handling robots. For instance, the group mask for the handling robots shown in Figure 6–4 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 6–4 , 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.

Chapter 7

TROUBLESHOOTING

Contents

7.1 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 7.2 if you have an error during calibration.
- Refer to the coordinated motion error codes listed in Section 7.3 if you want to look up a specific coordinated motion error code.

7.2 CALIBRATION ERRORS

Refer to Table 7–1 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 7–1. 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.

Table 7–1. Calibration Messages (Cont'd)

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 labelled incorrectly. Verify that the desired frame has been defined, and that all axes have been labelled 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.

7.3 ERROR CODES

Error codes appear on the alarm log.

Refer to the *Error Code Manual* for a complete listing of error codes.

Glossary

A

abort

Abnormal termination of a computer program caused by hardware or software malfunction or operator cancellation.

absolute pulse code system

A positional information system for servomotors that relies on battery-backed RAM to store encoder pulse counts when the robot is turned off. This system is calibrated when it is turned on.

A/D value

An analog to digital-value. Converts a multilevel analog electrical system pattern into a digital bit.

AI

Analog input.

AO

Analog output.

alarm

The difference in value between actual response and desired response in the performance of a controlled machine, system or process. Alarm=Error.

algorithm

A fixed step-by-step procedure for accomplishing a given result.

alphanumeric

Data that are both alphabetical and numeric.

AMPS

Amperage amount.

analog

The representation of numerical quantities by measurable quantities such as length, voltage or resistance. Also refers to analog type I/O blocks and distinguishes them from discrete I/O blocks. Numerical data that can vary continuously, for example, voltage levels that can vary within the range of -10 to +10 volts.

AND

An operation that places two contacts or groups of contacts in series. All contacts in series control the resulting status and also mathematical operator.

ANSI

American National Standard Institute, the U.S. government organization with responsibility for the development and announcement of technical data standards.

APC

See absolute pulse code system.

APC motor

See servomotor.

application program

The set of instructions that defines the specific intended tasks of robots and robot systems to make them reprogrammable and multifunctional. You can initiate and change these programs.

arm

A robot component consisting of an interconnecting set of links and powered joints that move and support the wrist socket and end effector.

articulated arm

A robot arm constructed to simulate the human arm, consisting of a series of rotary motions and joints, each powered by a motor.

ASCII

Abbreviation for American Standard Code for Information Interchange. An 8-level code (7 bits plus 1 parity bit) commonly used for the exchange of data.

automatic mode

The robot state in which automatic operation can be initiated.

automatic operation

The time during which robots are performing programmed tasks through unattended program execution.

axis

1. A straight line about which a robot joint rotates or moves. 2. One of the reference lines or a coordinate system. 3. A single joint on the robot arm.

B

backplane

A group of connectors mounted at the back of a controller rack to which printed circuit boards are mated.

BAR

A unit of pressure equal to 100,000 pascals.

barrier

A means of physically separating persons from the restricted work envelope; any physical boundary to a hazard or electrical device/component.

battery low alarm

A programmable value (in engineering units) against which the analog input signal automatically is compared on Genius I/O blocks. A fault is indicated if the input value is equal to or less than the low alarm value.

baud

A unit of transmission speed equal to the number of code elements (bits) per second.

big-endian

The adjectives big-endian and little-endian refer to which bytes are most significant in multi-byte data types and describe the order in which a sequence of bytes is stored in a computer's memory. In a big-endian system, the most significant value in the sequence is stored at the lowest storage address (i.e., first). In a little-endian system, the least significant value in the sequence is stored first.

binary

A numbering system that uses only 0 and 1.

bit

Contraction of binary digit. 1. The smallest unit of information in the binary numbering system, represented by a 0 or 1. 2. The smallest division of a programmable controller word.

bps

Bits per second.

buffer

A storage area in the computer where data is held temporarily until the computer can process it.

bus

A channel along which data can be sent.

bus controller

A Genius bus interface board for a programmable controller.

bus scan

One complete communications cycle on the serial bus.

Bus Switching Module

A device that switches a block cluster to one bus or the other of a dual bus.

byte

A sequence of binary digits that can be used to store a value from 0 to 255 and usually operated upon as a unit. Consists of eight bits used to store two numeric or one alpha character.

C

calibration

The process whereby the joint angle of each axis is calculated from a known reference point.

Cartesian coordinate system

A coordinate system whose axes (x, y, and z) are three intersecting perpendicular straight lines. The origin is the intersection of the axes.

Cartesian coordinates

A set of three numbers that defines the location of a point within a rectilinear coordinate system and consisting of three perpendicular axes (x, y, z).

cathode ray tube

A device, like a television set, for displaying information.

central processing unit

The main computer component that is made up of a control section and an arithmetic-logic section. The other basic units of a computer system are input/output units and primary storage.

channel

The device along which data flow between the input/output units of a computer and primary storage.

character

One of a set of elements that can be arranged in ordered groups to express information. Each character has two forms: 1. a man-intelligible form, the graphic, including the decimal digits 0-9, the letters A-Z, punctuation marks, and other formatting and control symbols; 2. a computer intelligible form, the code, consisting of a group of binary digits (bits).

circular

A MOTYPE option in which the robot tool center point moves in an arc defined by three points. These points can be positions or path nodes.

clear

To replace information in a storage unit by zero (or blank, in some machines).

closed loop

A control system that uses feedback. An open loop control system does not use feedback.

C-MOS RAM

Complementary metal-oxide semiconductor random-access memory. A read/write memory in which the basic memory cell is a pair of MOS (metal-oxide semiconductor) transistors. It is an implementation of S-RAM that has very low power consumption, but might be less dense than other S-RAM implementations.

coaxial cable

A transmission line in which one conductor is centered inside and insulated from an outer metal tube that serves as the second conductor. Also known as coax, coaxial line, coaxial transmission line, concentric cable, concentric line, concentric transmission line.

component

An inclusive term used to identify a raw material, ingredient, part or subassembly that goes into a higher level of assembly, compound or other item.

computer

A device capable of accepting information, applying prescribed processes to the information, and supplying the results of these processes.

configuration

The joint positions of a robot and turn number of wrist that describe the robot at a specified position. Configuration is designated by a STRING value and is included in positional data.

continuous path

A trajectory control system that enables the robot arm to move at a constant tip velocity through a series of predefined locations. A rounding effect of the path is required as the tip tries to pass through these locations.

continuous process control

The use of transducers (sensors) to monitor a process and make automatic changes in operations through the design of appropriate feedback control loops. While such devices historically have been mechanical or electromechanical, microcomputers and centralized control is now used, as well.

continuous production

A production system in which the productive equipment is organized and sequenced according to the steps involved to produce the product. Denotes that material flow is continuous during the production process. The routing of the jobs is fixed and set-ups are seldom changed.

controlled stop

A controlled stop controls robot deceleration until it stops. When a safety stop input such as a safety fence signal is opened, the robot decelerates in a controlled manner and then stops. After the robot stops, the Motor Control Contactor opens and drive power is removed.

controller

A hardware unit that contains the power supply, operator controls, control circuitry, and memory that directs the operation and motion of the robot and communications with external devices. See control unit.

controller memory

A medium in which data are retained. Primary storage refers to the internal area where the data and program instructions are stored for active use, as opposed to auxiliary or external storage (magnetic tape, disk, diskette, and so forth.)

control, open-loop

An operation where the computer applies control directly to the process without manual intervention.

control unit

The portion of a computer that directs the automatic operation of the computer, interprets computer instructions, and initiates the proper signals to the other computer circuits to execute instructions.

coordinate system

See Cartesian coordinate system.

CPU

See central processing unit.

CRT

See cathode ray tube.

cps (viscosity)

Centipoises per second.

CRT/KB

Cathode ray tube/keyboard. An optional interface device for the robot system. The CRT/KB is used for some robot operations and for entering programs. It can be a remote device that attaches to the robot via a cable.

cycle

1. A sequence of operations that is repeated regularly. The time it takes for one such sequence to occur. 2. The interval of time during which a system or process, such as seasonal demand or a manufacturing operation, periodically returns to similar initial conditions. 3. The interval of time during which an event or set of events is completed. In production control, a cycle is the length of time between the release of a manufacturing order and shipment to the customer or inventory.

cycle time

1. In industrial engineering, the time between completion of two discrete units of production. 2. In materials management, the length of time from when material enters a production facility until it exits. See throughput.

cursor

An indicator on a teach pendant or CRT display screen at which command entry or editing occurs. The indicator can be a highlighted field or an arrow (> or ^).

cylindrical

Type of work envelope that has two linear major axes and one rotational major axis. Robotic device that has a predominantly cylindrical work envelope due to its design. Typically has fewer than 6 joints and typically has only 1 linear axis.

D

D/A converter

A digital-to-analog converter. A device that transforms digital data into analog data.

D/A value

A digital-to-analog value. Converts a digital bit pattern into a multilevel analog electrical system.

daisy chain

A means of connecting devices (readers, printers, etc.) to a central processor by party-line input/output buses that join these devices by male and female connectors. The last female connector is shorted by a suitable line termination.

daisy chain configuration

A communications link formed by daisy chain connection of twisted pair wire.

data

A collection of facts, numeric and alphabetical characters, or any representation of information that is suitable for communication and processing.

data base

A data file philosophy designed to establish the independence of computer program from data files. Redundancy is minimized and data elements can be added to, or deleted from, the file designs without changing the existing computer programs.

DC

Abbreviation for direct current.

DEADMAN switch

A control switch on the teach pendant that is used to enable servo power. Pressing the DEADMAN switch while the teach pendant is on activates servo power and releases the robot brakes; releasing the switch deactivates servo power and applies the robot brakes.

debugging

The process of detecting, locating and removing mistakes from a computer program, or manufacturing control system. See diagnostic routine.

deceleration tolerance
The specification of the percentage of deceleration that must be completed before a motion is considered finished and another motion can begin.

default
The value, display, function or program automatically selected if you have not specified a choice.

deviation
Usually, the absolute difference between a number and the mean of a set of numbers, or between a forecast value and the actual data.

device
Any type of control hardware, such as an emergency-stop button, selector switch, control pendant, relay, solenoid valve, or sensor.

diagnostic routine
A test program used to detect and identify hardware/software malfunctions in the controller and its associated I/O equipment. See debugging.

diagnostics
Information that permits the identification and evaluation of robot and peripheral device conditions.

digital
A description of any data that is expressed in numerical format. Also, having the states On and Off only.

digital control
The use of a digital computer to perform processing and control tasks in a manner that is more accurate and less expensive than an analog control system.

digital signal
A single point control signal sent to or from the controller. The signal represents one of two states: ON (TRUE, 1. or OFF (FALSE, 0).

directory
A listing of the files stored on a device.

discrete
Consisting of individual, distinct entities such as bits, characters, circuits, or circuit components. Also refers to ON/OFF type I/O blocks.

disk
A secondary memory device in which information is stored on a magnetically sensitive, rotating disk.

disk memory
A non-programmable, bulk-storage, random-access memory consisting of a magnetized coating on one or both sides of a rotating thin circular plate.

drive power

The energy source or sources for the robot servomotors that produce motion.

DRAM

Dynamic Random Access Memory. A read/write memory in which the basic memory cell is a capacitor. DRAM (or D-RAM) tends to have a higher density than SRAM (or S-RAM). Due to the support circuitry required, and power consumption needs, it is generally impractical to use. A battery can be used to retain the content upon loss of power.

E

edit

1. A software mode that allows creation or alteration of a program. 2. To modify the form or format of data, for example, to insert or delete characters.

emergency stop

The operation of a circuit using hardware-based components that overrides all other robot controls, removes drive power from the actuators, and causes all moving parts of to stop. The operator panel and teach pendant are each equipped with EMERGENCY STOP buttons.

enabling device

A manually operated device that, when continuously activated, permits motion. Releasing the device stops the motion of the robot and associated equipment that might present a hazard.

encoder

1. A device within the robot that sends the controller information about where the robot is. 2. A transducer used to convert position data into electrical signals. The robot system uses an incremental optical encoder to provide position feedback for each joint. Velocity data is computed from the encoder signals and used as an additional feedback signal to assure servo stability.

end effector

An accessory device or tool specifically designed for attachment to the robot wrist or tool mounting plate to enable the robot to perform its intended tasks. Examples include gripper, spot weld gun, arc weld gun, spray paint gun, etc.

end-of-arm tooling

Any of a number of tools, such as welding guns, torches, bells, paint spraying devices, attached to the faceplate of the robot wrist. Also called end effector or EOAT.

engineering units

Units of measure as applied to a process variable, for example, psi, Degrees F., etc.

envelope, maximum

The volume of space encompassing the maximum designed movements of all robot parts including the end effector, workpiece, and attachments.

EOAT

See end of arm tooling, tool.

EPROM

Erasable Programmable Read Only Memory. Semiconductor memory that can be erased and reprogrammed. A non-volatile storage memory.

error

The difference in value between actual response and desired response in the performance of a controlled machine, system or process. Alarm=Error.

error message

A numbered message, displayed on the CRT/KB and teach pendant, that indicates a system problem or warns of a potential problem.

Ethernet

A Local Area Network (LAN) bus-oriented, hardware technology that is used to connect computers, printers, terminal concentrators (servers), and many other devices together. It consists of a master cable and connection devices at each machine on the cable that allow the various devices to "talk" to each other. Software that can access the Ethernet and cooperate with machines connected to the cable is necessary. Ethernets come in varieties such as baseband and broadband and can run on different media, such as coax, twisted pair and fiber. Ethernet is a trademark of Xerox Corporation.

execute

To perform a specific operation, such as one that would be accomplished through processing one statement or command, a series of statements or commands, or a complete program or command procedure.

extended axis

An optional, servo-controlled axis that provides extended reach capability for a robot, including in-booth rail, single- or double-link arm, also used to control motion of positioning devices.

F

faceplate

The tool mounting plate of the robot.

feedback

1. The signal or data fed back to a commanding unit from a controlled machine or process to denote its response to the command signal. The signal representing the difference between actual response and desired response that is used by the commanding unit to improve performance of the controlled machine or process. 2. The flow of information back into the control system so that actual performance can be compared with planned performance, for instance in a servo system.

field

A specified area of a record used for a particular category of data. 2. A group of related items that occupy the same space on a CRT/KB screen or teach pendant LCD screen. Field name is the name of the field; field items are the members of the group.

field devices

User-supplied devices that provide information to the PLC (inputs: push buttons, limit switches, relay contacts, an so forth) or perform PLC tasks (outputs: motor starters, solenoids, indicator lights, and so forth.)

file

1. An organized collection of records that can be stored or retrieved by name. 2. The storage device on which these records are kept, such as bubble memory or disk.

filter

A device to suppress interference that would appear as noise.

Flash File Storage

A portion of FROM memory that functions as a separate storage device. Any file can be stored on the FROM disk.

Flash ROM

Flash Read Only Memory. Flash ROM is not battery-backed memory but it is non-volatile. All data in Flash ROM is saved even after you turn off and turn on the robot.

flow chart

A systems analysis tool to graphically show a procedure in which symbols are used to represent operations, data, flow, and equipment. See block diagram, process chart.

flow control

A specific production control system that is based primarily on setting production rates and feeding work into production to meet the planned rates, then following it through production to make sure that it is moving. This concept is most successful in repetitive production.

format

To set up or prepare a memory card or floppy disk (not supported with version 7.20 and later) so it can be used to store data in a specific system.

FR

See Flash ROM.

F-ROM

See Flash ROM.

FROM disk

See Flash ROM.

G

general override stat

A percentage value that governs the maximum robot jog speed and program run speed.

Genius I/O bus

The serial bus that provides communications between blocks, controllers, and other devices in the system especially with respect to GE FANUC Genius I/O.

gripper

The "hand" of a robot that picks up, holds and releases the part or object being handled. Sometimes referred to as a manipulator. See EOAT, tool.

group signal

An input/output signal that has a variable number of digital signals, recognized and taken as a group.

gun

See applicator.

H

Hand Model.

Used in Interference Checking, the Hand Model is the set of virtual model elements (spheres and cylinders) that are used to represent the location and shape of the end of arm tooling with respect to the robot's faceplate.

hardware

1. In data processing, the mechanical, magnetic, electrical and electronic devices of which a computer, controller, robot, or panel is built. 2. In manufacturing, relatively standard items such as nuts, bolts, washers, clips, and so forth.

hard-wire

To connect electric components with solid metallic wires.

hard-wired

1. Having a fixed wired program or control system built in by the manufacturer and not subject to change by programming. 2. Interconnection of electrical and electronic devices directly through physical wiring.

hazardous motion

Unintended or unexpected robot motion that can cause injury.

hexadecimal

A numbering system having 16 as the base and represented by the digits 0 through 9, and A through F.

hold

A smoothly decelerated stopping of all robot movement and a pause of program execution. Power is maintained on the robot and program execution generally can be resumed from a hold.

HTML.

Hypertext Markup Language. A markup language that is used to create hypertext and hypermedia documents incorporating text, graphics, sound, video, and hyperlinks.

http.

Hypertext transfer protocol. The protocol used to transfer HTML files between web servers.

I

impedance

A measure of the total opposition to current flow in an electrical circuit.

incremental encoder system

A positional information system for servomotors that requires calibrating the robot by moving it to a known reference position (indicated by limit switches) each time the robot is turned on or calibration is lost due to an error condition.

index

An integer used to specify the location of information within a table or program.

index register

A memory device containing an index.

industrial robot

A reprogrammable multifunctional manipulator designed to move material, parts, tools, or specialized devices through variable programmed motions in order to perform a variety of tasks.

industrial robot system

A system that includes industrial robots, end effectors, any equipment devices and sensors required for the robot to perform its tasks, as well as communication interfaces for interlocking, sequencing, or monitoring the robot.

information

The meaning derived from data that have been arranged and displayed in a way that they relate to that which is already known. See data.

initialize

1. Setting all variable areas of a computer program or routine to their desired initial status, generally done the first time the code is executed during each run. 2. A program or hardware circuit that returns a program a system, or hardware device to an original state. See startup, initial.

input

The data supplied from an external device to a computer for processing. The device used to accomplish this transfer of data.

input device

A device such as a terminal keyboard that, through mechanical or electrical action, converts data from the form in which it has been received into electronic signals that can be interpreted by the CPU or programmable controller. Examples are limit switches, push buttons, pressure switches, digital encoders, and analog devices.

input processing time

The time required for input data to reach the microprocessor.

input/output

Information or signals transferred between devices, discreet electrical signals for external control.

input/output control

A technique for controlling capacity where the actual output from a work center is compared with the planned output developed by CRP. The input is also monitored to see if it corresponds with plans so that work centers will not be expected to generate output when jobs are not available to work on.

integrated circuit

A solid-state micro-circuit contained entirely within a chip of semiconductor material, generally silicon. Also called chip.

interactive

Refers to applications where you communicate with a computer program via a terminal by entering data and receiving responses from the computer.

interface

1. A concept that involves the specifications of the inter-connection between two equipments having different functions. 2. To connects a PLC with the application device, communications channel, and peripherals through various modules and cables. 3. The method or equipment used to communicate between devices.

interference zone

An area that falls within the work envelope of a robot, in which there is the potential for the robot motion to coincide with the motion of another robot or machine, and for a collision to occur.

interlock

An arrangement whereby the operation of one control or mechanism brings about, or prevents, the operations of another.

interrupt

A break in the normal flow of a system or program that occurs in a way that the flow can be resumed from that point at a later time. Interrupts are initiated by two types of signals: 1. signals originating within the computer system to synchronize the operation of the computer system with the outside world; 2. signals originating exterior to the computer system to synchronize the operation of the computer system with the outside world.

I/O

Abbreviation for input/output or input/output control.

I/O block

A microprocessor-based, configurable, rugged solid state device to which field I/O devices are attached.

I/O electrical isolation

A method of separating field wiring from logic level circuitry. This is typically done through optical isolation devices.

I/O module

A printed circuit assembly that is the interface between user devices and the Series Six PLC.

I/O scan

A method by which the CPU monitors all inputs and controls all outputs within a prescribed time. A period during which each device on the bus is given a turn to send information and listen to all of the broadcast data on the bus.

ISO

The International Standards Organization that establishes the ISO interface standards.

isolation

1. The ability of a logic circuit having more than one inputs to ensure that each input signal is not affected by any of the others. 2. A method of separating field wiring circuitry from logic level circuitry, typically done optically.

item

1. A category displayed on the teach pendant on a menu. 2. A set of adjacent digits, bits, or characters that is treated as a unit and conveys a single unit of information. 3. Any unique manufactured or purchased part or assembly: end product, assembly, subassembly, component, or raw material.

J

jog coordinate systems

Coordinate systems that help you to move the robot more effectively for a specific application. These systems include JOINT, WORLD, TOOL, and USER.

JOG FRAME

A jog coordinate system you define to make the robot jog the best way possible for a specific application. This can be different from world coordinate frame.

jogging

Pressing special keys on the teach pendant to move the robot.

jog speed

Is a percentage of the maximum speed at which you can jog the robot.

joint

1. A single axis of rotation. There are up to six joints in a robot arm (P-155 swing arm has 8). 2. A jog coordinate system in which one axis is moved at a time.

JOINT

A motion type in which the robot moves the appropriate combination of axes independently to reach a point most efficiently. (Point to point, non-linear motion).

joint interpolated motion

A method of coordinating the movement of the joints so all joints arrive at the desired location at the same time. This method of servo control produces a predictable path regardless of speed and results in the fastest cycle time for a particular move. Also called joint motion.

K

K

Abbreviation for kilo, or exactly 1024 in computer jargon. Related to 1024 words of memory.

KAREL

The programming language developed for robots by the FANUC America Corporation.

L

label

An ordered set of characters used to symbolically identify an instruction, a program, a quantity, or a data area.

LCD

See liquid crystal display.

lead time

The span of time needed to perform an activity. In the production and inventory control context, this activity is normally the procurement of materials and/or products either from an outside supplier or from one’s own manufacturing facility. Components of lead time can include order preparation time, queue time, move or transportation time, receiving and inspection time.

LED

See Light Emitting Diode.

LED display

An alphanumeric display that consists of an array of LEDs.

Light Emitting Diode

A solid-state device that lights to indicate a signal on electronic equipment.

limiting device

A device that restricts the work envelope by stopping or causing to stop all robot motion and that is independent of the control program and the application programs.

limit switch

A switch that is actuated by some part or motion of a machine or equipment to alter the electrical circuit associated with it. It can be used for position detection.

linear

A motion type in which the appropriate combination of axes move in order to move the robot TCP in a straight line while maintaining tool center point orientation.

liquid crystal display

A digital display on the teach pendant that consists of two sheets of glass separated by a sealed-in, normally transparent, liquid crystal material. Abbreviated LCD.

little-endian

The adjectives big-endian and little-endian refer to which bytes are most significant in multi-byte data types and describe the order in which a sequence of bytes is stored in a computer's memory. In a big-endian system, the most significant value in the sequence is stored at the lowest storage address (i.e., first). In a little-endian system, the least significant value in the sequence is stored first.

load

1. The weight (force) applied to the end of the robot arm. 2. A device intentionally placed in a circuit or connected to a machine or apparatus to absorb power and convert it into the desired useful form. 3. To copy programs or data into memory storage.

location

1. A storage position in memory uniquely specified by an address. 2. The coordinates of an object used in describing its x, y, and z position in a Cartesian coordinate system.

lockout/tagout

The placement of a lock and/or tag on the energy isolating device (power disconnecting device) in the off or open position. This indicates that the energy isolating device or the equipment being controlled will not be operated until the lock/tag is removed.

log

A record of values and/or action for a given function.

logic

A fixed set of responses (outputs) to various external conditions (inputs). Also referred to as the program.

loop

The repeated execution of a series of instructions for a fixed number of times, or until interrupted by the operator.

M

mA

See milliampere.

machine language

A language written in a series of bits that are understandable by, and therefore instruct, a computer. This is a "first level" computer language, as compared to a "second level" assembly language, or a "third level" compiler language.

machine lock

A test run option that allows the operator to run a program without having the robot move.

macro

A source language instruction from which many machine-language instructions can be generated.

magnetic disk

A metal or plastic floppy disk (not supported on version 7.10 and later) that looks like a phonograph record whose surface can store data in the form of magnetized spots.

magnetic disk storage

A storage device or system consisting of magnetically coated metal disks.

magnetic tape

Plastic tape, like that used in tape recorder, on which data is stored in the form of magnetized spots.

maintenance

Keeping the robots and system in their proper operating condition.

MC

See memory card.

mechanical unit

The robot arm, including auxiliary axis, and hood/deck and door openers.

medium

plural **media** . The physical substance upon which data is recorded, such as a memory card (or floppy disk which is not supported on version 7.10 and later).

memory

A device or media used to store information in a form that can be retrieved and is understood by the computer or controller hardware. Memory on the controller includes C-MOS RAM, Flash ROM and D-RAM.

memory card

A C-MOS RAM memory card or a flash disk-based PC card.

menu

A list of options displayed on the teach pendant screen.

message

A group of words, variable in length, transporting an item of information.

microprocessor

A single integrated circuit that contains the arithmetic, logic, register, control and memory elements of a computer.

microsecond

One millionth (0.000001) of a second

milliampere

One one-thousandth of an ampere. Abbreviated mA.

millisecond

One thousandth of a second. Abbreviated msec.

module

A distinct and identifiable unit of computer program for such purposes as compiling, loading, and linkage editing. It is eventually combined with other units to form a complete program.

motion type

A feature that allows you to select how you want the robot to move from one point to the next. MOTYPES include joint, linear, and circular.

mode

1. One of several alternative conditions or methods of operation of a device. 2. The most common or frequent value in a group of values.

N

network

1. The interconnection of a number of devices by data communication facilities. "Local networking" is the communications network internal to a robot."Global networking" is the ability to provide communications connections outside of the robot’s internal system. 2. Connection of geographically separated computers and/or terminals over communications lines. The control of transmission is managed by a standard protocol.

non-volatile memory

Memory capable of retaining its stored information when power is turned off.

O

Obstacle Model.
Used in Interference Checking, the Obstacle Model is the set of virtual model elements (spheres, cylinders, and planes) that are used to represent the shape and the location of a given obstacle in space.

off-line
Equipment or devices that are not directly connected to a communications line.

off-line operations
Data processing operations that are handled outside of the regular computer program. For example, the computer might generate a report off-line while the computer was doing another job.

off-line programming
The development of programs on a computer system that is independent of the "on-board" control of the robot. The resulting programs can be copied into the robot controller memory.

offset
The count value output from a A/D converter resulting from a zero input analog voltage. Used to correct subsequent non-zero measurements also incremental position or frame adjustment value.

on-line
A term to describe equipment or devices that are connected to the communications line.

on-line processing
A data processing approach where transactions are entered into the computer directly, as they occur.

operating system
Lowest level system monitor program.

operating work envelope
The portion of the restricted work envelope that is actually used by the robot while it is performing its programmed motion. This includes the maximum the end-effector, the workpiece, and the robot itself.

operator
A person designated to start, monitor, and stop the intended productive operation of a robot or robot system.

operator box
A control panel that is separate from the robot and is designed as part of the robot system. It consists of the buttons, switches, and indicator lights needed to operate the system.

operator panel
A control panel designed as part of the robot system and consisting of the buttons, switches, and indicator lights needed to operate the system.

optional features
Additional capabilities available at a cost above the base price.

OR

An operation that places two contacts or groups of contacts in parallel. Any of the contacts can control the resultant status, also a mathematical operation.

orientation

The attitude of an object in space. Commonly described by three angles: rotation about x (w), rotation about y (p), and rotation about z (r).

origin

The point in a Cartesian coordinate system where axes intersect; the reference point that defines the location of a frame.

OT

See overtravel.

output

Information that is transferred from the CPU for control of external devices or processes.

output device

A device, such as starter motors, solenoids, that receive data from the programmable controller.

output module

An I/O module that converts logic levels within the CPU to a usable output signal for controlling a machine or process .

outputs

Signals, typically on or off, that controls external devices based upon commands from the CPU.

override

See general override.

overtravel

A condition that occurs when the motion of a robot axis exceeds its prescribed limits.

overwrite

To replace the contents of one file with the contents of another file when copying.

P

parity

The anticipated state, odd or even, of a set of binary digits.

parity bit

A binary digit added to an array of bits to make the sum of all bits always odd or always even.

parity check

A check that tests whether the number of ones (or zeros) in an array of binary digits is odd or even.

parity error

A condition that occurs when a computed parity check does not agree with the parity bit.

part

A material item that is used as a component and is not an assembly or subassembly.

pascal

A unit of pressure in the meter-kilogram-second system equivalent to one newton per square meter.

path

1. A variable type available in the KAREL system that consists of a list of positions. Each node includes positional information and associated data. 2. The trajectory followed by the TCP in a move.

PCB

See printed circuit board.

PC Interface

The PC Interface option provides the RPC functions and PC send macros required by applications created using PC Developer's Kit.

pendant

See teach pendant.

PLC

See programmable logic controller or cell controller.

PMC

The programmable machine controller (PMC) functions provide a ladder logic programming environment to create PMC functions. This provides the capability to use the robot I/O system to run PLC programs in the background of normal robot operations. This function can be used to control bulk supply systems, fixed automation that is part of the robot workcell, or other devices that would normally require basic PLC controls.

printed circuit board

A flat board whose front contains slots for integrated circuit chips and connections for a variety of electronic components, and whose back is printed with electrically conductive pathways between the components.

production mode

See automatic mode.

program

1. A plan for the solution of a problem. A complete program includes plans for the transcription of data, coding for the computer, and plans for the absorption of the results into the system. 2. A sequence of instructions to be executed by the computer or controller to control a robot/robot system. 3. To furnish a computer with a code of instructions. 4. To teach a robot system a specific set of movements and instructions to do a task.

programmable controller

See programmable logic controller or cell controller.

programmable logic controller

A solid-state industrial control device that receives inputs from user-supplied control devices, such as switches and sensors, implements them in a precise pattern determined by ladder diagram-based programs stored in the user memory, and provides outputs for control of processes or user-supplied devices such as relays and motor starters.

Program ToolBox

The Program ToolBox software provides programming utilities such as mirror image and flip wrist editing capabilities.

protocol

A set of hardware and software interfaces in a terminal or computer that allows it to transmit over a communications network, and that collectively forms a communications language.

psi

Pounds per square inch.

Q

queue.

1. Waiting lines resulting from temporary delays in providing service. 2. The amount of time a job waits at a work center before set-up or work is performed on the job. See also job queue.

R

RAM

See Random Access Memory.

random access

A term that describes files that do not have to be searched sequentially to find a particular record but can be addressed directly.

Random Access Memory

1. Volatile, solid-state memory used for storage of programs and locations; battery backup is required. 2. The working memory of the controller. Programs and variable data must be loaded into RAM before the program can execute or the data can be accessed by the program.

range

1. A characterization of a variable or function. All the values that a function can possess. 2. In statistics, the spread in a series of observations. 3. A programmable voltage or current spectrum of values to which input or output analog signals can be limited.

RI

Robot input.

RO

Robot output.

read

To copy, usually from one form of storage to another, particularly from external or secondary storage to internal storage. To sense the meaning of arrangements of hardware. To sense the presence of information on a recording medium.

Read Only Memory

A digital memory containing a fixed pattern of bits that you cannot alter.

record

To store the current set or sets of information on a storage device.

recovery

The restoration of normal processing after a hardware or software malfunction through detailed procedures for file backup, file restoration, and transaction logging.

register

1. A special section of primary storage in a computer where data is held while it is being worked on.
2. A memory device capable of containing one or more computer bits or words.

remote/local

A device connection to a given computer, with remote devices being attached over communications lines and local devices attached directly to a computer channel; in a network, the computer can be a remote device to the CPU controlling the network.

repair

To restore robots and robot systems to operating condition after damage, malfunction, or wear.

repeatability

The closeness of agreement among the number of consecutive movements made by the robot arm to a specific point.

reset

To return a register or storage location to zero or to a specified initial condition.

restricted work envelope

That portion of the work envelope to which a robot is restricted by limiting devices that establish limits that will not be exceeded in the event of any reasonably foreseeable failure of the robot or its controls. The maximum distance the robot can travel after the limited device is actuated defines the restricted work envelope of the robot.

RIA

Robotic Industries Association Subcommittee of the American National Standards Institute, Inc.

robot

A reprogrammable multifunctional manipulator designed to move material, parts, tools, or specialized devices, through variable programmed motions for the performance of a variety of tasks.

Robot Model.

Used in Interference Checking, the Robot Model is the set of virtual model elements (sphere and cylinders) that are used to represent the location and shape of the robot arm with respect to the robot's base. Generally, the structure of a six axes robot can be accurately modeled as a series of cylinders and spheres. Each model element represents a link or part of the robot arm.

ROM

See Read Only Memory.

routine

1. A list of coded instructions in a program. 2. A series of computer instructions that performs a specific task and can be executed as often as needed during program execution.

S

saving data.

Storing program data in Flash ROM, to a floppy disk (not supported on version 7.10 and later), or memory card.

scfm

Standard cubic feet per minute.

scratch start

Allows you to enable and disable the automatic recovery function.

sensor

A device that responds to physical stimuli, such as heat, light, sound pressure, magnetism, or motion, and transmits the resulting signal or data for providing a measurement, operating a control or both. Also a device that is used to measure or adjust differences in voltage in order to control sophisticated machinery dynamically.

serial communication

A method of data transfer within a PLC whereby the bits are handled sequentially rather than simultaneously as in parallel transmission.

serial interface

A method of data transmission that permits transmitting a single bit at a time through a single line. Used where high speed input is not necessary.

Server Side Include (SSI)

A method of calling or "including" code into a web page.

servomotor
An electric motor that is controlled to produce precision motion. Also called a "smart" motor.

SI
System input.

signal
The event, phenomenon, or electrical quantity that conveys information from one point to another.

significant bit
A bit that contributes to the precision of a number. These are counted starting with the bit that contributes the most value, of "most significant bit", and ending with the bit that contributes the least value, or "least significant bit".

singulating
Separating parts into a single layer.

slip sheet
A sheet of material placed between certain layers of a unit load. Also known as tier sheet.

SO
System output.

specific gravity
The ratio of a mass of solid or liquid to the mass of an equal volume of water at 45C. You must know the specific gravity of the dispensing material to perform volume signal calibration. The specific gravity of a dispensing material is listed on the MSDS for that material.

SRAM
A read/write memory in which the basic memory cell is a transistor. SRAM (or S-RAM) tends to have a lower density than DRAM. A battery can be used to retain the content upon loss of power.

slpm
Standard liters per minute.

Standard Operator Panel (SOP).
A panel that is made up of buttons, keyswitches, and connector ports.

state
The on or off condition of current to and from and input or output device.

statement
See instruction.

storage device
Any device that can accept, retain, and read back one or more times. The available storage devices are SRAM, Flash ROM (FROM or F-ROM), floppy disks (not available on version 7.10 and later), memory cards, or a USB memory stick.

system variable

An element that stores data used by the controller to indicate such things as robot specifications, application requirements, and the current status of the system.

T

Tare

The difference between the gross weight of an object and its contents, and the object itself. The weight of an object without its contents.

TCP

See tool center point.

teaching

Generating and storing a series of positional data points effected by moving the robot arm through a path of intended motions.

teach mode

1. The mode of operation in which a robot is instructed in its motions, usually by guiding it through these motions using a teach pendant. 2. The generation and storage of positional data. Positional data can be taught using the teach pendant to move the robot through a series of positions and recording those positions for use by an application program.

teach pendant

1. A hand-held device used to instruct a robot, specifying the character and types of motions it is to undertake. Also known as teach box, teach gun. 2. A portable device, consisting of an LCD display and a keypad, that serves as a user interface to the KAREL system and attaches to the operator box or operator panel via a cable. The teach pendant is used for robot operations such as jogging the robot, teaching and recording positions, and testing and debugging programs.

telemetry

The method of transmission of measurements made by an instrument or a sensor to a remote location.

termination type

Feature that controls the blending of robot motion between segments.

tool

A term used loosely to define something mounted on the end of the robot arm, for example, a hand, gripper, or an arc welding torch.

tool center point

1. The location on the end-effector or tool of a robot hand whose position and orientation define the coordinates of the controlled object. 2. Reference point for position control, that is, the point on the tool that is used to teach positions. Abbreviated TCP.

TOOL Frame

The Cartesian coordinate system that has the position of the TCP as its origin to stet. The z-axis of the tool frame indicates the approach vector for the tool.

TP.

See teach pendant.

transducer

A device for converting energy from one form to another.

U

UOP

See user operator panel.

URL

Universal Resource Locator. A standard addressing scheme used to locate or reference files on web servers.

USB memory stick

The controller USB memory stick interface supports a USB 1.1 interface. The USB Organization specifies standards for USB 1.1 and 2.0. Most memory stick devices conform to the USB 2.0 specification for operation and electrical standards. USB 2.0 devices as defined by the USB Specification must be backward compatible with USB 1.1 devices. However, FANUC America Corporation does not support any security or encryption features on USB memory sticks. The controller supports most widely-available USB Flash memory sticks from 32MB up to 1GB in size.

USER Frame

The Cartesian coordinate system that you can define for a specific application. The default value of the User Frame is the World Frame. All positional data is recorded relative to User Frame.

User Operator Panel

User-supplied control device used in place of or in parallel with the operator panel or operator box supplied with the controller. Abbreviated UOP .

V

variable

A quantity that can assume any of a given set of values.

variance

The difference between the expected (or planned) and the actual, also statistics definitions.

vision system

A device that collects data and forms an image that can be interpreted by a robot computer to determine the position or to “see” an object.

volatile memory

Memory that will lose the information stored in it if power is removed from the memory circuit device.

W

web server

An application that allows you to access files on the robot using a standard web browser.

warning device

An audible or visible device used to alert personnel to potential safety hazards.

work envelope

The volume of space that encloses the maximum designed reach of the robot manipulator including the end effector, the workpiece, and the robot itself. The work envelope can be reduced or restricted by limiting devices. The maximum distance the robot can travel after the limit device is actuated is considered the basis for defining the restricted work envelope.

write

To deliver data to a medium such as storage.

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