

A255 Robot Arm User Guide

For use with C500C Controller

UMI-33-255-A



Revision History		
Number	Details	Date
001	Original issue as A255 for C500C. Updated to CROS 1.16.	99-05
002	Revised shut down procedure.	00-06

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Preface

This user guide accompanies the A255 robot arm used with the C500C controller.

This Guide

This user guide contains general information, arm specifications, safety precautions, installation instructions, startup procedures, and basic operation instructions for the CRS Robotics A255 robot arm.

This A255 User Guide is available in English.

Other Guides

Additional information is available in the following documents.

- C500C Controller User Guide
- Application Development Guide
- RAPL-3 Language Reference Guide

Additional copies of this arm user guide, or other CRS Robotics literature, may be obtained from your distributor or the CRS Robotics Sales Department.

Training

This installation guide is not intended as a self-teaching tool. It is intended as a guide for those who have attended a CRS Robotics robot training course and have a basic knowledge of CRS Robotics robots.

Training courses are offered at our facility in Burlington, Ontario, Canada, or can be conducted at your facility. For additional information, contact the Customer Support Group.

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How to Use This User Guide

This user guide is organized with each chapter covering a different topic.

- If you are installing or using the robot, read the Safety Precautions chapter.
- If you have received a robot for the first time, read the Specifications and Installation chapter.
- If you are installing the robot yourself, read the Installation and Commissioning chapter.
- If the robot was installed by CRS or a distributor, read the chapters on Commissioning and Operation Basics.

Before attempting to follow a procedure or examples, read the entire section first.



Throughout this user guide, warnings are marked by an “!” icon in the left margin. Failure to comply with these warnings can result in injury to persons; damage to the robot, tooling, or work pieces; loss in memory; or errors in the system.

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CHAPTER 1

Introduction

The A255 arm is articulated with five joints or axes, providing it with five degrees of freedom. This allows the arm to move a gripper or other tool to cartesian spatial coordinates and orientation defined by X, Y, Z, Z-rotation, Y-rotation, and X-rotation.

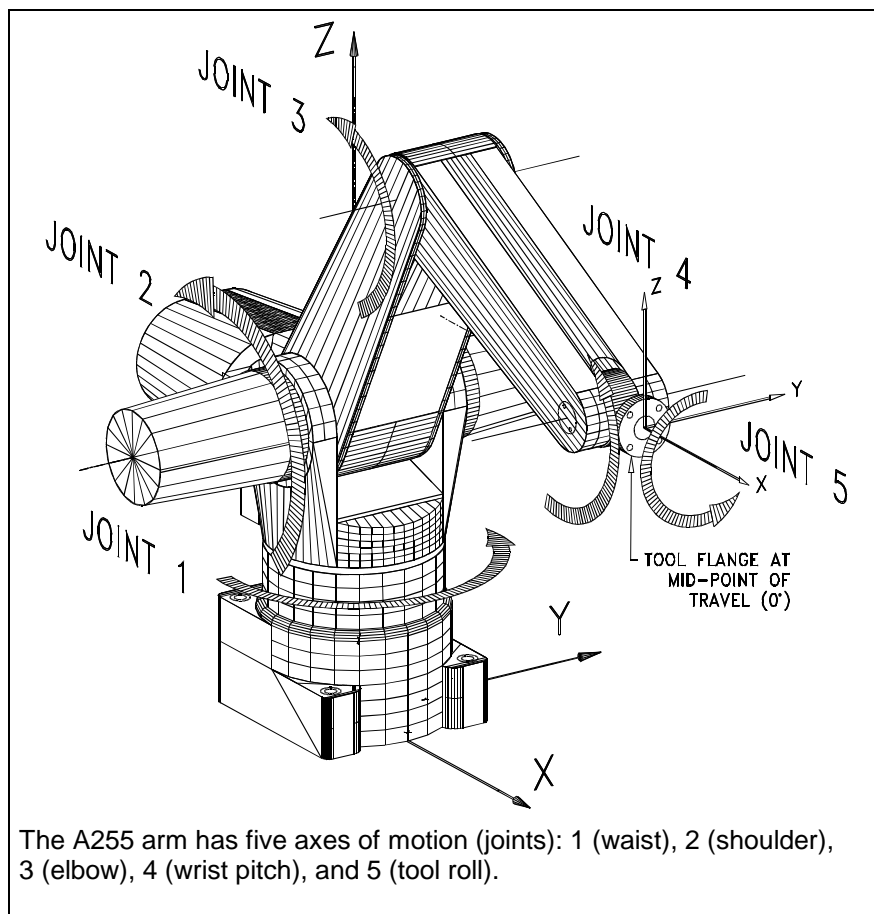
The A255 robot system consists of an A255 arm and a C500C controller. The controller runs the CROS-500C operating system and programs written in the RAPL-3 programming language.

You can operate the A255 by a teach pendant, a terminal, or a RAPL-3 program.

For standard applications, you can edit programs, move the arm, teach locations, and run programs from either the teach pendant or the terminal.

For advanced applications, you can also edit and compile programs off line on a computer and use advanced tools through the terminal.

The A255 is designed for laboratory automation, machine loading, product testing, parts assembling, material handling, education and research, and other tasks.



Optional Equipment

The following options are available from CRS or an authorized CRS distributor.

End Effectors

- Servo Gripper and Adapter
- Pneumatic Gripper and Adapter
- Microplate Fingers for Servo Gripper

Hardware and Equipment

- Teach Pendant
- Extra-Length Umbilical Cables
- Linear Track
- Remote Operator Panel
- End Effector Custom Cabling
- Homing Bracket
- Force Sensor
- Pressurized Suit

Software

- Robcomm3 (RAPL-3 Program Development Environment and Interface to C500C)
- POLARA (Laboratory Automation Software)

CHAPTER 2

Specifications

This chapter describes the A255 arm:

- Range of Motion, Dimensions, and Weight
- Reach
- Torque Ratings
- Joint Speed and Acceleration Rates
- Payload
- Resolution
- Brakes
- Gripper

Range of Motion, Dimensions, and Weight

The arm's range of motion depends on the dimensions of each arm section (base, links, tool flange) and the extent of travel of each joint. These measurements determine the shape of the arm's workspace. See the following figures and tables.

Note: A dimension involving a joint is measured to the joint axis.

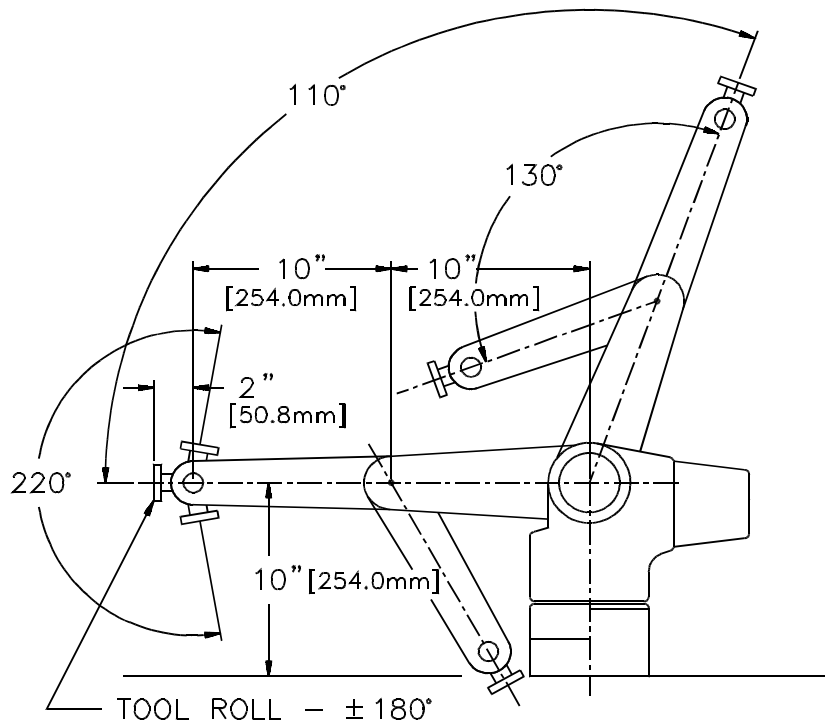
The arm weighs approximately 37 lb [17 kg].

Weight (approx.)	lb	kg
Arm	37	17

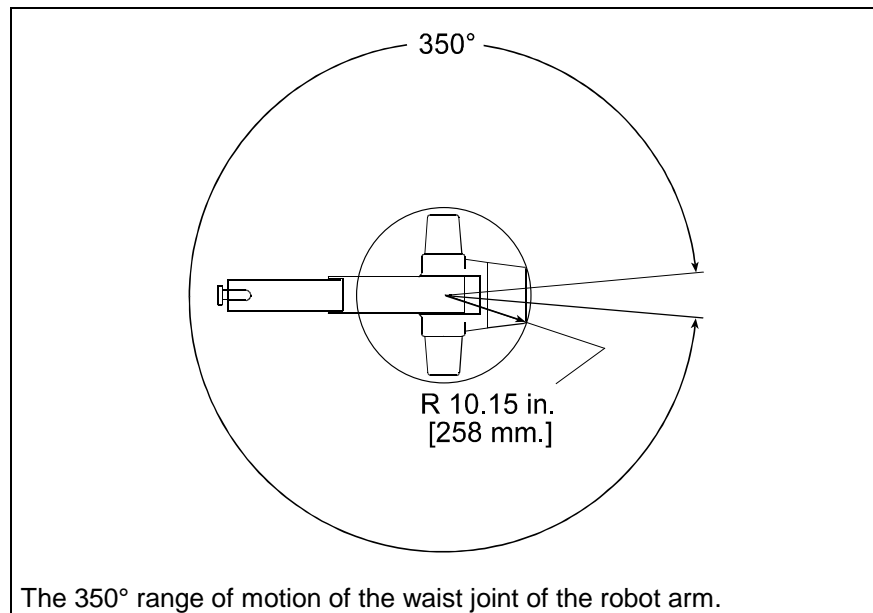
Joint	Axis	Range of Motion
Waist	1	+175° to -175°
Shoulder	2	+110° to 0°
Elbow	3	0° to -125°
Wrist pitch	4	+110° to -110°
Tool roll	5	+180° to -180°

Note: The range of motion of the elbow (joint 3) is dependent on the positions of the shoulder (joint 2) and the wrist pitch (joint 4).

Section	Dimensions	
	inch	mm
Base mounting surface to shoulder	10	254.0
Shoulder to elbow	10	254.0
Elbow to wrist pivot (joint 5)	10	254.0
Wrist pivot to tool flange surface	2	50.8



The range of motion of the joints and the dimensions of the sections of the robot arm.



Reach

The maximum reach of the arm is calculated horizontally outward from the shoulder joint (axis 2) and vertically upward from the bottom of the base.

The arm can reach points below the level of the bottom of the base.

A255 Maximum Arm Reach			
		inch	mm
Horizontal outward from the shoulder axis in the X, Y plane	to tool flange	22.00	558.8
	to finger platform of servo gripper	25.78	654.8
Vertical upwards along the Z axis	to tool flange	32.00	812.8
	to finger platform of servo gripper	35.78	908.8
Vertical downwards below the base level	to tool flange	2.00	50.8
	to finger platform of servo gripper	5.78	146.8

Torque Ratings

This table shows the torque rating for each arm joint.

Continuous Torque Rating			
Joint	Axis	Torque	
		in-lb	N-m
Waist	1	57.0	6.4
Shoulder	2	57.0	6.4
Elbow	3	57.0	6.4
Wrist pitch	4	13.0	1.4
Tool roll	5	6.3	0.71

Joint Speeds and Acceleration Rates

The standard pick and place cycle is 1.8 seconds.

The following tables show the speed and acceleration rates for each arm joint.

Maximum speeds	
Motion	m/s
Compounded joint interpolated motions	3.210
Linear and path motions	0.508

Joint Speeds at 100% Program Speed					
Joint	Axis	pulse/ms	Gear Reduction	Maximum Speed	
				rad/s	deg/s
Waist	1	42	72:1	3.67	210
Shoulder	2	42	72:1	3.67	210
Elbow	3	42	72:1	3.67	210
Wrist pitch	4	30	16:1	11.8	675
Tool roll	5	30	8:1	23.6	1350

Default Acceleration Rates				
Joint	Axis	pulse/s ²	rad/s ²	deg/s ²
Waist	1	1000	8.7	498
Shoulder	2	1000	8.7	498
Elbow	3	1000	8.7	498
Wrist pitch	4	1000	39.3	2240
Tool roll	5	1000	78.5	4490

Payload

Payload is the amount of mass (weight) carried by the arm and/or the amount of force the arm can exert on an object. This includes the gripper and any load that it carries.

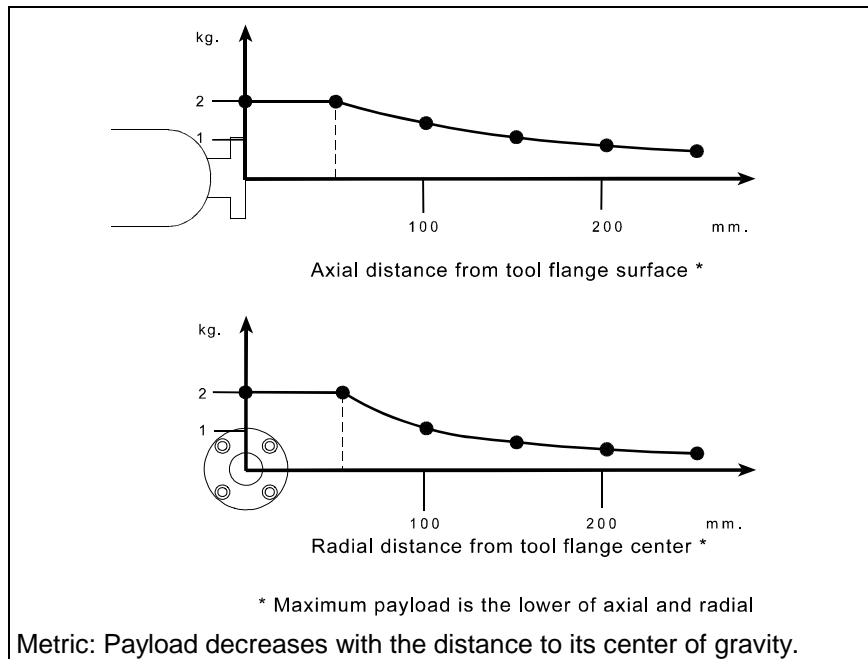
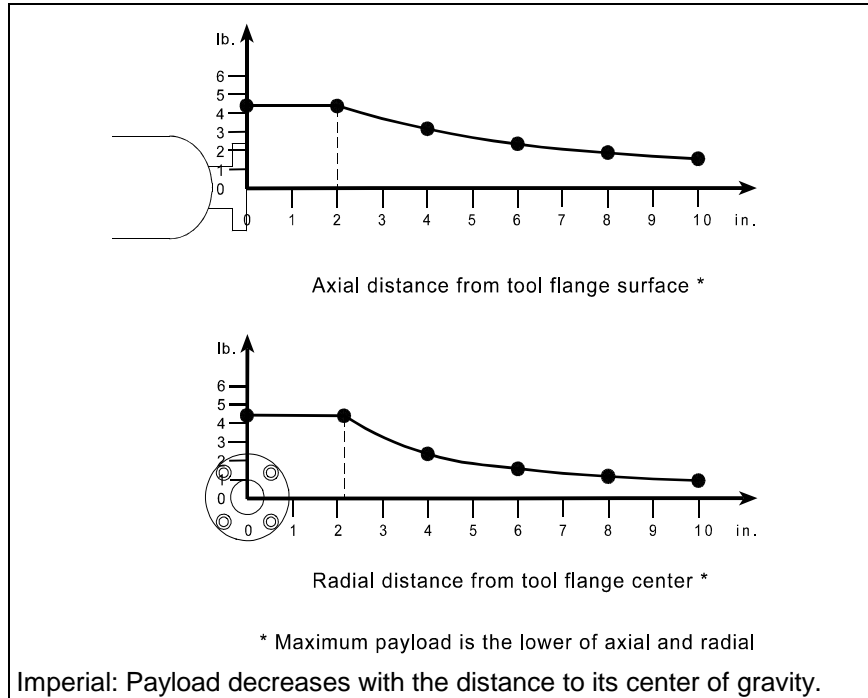
The maximum and nominal payloads are determined for speed and acceleration that maintain rated precision. For rated precision, the arm travels at a reduced speed to carry the maximum payload, and the arm must carry a reduced payload to travel at maximum speed.

The maximum payload depends on the distance between the center of the tool flange surface and the center of gravity of the payload as shown in the payload derating tables and curves.

Payload	Speed	Mass
Maximum	80% speed or acceleration	2.0 kilograms
Nominal	100% speed or acceleration	1.0 kilograms

Axial Distance From Tool Flange Surface			
Distance		Mass	
inch	mm	lbs.	kg
0.00	0.0	4.40	2.00
2.00	50.8	4.40	2.00
4.00	101.6	3.17	1.44
6.00	152.4	2.37	1.08
8.00	203.2	1.90	0.86
10.00	254.0	1.58	0.72

Radial Distance From Tool Flange Center			
Distance		Mass	
inch	mm	lbs.	kg
0.00	0.0	4.40	2.00
2.16	54.8	4.40	2.00
4.00	101.6	2.37	1.08
6.00	152.4	1.58	0.72
8.00	203.2	1.18	0.54
10.00	254.0	0.95	0.43



Resolution

Resolution is the smallest increment of motion or distance that can be detected or controlled. Resolution depends on the distance between the center of the tool flange surface and the center of gravity of the payload, as shown in the resolution derating tables and curves.

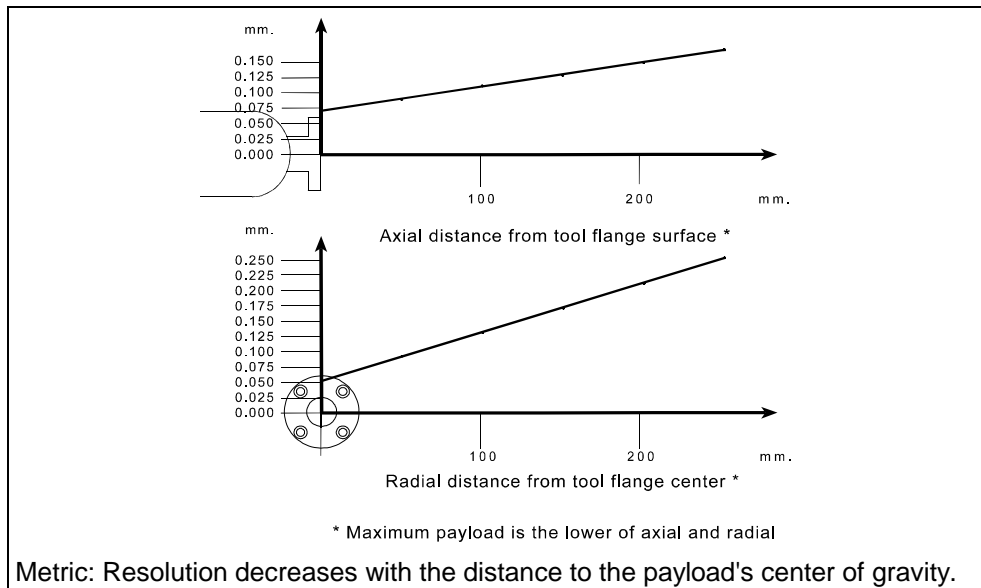
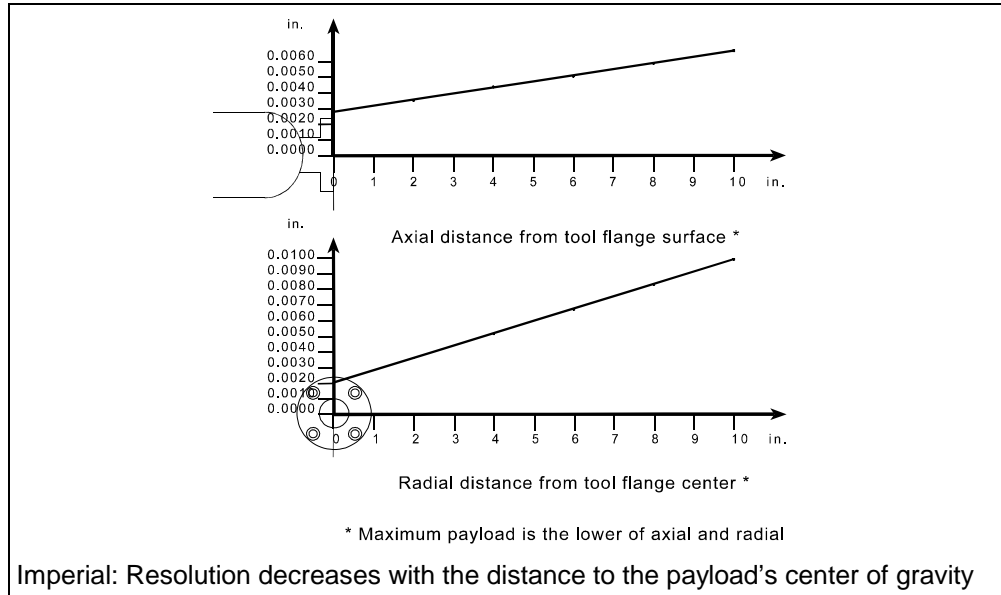
Axial Distance From Tool Flange Surface			
Distance		Resolution	
inch	mm	inch	mm
0.00	0.00	0.0028	0.0711
2.00	50.80	0.0036	0.0914
4.00	101.60	0.0044	0.1118
6.00	152.40	0.0051	0.1295
8.00	203.20	0.0059	0.1499
10.00	254.00	0.0067	0.1702

Radial Distance From Tool Flange Center			
Distance		Resolution	
inch	mm	inch	mm
0.00	0.00	0.0020	0.0508
2.00	50.80	0.0036	0.0914
4.00	101.60	0.0051	0.1295
6.00	152.40	0.0067	0.1702
8.00	203.20	0.0083	0.2108
10.00	254.00	0.0099	0.2515

Repeatability

Repeatability is the ability to repeat the same motion or achieve the same points when presented with the same control signals. It can also be defined as the cycle-to-cycle error when trying to perform a specific task.

Repeatability	± 0.002 inch	± 0.05 mm
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Brakes

Fail-safe brakes prevent the robot from moving under the influence of gravity or inertia when power is removed. Each brake consists of a spring-loaded clamp on a rotating disk. A 35 Volt DC signal energizes a magnetic solenoid which unloads the clamp.

Brakes are installed on all joints except joint 1.



Do not move the joints by hand when brakes are engaged. This may damage some components.

Gripper

An A255 robot requires the attachment of a gripper (or other end effector) to perform its intended task. Custom-designed grippers and other end effectors are available from CRS. Refer to page 57 for gripper installation instructions.

Standard Grippers

Servo Gripper (SGRIP)

An electric servo-controlled, parallel motion, two-finger gripper, capable of measuring objects between its fingers. Finger travel is 2.0 in. [50.8 mm] with programmable position and force.

Servo Gripper with Microplate Fingers (SEC-B0-645)

An electric servo-controlled, parallel motion, two-finger gripper, with fingers specially designed for handling laboratory microplates. Finger travel is 2.0 in. [50.8 mm] with programmable position and force.

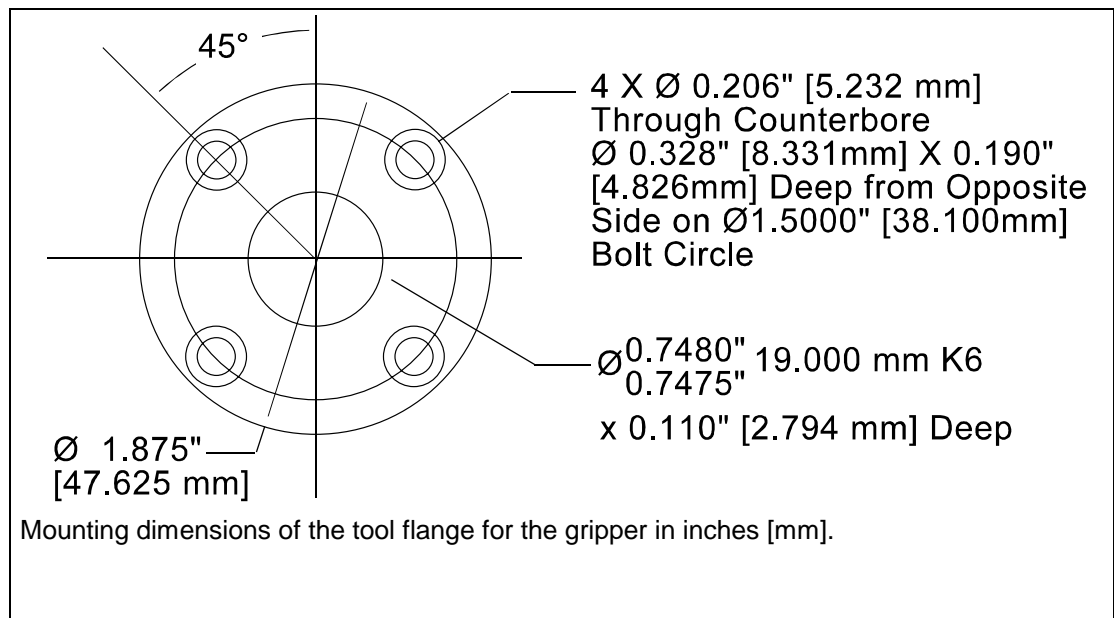
Pneumatic Gripper (PGR112/3)

A two-jaw, double acting, air gripper with 3 in. [76.2 mm] long, angular motion, re-toolable fingers. Fingers can be machined to meet specific needs. Travel is 0–10 degrees per finger.

Grippers (other than CRS)

Grippers must be designed and constructed, so that:

- Power failure does not cause the release of the load, or result in a hazardous condition.
- Static and dynamic forces exerted by the load and the gripper together are within the load capacity and dynamic response of the robot.



CHAPTER 3

Safety Precautions

This chapter describes the design of safeguards and other precautions for the safe use of the robot system and its workcell.



Danger! Design your robot workcell for safety. The robot is a potentially hazardous machine. Injury to persons or damage to the robot, tooling, or other work cell components can occur from unsafe work cell design, robot installation, operation, or from system failure.

There are residual safety risks with operating robotic systems. System integrators and end-users have the responsibility of assessing risks and determining appropriate safety measures throughout the life-cycle of the robot system.

Safeguards and Safety Measures

Safeguards may include, but are not limited to: fixed barriers, interlock barriers, perimeter guarding, awareness barriers, and awareness signals.

Incorporate safety measures into your design to reduce the risk of hazards. Ensure that you:

- Use a diverse and redundant set of safety measures to provide an adequate level of safety.
- Design measures so that the activation of an interlock installed to prevent against one hazard does not create a new hazard.
- Correctly install and operate the robot.

Prevent Personal Injury



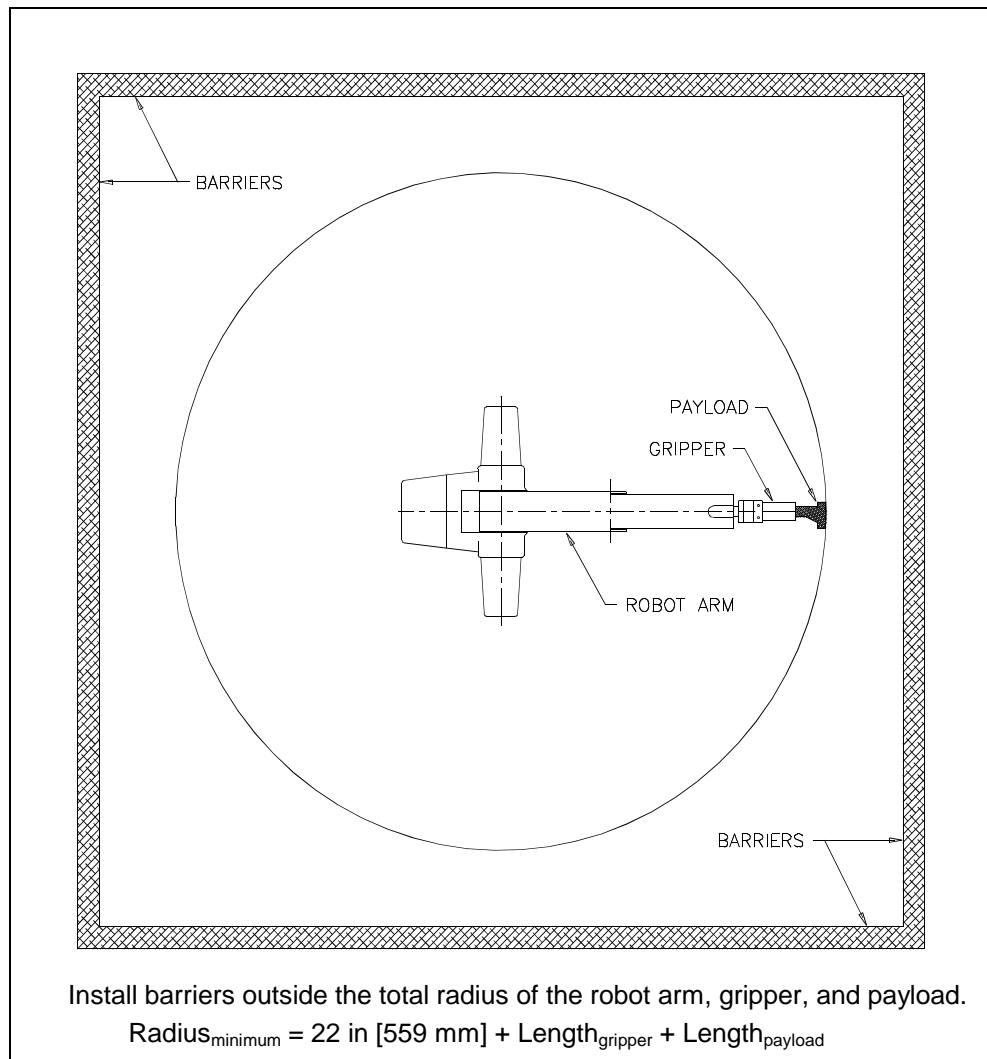
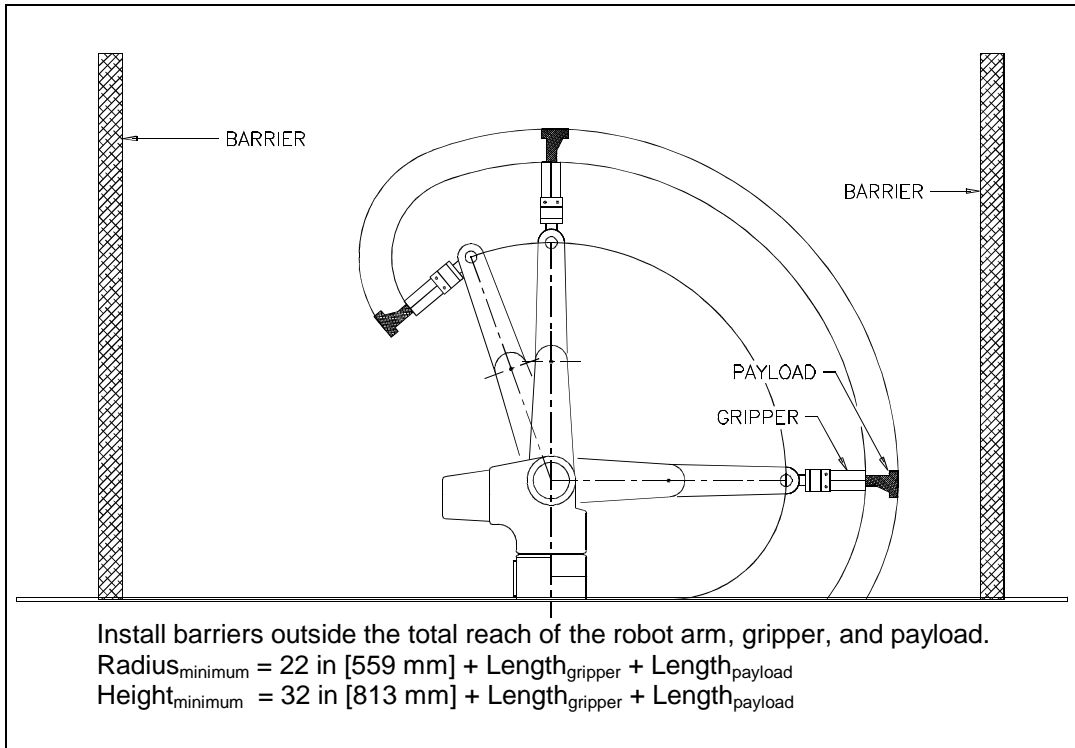
Danger! Never enter or obstruct the workspace while the robot is in use. The robot arm is capable of fast movement without warning. Install safeguards to prohibit access to the workspace when the robot is in use.

Physical Barriers

Physical safety barriers prohibit or inhibit access to the robot arm's workspace.

Install safety barriers:

- Beyond the limit of the total possible workspace of the robot arm, even if your robot arm is programmed for only a portion of the total possible workspace.
- With sufficient clearance between the barriers and the total robot workspace (arm, gripper, and payload) to avoid trapping or crushing any object.



Emergency Stops (E-stops)

An emergency stop (e-stop) button is a large, red, mushroom-shaped button that removes arm power when struck. It must be manually reset to restore arm power.

The controller e-stop circuit removes arm power. When arm power is removed, fail-safe brakes engage to prevent the robot from moving due to gravity or inertia. Brakes are installed on all joints except joint 1.

The e-stop circuit is connected to the:

- E-stop button on the front panel of the controller.
- E-stop button on the front of the teach pendant.
- Live-man switch on the teach pendant.

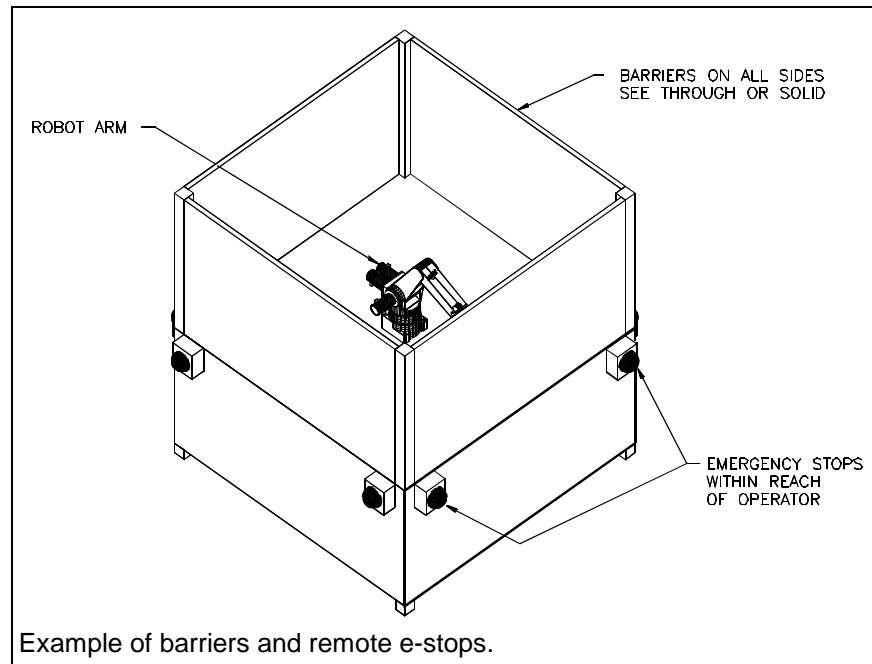
To ensure safety, you can install similar e-stop buttons:

- At or near the robot arm location.
- Within human reach of any approachable side of the robot arm work cell.

Design your workcell so that:

- All e-stop buttons are unobstructed.
- Personnel can reach and activate the e-stop without difficulty.
- All e-stops are outside the total safeguarded space of the robot arm, its gripper, and any payload. For the dimensions of the workspace of the robot arm, see Range of Motion on page 4 and Reach on page 6.

If installing other e-stop buttons, see “Installing a Custom E-Stop Circuit” in the C500C Controller User Guide for connector pin identification and DIP switch positioning.



Presence Sensors

Install a presence-sensing safety interlock at any point of access through a barrier into the arm workspace. Design the interlock as part of the robot's e-stop circuit. For example, a door-mounted contact switch connected to the e-stop circuit stops the arm when the door is opened and the contact broken, and it permits arm operation when the door is closed and contact is restored.

If connecting a device to the e-stop circuit, see "Installing a Custom E-Stop Circuit" in the C500C Controller User Guide for connector pin identification and DIP switch positioning.

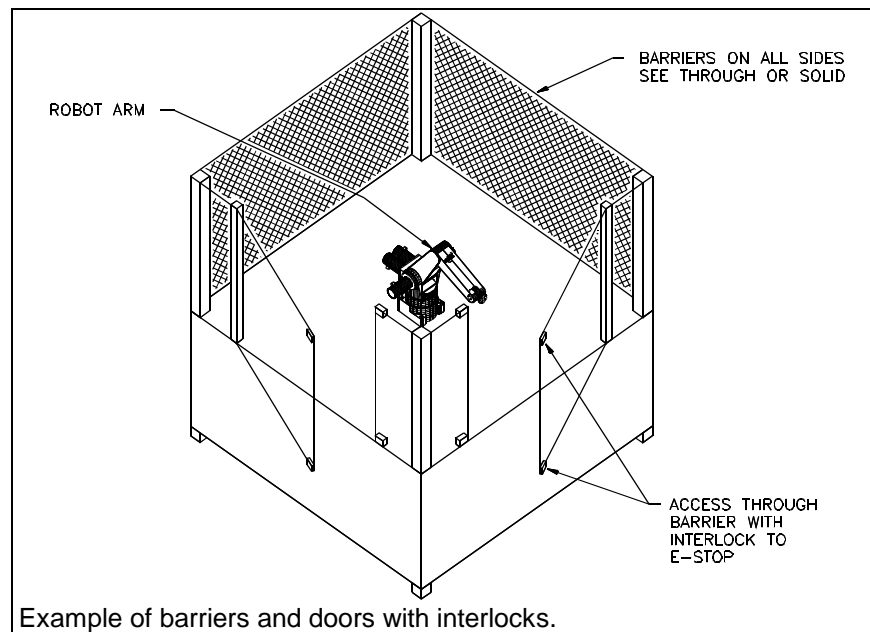
Presence-sensing devices include:

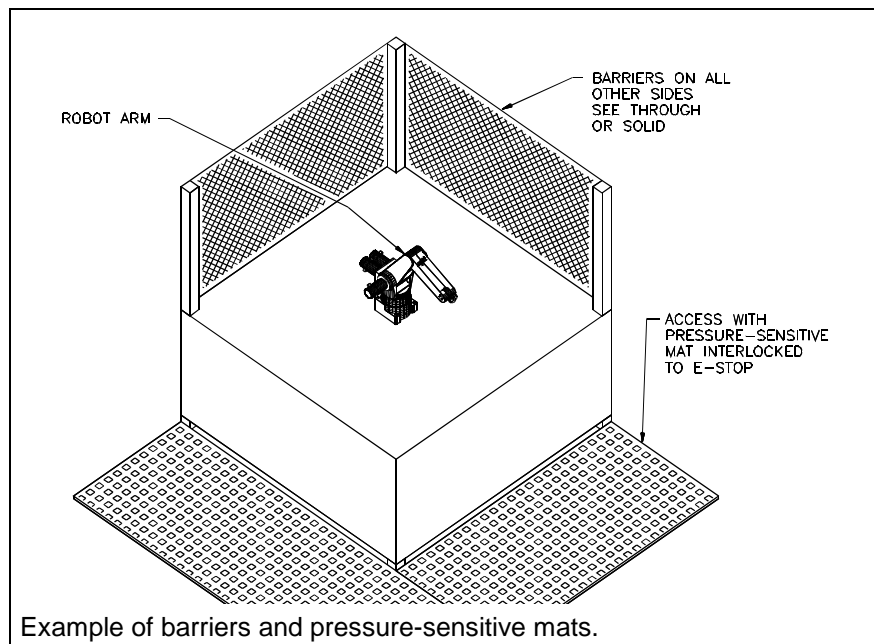
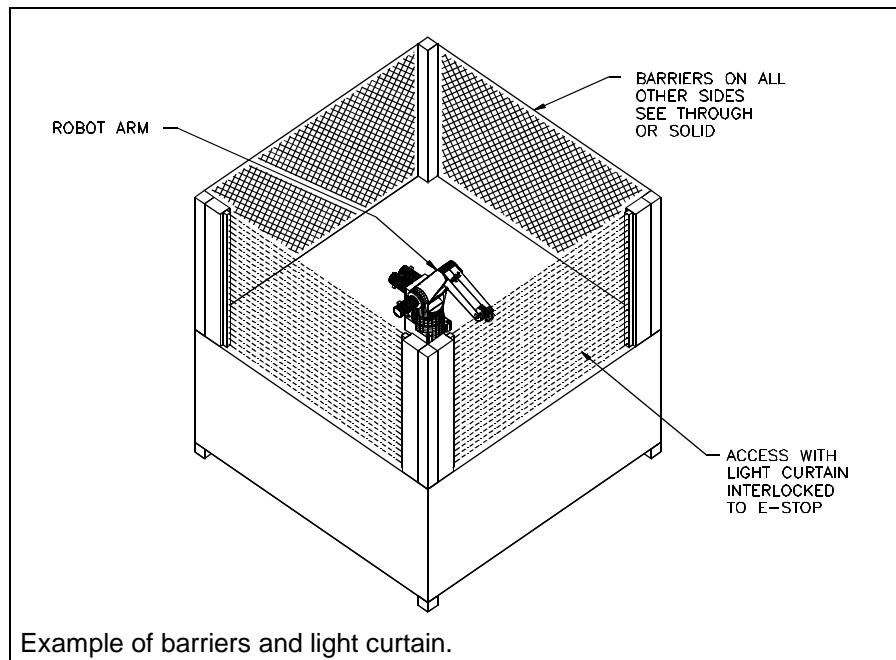
- Interlocks on doors.
- Light curtains.
- Pressure-sensitive floor mats, etc.

Design and construct any presence-sensing device so that:

- When any component fails, the e-stop circuit is interrupted.

The presence-sensing envelope is far enough from the robot arm to stop robot arm motion before the intruder can reach the arm workspace.





Other Safeguards

In addition to physical barriers, e-stops, and presence-sensing devices, safeguards can include, but are not limited to:

- **Awareness signals**

An awareness signal is an audio or visual alarm, such as a buzzer or light, activated by a sensor in a larger envelope outside the inner, e-stop connected envelope. The signal alerts the intruder to move away before tripping the e-stop circuit.

- **Awareness barriers**
An awareness barrier, such as a length of yellow chain, alerts personnel to their nearness to the workspace, but is not sufficient to prohibit access into the workspace.
- **Passive warnings**
Passive warnings include markings on the floor or table top.
- **Beacon light**
A prominent light which is lit when the robot system has power on.
- **Training**
Ensure that personnel who program, operate, maintain, or repair the robot are adequately trained and demonstrate competence to perform their jobs safely.

Safety Regulations

In addition, your installation should comply with any applicable safety regulations or standards of your national or local jurisdiction.

Note: Care should be taken to ensure that the activation of an interlock installed to prevent against one hazard does not create a new hazard.

Power

Power Supply

Power supplied to the robot controller must be stable. If your power supply is unstable (has fluctuations in frequency or surges), install a regulating system in the power supply.

- Do not exceed voltage fluctuations $\pm 10\%$ of the nominal voltage.
- For variations in voltage only, install a regulating transformer. A more complete regulating system, such as an Uninterruptible Power Supply (UPS), can be used for all robot systems.
- Do not exceed the power rating or fuse rating for the robot controller.

Note: Before entering within the robot's safeguarded area, perform the checks and safety precautions as listed on pages 23 and 24.

Power Failure

If a power failure occurs, the robot controller automatically removes arm power. This prevents the arm from moving when power is restored.

- You must restart the robot controller after a power failure.

Ground

Ensure that the AC power supply is properly grounded. The incoming AC plug has three wires: hot, neutral, and chassis ground. All three wires must be used. Hot and neutral supply power to the system and the ground shields the controller from external noise and voltage potentials.

- Ground the arm to an industrial grounding rod. If a grounding rod is not available, use a utility ground.
- Ideally, grounding points should be equipotential.

Environment

Indoor Use

Install the robot indoors only.

Temperature

Maintain the air temperature between 50° F [10°C] and 104°F [40°C].

- **Do not** install the robot near heating or cooling units.
- **Do not** expose the robot to temperatures below 50° F [10°C] or above 104° F [40°C] without a CRS-certified protective cover. Use a protective cover if temperatures fall above or below this range.

Humidity

Maintain the relative humidity below 50%, non-condensing.

Corrosive Fumes

Do not expose the robot to an environment of corrosive fumes without a CRS-certified protective cover.

Contamination

Use a protective cover to protect the arm from contaminated environments.

- Protecting the arm and controller from contaminants will lead to extended use.

Note: Purge the air in the controlled covers at regular intervals.

Robot Handling

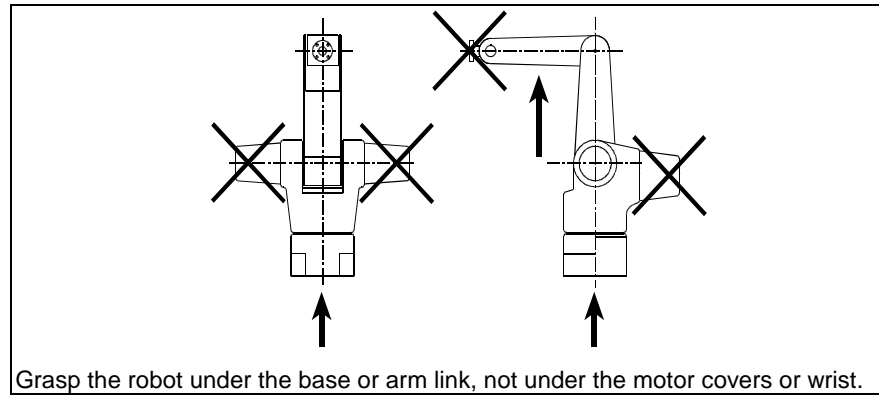
The robot is a precision instrument and must be handled with care.

Moving

Grasp the robot under the cast aluminum base and under one of the machined aluminum arm links.

- **Do not** grasp the robot under the thin ABS-plastic motor covers on the back or sides, or under the wrist or gripper.
- **Do not** drop the robot.

- Do not carry the arm any distance. Use a cart when transporting the arm.



Wiring and Encoders

- **Do not** apply pressure to the motor covers or wrist.
- **Do not** damage the umbilical cable and the cable connectors. Protect the cables and connectors from damage or deterioration.

Electrically Conductive Objects

- **Do not** allow electrically conductive objects or liquid to come into contact with the robot arm or controller circuitry.

Electrically Live Contacts

- **Do not** allow anything electrically live to come into contact with the arm or controller.

Operator Safety

Operator Attitude of Robot

Maintain an attitude of respect for the robot as a potentially dangerous machine.

Operator Awareness of Robot

When working near the robot, continue to be aware of the arm's position and motion.

- For occasional close approach to the workspace, have a second person observe the arm while prepared to activate an e-stop.
- For continual close approach to the workspace, install precise presence-sensing devices interlocked to the e-stop circuit.

Operator Position Near Robot

Avoid any location that places you between the arm and another object.

Operator Training

Ensure that personnel who program, operate, maintain, or repair the robot are adequately trained and demonstrate competence to perform their jobs safely. Attend a CRS training course for proper training.

Ensure that operators:

- Are familiar with the applicable safety precautions as stated in this chapter.
- Have a clear definition of their assigned task.
- Can identify the control devices and their functions used in performing their assigned task.
- Have designated methods of safeguarding, including safe work procedures from identified hazards.
- Test and ensure that the safeguards and interlocks function properly.

Safety and Operation Checks

Ensure that you have followed all the instructions supplied within this manual.

BEFORE applying power to the arm, verify that:

- The robot is properly installed, mounted, and is stable (refer to Chapter 4 “Installation” for mounting and installation procedures).
- The electrical connections are correct and that the power supplies (voltage, frequency and interference levels) are within the specified ranges (refer to page 20 for specified ranges).
- If you have modified your system, added hardware, software, or serviced your robot, recheck all the changes or additions.
- User memory is intact. Errors should not appear in your programs, location, or variable files.
- Safeguards are in place.
- The physical environment (humidity, atmospheric conditions, and temperature) is as specified. For more information refer to page 21.

AFTER applying arm power, verify that:

- The start, stop, and function keys on the teach pendant and controller front panel function as intended.
- E-stops, safety stops, safeguards, and interlocks are functional.
- At reduced speed the robot operates properly and has the ability to handle the payload.
- Under normal operation, the robot functions properly and has the capability to perform its intended task at the rated speed and load.

Working Within the Robot's Workspace

Before entering within the robot's workspace, perform the following checks and safety precautions.

- Visually inspect the robot to determine if any conditions exist that can cause malfunctions or injury to persons.
- If the teach pendant controls are used, test them to ensure that they function correctly. If any damage or malfunction is found in the teach pendant, complete the required repairs before allowing personnel to enter within the robot workspace.
- While programming or teaching locations, the robot system must be under the sole control of the programmer.
 - When possible, program the robot with all personnel outside the safeguarded area.
 - When programming the robot and teaching locations within the safeguarded area, ensure that robot motion is reduced to at least 25% speed.
- While servicing the robot arm, the robot system must be under the sole control of the service person.
 - Ensure that the robot is off-line. The arm must not be stopped in, or running, a program.
 - Ensure that the robot does not respond to any remote signals.
 - Ensure that all safeguards and e-stops are functional.
 - Always shut down and remove power to the arm and controller before connecting or disconnecting cables.
 - Ensure that suspended safeguards are returned to their original effectiveness prior to initiating robot operation.
- When power to the robot arm is not required, it should be turned off.

CHAPTER 4

Installation

This chapter describes how to:

- Design a Workcell
- Unpack the Arm
- Prepare a Mounting Platform
- Mount the Arm on the Platform
- Ground the Arm
- Connect the Umbilical Cables to the Arm

Arm or Controller First?

You can install the arm first or the controller first. This chapter covers installation of the arm. A similar chapter in the controller user guide covers installation of the controller.

Gripper

Gripper installation is covered separately in a later chapter. Before attaching the gripper to the arm, the arm and controller must be installed and commissioned.

Required Tools and Supplies

You need the following tools and supplies to install the robot arm.

Procedure	Tools	Supplies
Designing a Workcell	—	—
Unpacking the Arm	<ul style="list-style-type: none"> • Utility knife • Hex key ($\frac{5}{16}$ in.), small wrench 	—
Preparing a Mounting Platform	<ul style="list-style-type: none"> • Machine tools to drill, tap, and ream 	<ul style="list-style-type: none"> • Metal plate 30 Ksi [210 MPa]
Mounting the Arm	<ul style="list-style-type: none"> • $\frac{5}{16}$ in. hex key, or 6 mm hex key 	<ul style="list-style-type: none"> • 4 cap screws • 2 dowel pins
Grounding the Arm	<ul style="list-style-type: none"> • Small adjustable wrench ($\frac{3}{8}$ in., approx. 9.5 mm.) 	<ul style="list-style-type: none"> • #12 gauge wire
Connecting the Umbilical Cables	<ul style="list-style-type: none"> • Small Phillips (+) screwdriver 	—

Component Parts

Before installing the robot, locate and check that you have received all the components.

- If you did not order options, the robot system is packaged in two containers.
- If you ordered options, the robot system is packaged in three or more containers.
- Options may include: gripper, teach pendant, arm user guide, controller user guide, software user guide(s) and diskette(s), cable extensions, spares, etc.

NO OPTIONS	
Container	Contents
labeled "DESCRIPTION: ARM"	<ul style="list-style-type: none"> • Arm
labeled "DESCRIPTION: CTRL"	<ul style="list-style-type: none"> • Controller • Feedback cable • Motor power cable • Fuse kit with AC power cable • Override plug

OPTIONS	
Container	Contents
labeled "DESCRIPTION: ARM"	<ul style="list-style-type: none"> • Arm
labeled "DESCRIPTION: CTRL"	<ul style="list-style-type: none"> • Controller
labeled "OPTIONS"	<ul style="list-style-type: none"> • Feedback cable • Motor power cable • Fuse kit with AC power cable • Override plug • Options

Designing a Work Cell

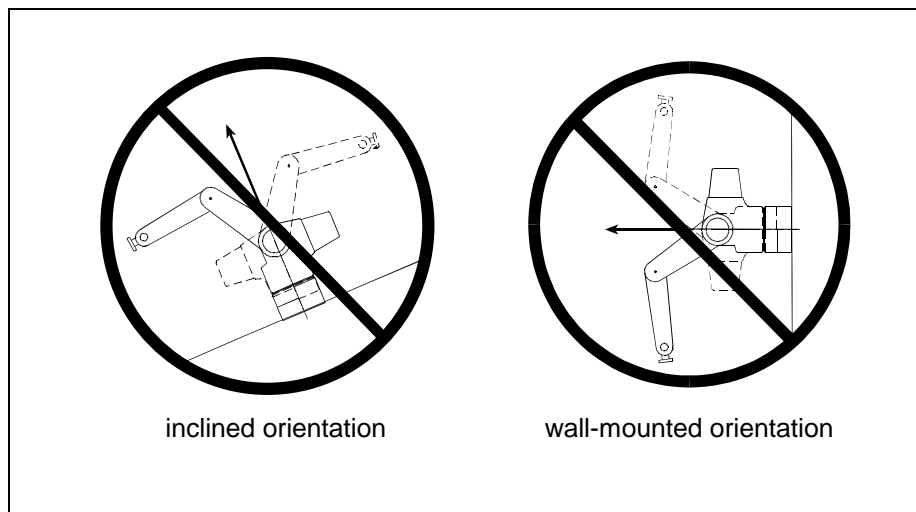
When designing your work cell, consider:

- The arm's range of motion, see page 4.
- The arm's reach, see page 6.
- Safety precautions, see page 15.

Keep the workspace clear of obstructions. If an obstruction cannot be removed, avoid it by programming arm limits. Before installation, determine whether any permanent obstructions, even with programming, will prevent the arm from accomplishing its task.

Positioning the Arm

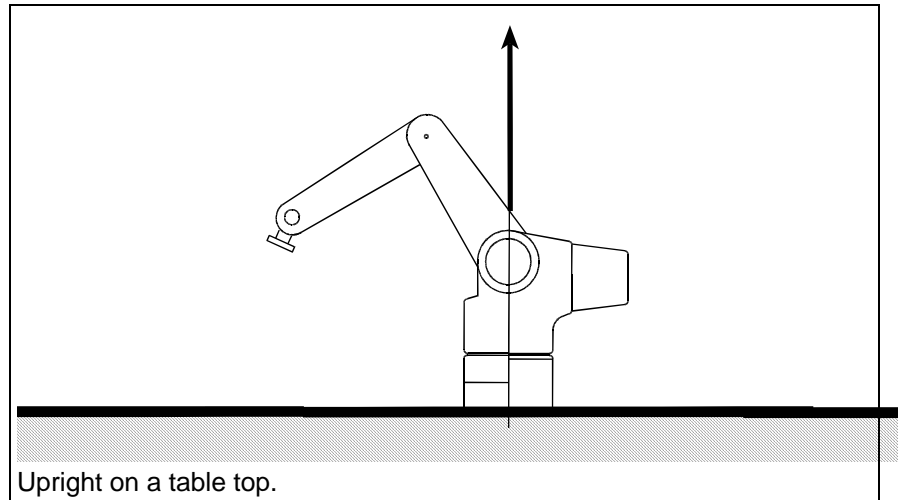
Install the arm in either an upright position (mounted on a table top or pillar) or in an inverted position (suspended from overhead brackets).



Warning! Do not install the arm on a wall or incline. Upon a power failure, joint 1 will fall due to gravity. Under normal operating conditions, joint 1 will be placed under excessive stress.

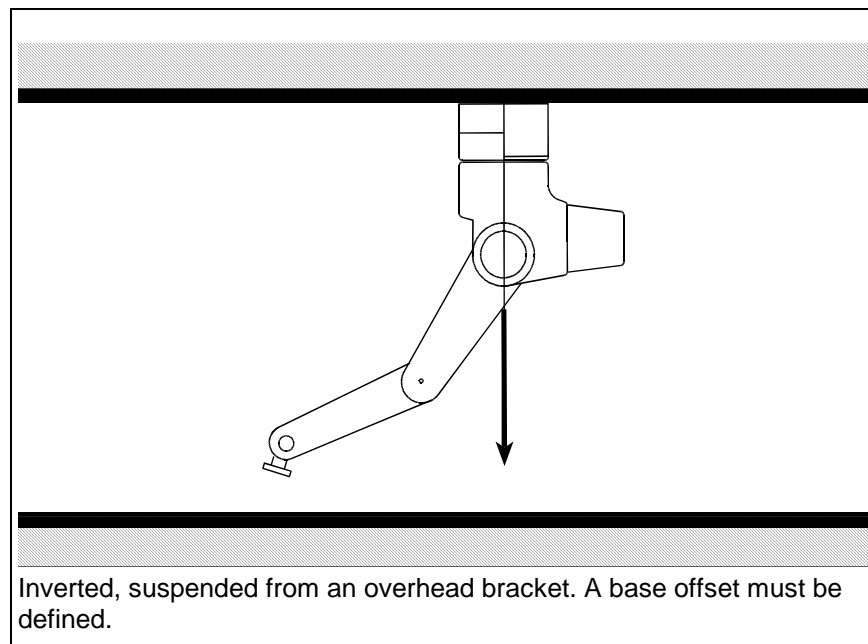
Upright Position

You can install the arm upright on a table top. A portion of the workspace is occupied by the arm.



Inverted Position

When the arm is inverted, a greater portion of the table surface is available as workspace, but joint 2 and 3 limits must be considered. A base offset must be defined. See the `base()` command (RAPL-3). For more information, refer to the tables and drawings on page 4 (Range of Motion) and page 6 (Reach).



Unpacking the Arm

You need:

- Utility knife
- $\frac{5}{16}$ hex key

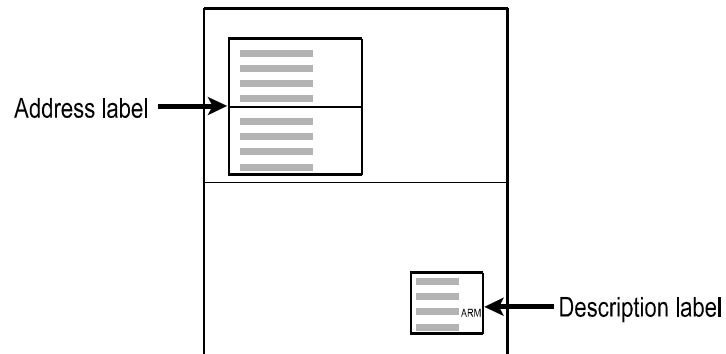
- Two or three persons

As you unpack the arm, keep *all* packaging materials.

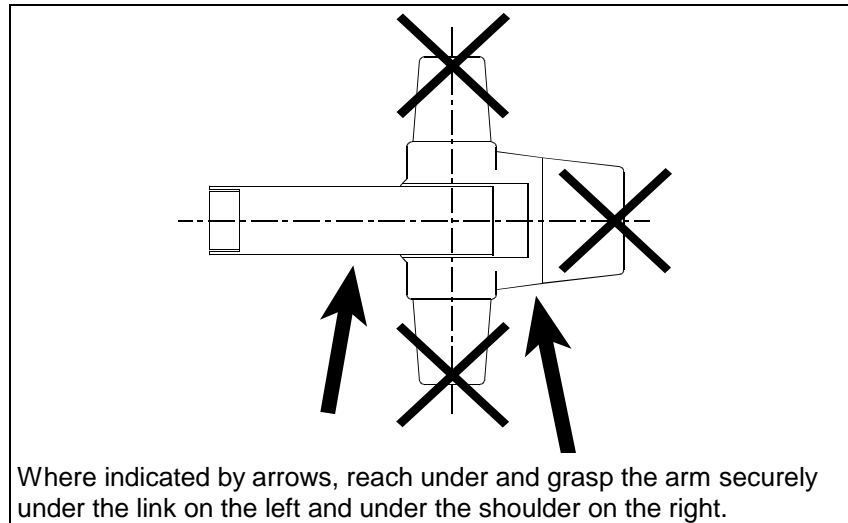
To avoid damaging the arm or the shipping foam, remove the arm from the shipping container as follows:

Getting Ready

1. Position the shipping container on the floor with shipping labels facing up. Position the container so that, when facing the container, the address label is at your far left and the description label is at the near right corner.



2. Slit open the tape on the top of the box, and open the flaps.
3. Remove the page with the serial numbers of the arm and the controller and place it in the front of this arm user guide for safe-keeping and future reference.
4. Remove the top foam cushion. Keep the anti-static plastic on the arm.
5. Place your left hand under the upper link of the arm (which is near the left side of the box), and place your right hand under the shoulder joint (which is close

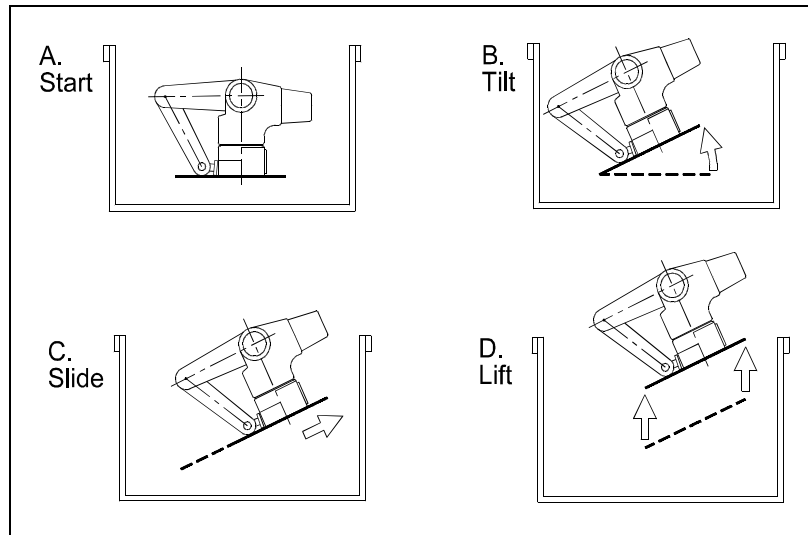


to the right side of the box).

Note: Do not grasp under the rear or side motor covers.



Warning! *Lift safely to prevent injury. The robot arm weighs approx. 37 lb. [17 kg].*



6. Tilt up the arm's back (on your right side). With the back higher, slide the arm out to your right, and then lift it up. Lifting the arm straight up from the bottom of the box is not possible, and will cause the shipping platform on the bottom of the arm to damage the foam packaging.
7. Place the robot arm on a level surface. The bolts extending below the shipping platform make the underside uneven.
8. Remove the anti-static plastic.

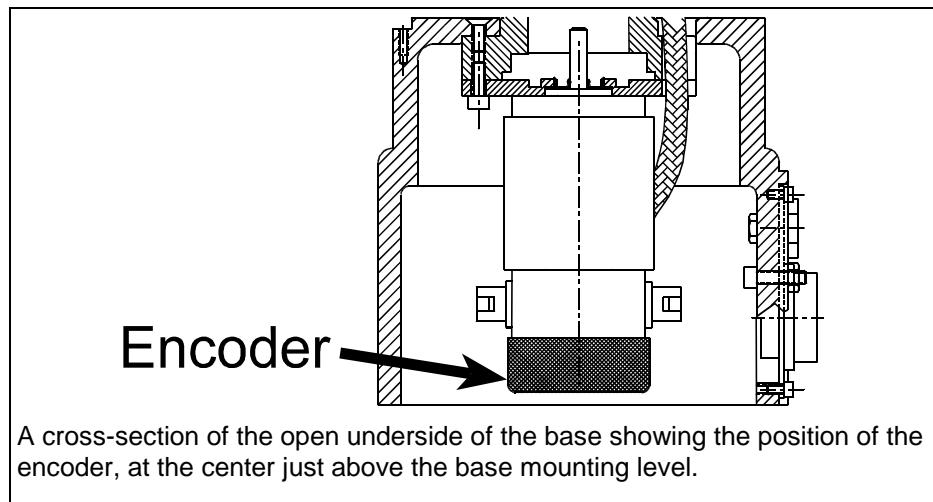
Removing the Wooden Shipping Platform

The encoder located at the base of the arm is a sensitive electronic component. When the arm is removed from the shipping platform, the encoder is exposed.

The encoder is black, metal or plastic covered, approximately two inches [50 mm] in diameter, and recessed approximately $\frac{3}{16}$ inches [4 mm] from the mounting surface.



Warning! Carefully remove the shipping platform. The encoder is exposed at the center of the open underside of the base. Do not damage the encoder when setting down the arm.



Before you begin:

- Clear any debris from the surface where you will place the base.
- 1. Using a $\frac{5}{16}$ hex key, unscrew the socket head cap screws fastening the base to the wooden shipping platform.
- 2. Remove the shipping platform. The encoder is now exposed on the open underside of the base.
- 3. Leave the white packing foam between the wrist and the base until the arm is completely installed.

Storing the Packaging Materials

Keep all packaging materials in case you need to ship the arm in the future. After installation, remove the white packing foam between the wrist and the base, and store it with the other packaging materials.

Preparing the Mounting Platform

The arm should be firmly mounted on a supporting platform rigid enough to support the arm and withstand repulsion forces during acceleration and deceleration.

There are two methods of preparing a mounting platform:

- By fastening a metal plate to your supporting structure (bench, bracket, etc.) and mounting the arm on that plate.
- By fastening the arm directly on a supporting structure.

Tip: Use dowel pins to align the robot in cases where the arm is regularly mounted and dismounted and precise relocation is necessary. Dowel pins are also useful during installation after repair.

You need:

- Machine tools to drill, tap, and ream.

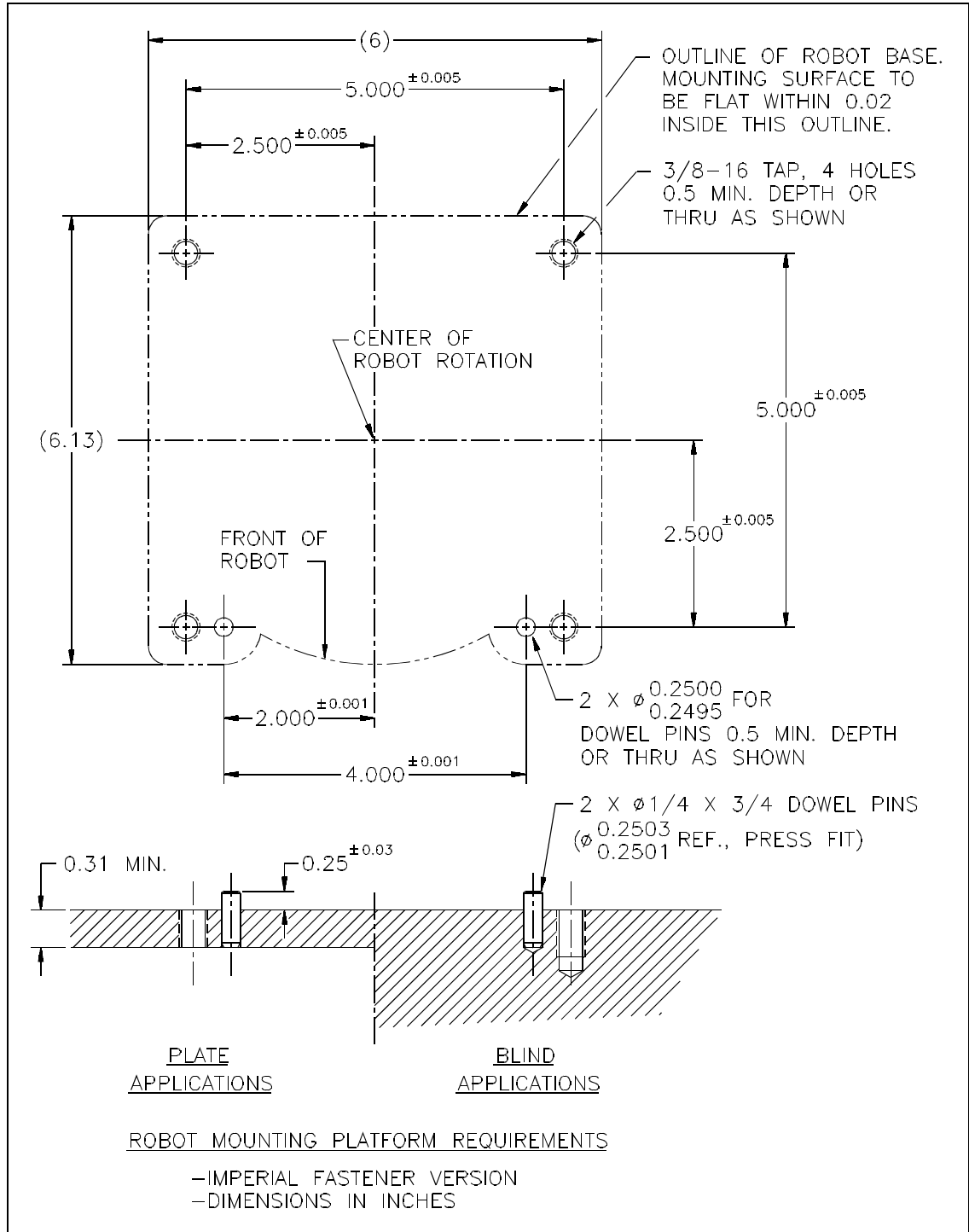
Before you begin:

- Ensure that the supporting structure (bench, bracket, etc.) is firmly fastened to the floor to prevent movement.
- If you are preparing a metal plate, the metal should have a minimum yield strength of 30 Ksi [210 MPa].

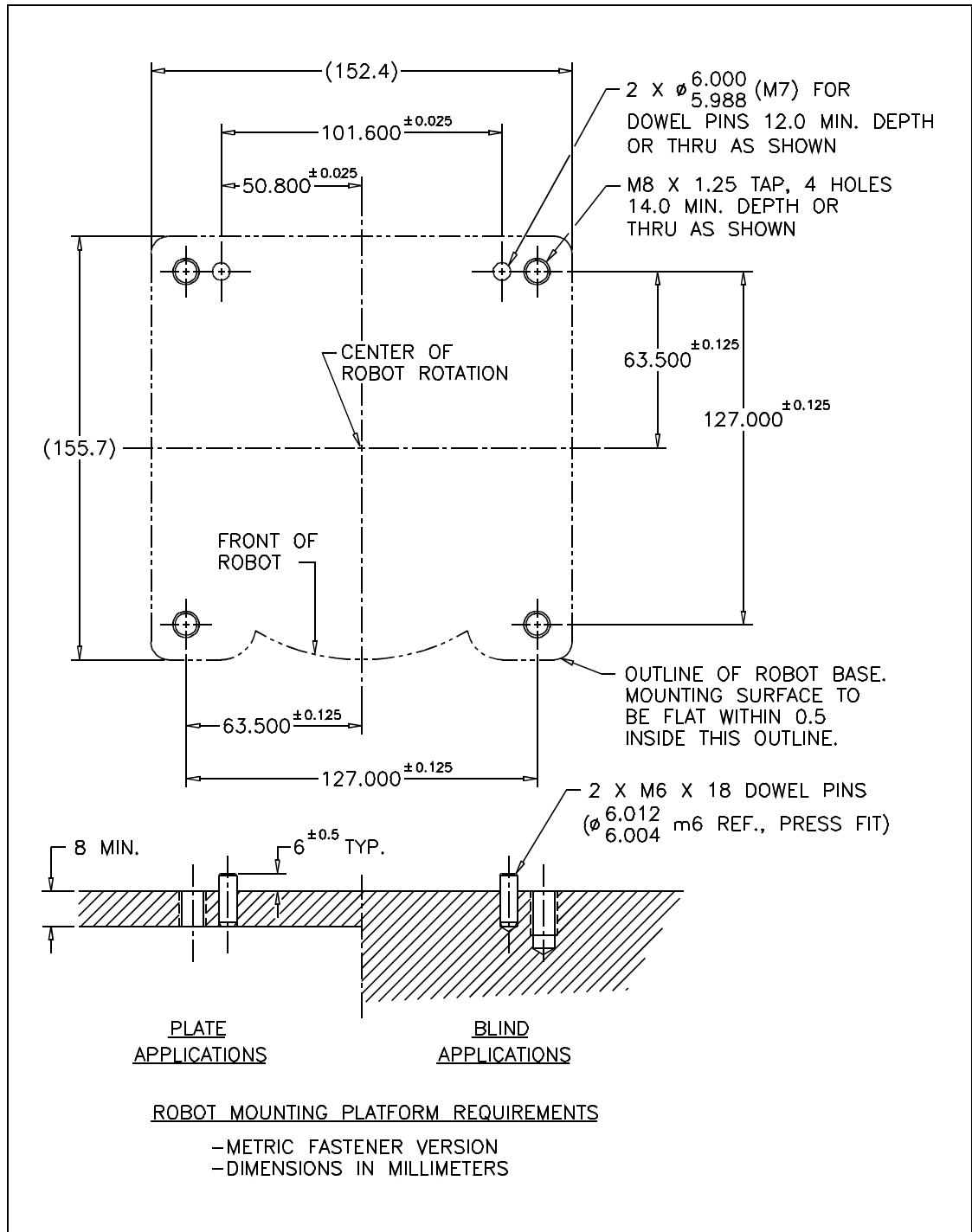
Note: The locations for the metric and imperial dowel pins are different, as shown in the drawings on the next page.

1. Use the dimensions shown in the drawings on the next pages to prepare a mounting platform.
2. Drill and tap four holes for the threaded fasteners:
 - Imperial: $\frac{3}{8}$ - 16 thread
 - Metric: M8 x 1.25 thread
3. If you require dowel pins, drill and ream two holes for the dowel pins:
 - Imperial: $\frac{1}{4}$ inch diameter
 - Metric: 6 mm diameter

4. If you prepared a plate, firmly fasten the plate to your bench, bracket, or similar supporting structure.



English (Imperial) units



Metric units

Mounting the Arm on the Platform

You need:

- Imperial: $\frac{5}{16}$ in. hex key
- Metric: 6 mm hex key

Before you begin:

- Ensure that the mounting platform is clear of any debris. An electronic component is exposed at the open underside of the base.
1. Lift the arm onto the mounting platform.
 2. Fasten the arm to the platform with the following fasteners. A mounting kit composed of these fasteners, imperial or metric, is available from CRS.

Imperial:

- Quantity 2, $\frac{3}{8}$ - 16 UNC x 2.00 inch long, stainless steel 18-8, hex socket cap screw
- Quantity 2, $\frac{3}{8}$ - 16 UNC x 3.50 inch long, stainless steel 18-8, hex socket cap screw
- Quantity 2, 0.2503/0.2501 diameter x 0.75 inch long, hardened steel, precision ground dowel pin

Metric:

- Quantity 2, M8 x 1.25 x 55 mm long, stainless steel 18-8 (A2), hex socket cap screw
- Quantity 2, M8 x 1.25 x 90 mm long, stainless steel 18-8 (A2), hex socket cap screw
- Quantity 4, 8 mm, stainless steel 18-8 (A2), spring lockwasher to DIN 127 or British Standard Type B
- Quantity 2, 6 mm diameter (M6 limits) x 18 mm long, hardened steel, precision ground dowel pins

Grounding the Arm

For proper operation of the robot, the arm and controller must be grounded. Ideally, the grounding points should be equipotential.



Warning! Improper grounding can result in memory corruption, loss of arm position, and unreliable operation in extreme cases.

Attaching the Grounding Wire

The robot base has a grounding stud which is used to drain any electrostatic buildup on the arm.

You need:

- Small adjustable wrench ($\frac{3}{8}$ inch or 9.5 mm)

- Electrical wire, minimum #12 gauge, from arm to grounding point.

Procedure:

1. Connect the wire to the grounding stud with the nut. The stud is located on the left side of the rear of the robot arm base, beside the umbilical cable connectors.
2. Connect the wire to an industrial grounding rod. If a grounding rod is not available, use a utility ground.

Connecting the Umbilical Cables

Two cables connect the robot arm to the controller: the feedback (or signal) cable with the 57 pin connector at each end, and the motor power cable with the 24 socket connector at the controller end. Each cable has one or two braided wire grounding straps at one end.

You need:

- Small Phillips(+) screwdriver

Before you begin:

- Ensure that the location for the cables is protected, and does not leave the cables exposed to damage.
 - If the controller is not yet installed, only connect the cables to the arm.
 - If the controller is installed, ensure that the controller is shut down and the controller's main power switch is OFF.
1. For each cable, connect the end with the grounding strap to the controller. This end is labeled "controller end".
 - a. When making a connection, ensure that the connector keys and keyways are properly aligned. If they are not, you may damage the connector.
 - b. Carefully turn the locking ring clockwise to draw the connectors together.
 - The motor power cable rotates about 360°.
 - The feedback cable rotates about 270°.
 - Stop turning when you feel it click, indicating that the connector is correctly locked in place.

Note: When turning the feedback cable (with the 57-pin connector), the last 10 degrees of rotation may require more force, as you compress the O-ring in the connector.



Warning! Use only hand pressure to secure plastic connectors. Using greater pressure with tools can damage the connectors.



Warning! Do not attempt to use a cable with a damaged connector.

2. Route all umbilicals, AC, I/O, and teach pendant cables away from high voltage sources such as: AC lines feeding other devices, AC or DC motors, heat, moving equipment, conveyors, etc.

3. Secure the cable grounding strap to the grounding point beside the connector, with the grounding screw, using a Phillips(+) screwdriver.



Warning! Secure the cable grounding strap to the grounding point. Improper cable grounding can subject the encoder signals to external noise and result in the loss of arm position.

4. Connect the other end of each cable to the base of the robot arm. There is no grounding strap or grounding screw at the arm end.
5. Check all four connections to ensure that they are secure.

Disconnecting the Umbilical Cables

If you need to disconnect the umbilicals, for example, for service, follow this procedure.

Before you begin:

- Ensure the controller is shut down and the main power switch is OFF.



Warning! Turn off power. Disconnecting the 57 pin feedback cable, while the other cable is connected and power is on, can cause incomplete control of the arm or cause the arm to run out of control.

1. At the controller, disconnect the grounding strap from the grounding point on the rear panel of the controller.
 - a. Turn the locking ring counter-clockwise to release the connector.
 - b. Pull the cable connector straight out from the controller connector.
2. At the arm, turn the locking ring counter-clockwise to release the connector.
 - a. Pull the cable connector straight out from the arm connector.

Next Steps

If you have not yet installed the controller, proceed to the C500C Controller User Guide, Installation chapter, and install the controller.

If you have installed the arm and the controller, proceed to the next chapter, Commissioning the Arm, to test the functionality of your system and ensure proper operation of the arm.

CHAPTER 5

Commissioning

Commissioning is a set of procedures for starting up the robot system and testing it to ensure that it is functioning properly.

Before commissioning, you must finish installing the arm and the controller.

Commissioning involves five procedures that must be performed in sequence:

1. Verify Installation
2. Check Encoder Feedback
3. Check All E-stops
4. Move Out of the Shipping Position
5. Check the Live-man Switch

Check the Installation of Arm and Controller

To check for proper functioning of the arm and to move the arm out of the shipping position, the arm and controller components must be installed and ready to operate.

Ensure that you have:

- Mounted and securely fastened the arm.
- Mounted the controller.
- Grounded the arm.
- Connected the umbilical cables and protected them from damage.
- Installed, or verified, the fuses and voltage selector in the controller.
- Verified the ground for the controller.
- Complied with the power requirements.

Check the Installation of Other Components

To check for proper functioning of the arm and to move the arm out of the shipping position other components must be installed and operating.

To commission, you need the following system tools.

Procedure	Required or Preferred Tool	Alternative Tool
Check Encoder Feedback	terminal	—
Check E-Stops	—	—
Move Out of Shipping Position	teach pendant	terminal
Check Live-man Switch	teach pendant	—

Terminal

CROS-500C

To use a terminal from a computer, ensure that you have:

- Connected a straight-through cable (not a null modem cable) from a serial i/o port of the computer to the front panel console port of the controller.
- Installed terminal emulator software, such as, Robcomm3 on the computer; started the software, and opened the terminal window.
- Powered up the controller.

CROSnt

Systems with CROSnt can, but do not have to, use the application shell of CROSnt. To use the application shell of CROSnt, ensure that you have:

- Connected the SimSockD cable from a serial i/o port of the computer to the teach pendant port of the controller.

- Installed CROSnt on the computer, started CROSnt, and have the CROSnt Command Prompt window active.
- Powered up the controller.
- Have communication over the SimSockD connection. (Have `\sbin\simsockd` in `-send` mode running on CROSnt and `\sbin\simsockd` in `-rcv` mode running on CROS-500 with compatible configuration from each `simsockd.cfg` file.)

Teach Pendant

To use the teach pendant, ensure that you have:

- Connected the teach pendant to its connector at the upper left corner of the front panel of the controller. If the over-ride plug is in that connector, remove the plug first.
- Powered up the controller.

Systems with CROSnt do not normally use the teach pendant. If you have a system with CROSnt, and want to use the teach pendant, ensure that you:

- Disconnected the SimSockD cable from the teach pendant connection. Configured the teach pendant port (port 0 of CROS-500) to 19200 baud, using the system shell's `siocfg` command.
- Connected the teach pendant to its connector on the front panel of the controller.
- Have the teach pendant process (`stpv3`) already running on CROS-500C or have started it by typing **pendant** at the C500C prompt.

Operation

Follow the Safety Operation Checks on page 23 before operating the arm.

Check Encoder Feedback

This procedure checks that the position signals from the arm are received by the controller.



Warning! Do not turn on arm power unless all robot axes demonstrate feedback.
Failure to verify feedback can result in the arm running away uncontrolled when arm power is applied.

Before you begin, ensure that you:

Have a terminal onto the controller. There are three different ways to do this, either:

- Have a terminal emulator on a computer or a simple terminal
- Have the Terminal window of Robcomm3 on a computer.
- If you have a system with CROSnt, have the command prompt window of CROSnt on a computer.

To check the encoder feedback:

1. Turn on your computer or terminal. Depending on the tool that you are using, start Robcomm3 and open the terminal window, start CROSnt, or start your terminal emulator.

2. Turn on the controller.
3. Start the application shell by typing **ash test**.
4. If the teach pendant is connected and obtains control, transfer control from the teach pendant to the terminal. At the teach pendant, press ESC until you reach the Terminate Pendant screen and then transfer control.
5. At the terminal's prompt (test>), type **w1** and press Enter. This command continuously displays the robot arm position as motor pulse counts.
6. With Arm Power OFF, by hand, gently push each axis in each direction of motion and observe the readout on the screen. The pulse count increments (increases) or decrements (decreases).
 - The axis should display positive and negative feedback when moved back and forth.
 - If the axis displays only positive or only negative feedback, re-check all umbilical connections to the robot.
7. Once you have verified feedback for all axes, press Ctrl + E.

You are now ready to check the functionality of the e-stops.

Check All E-Stops

This procedure checks each e-stop device to verify that it works.

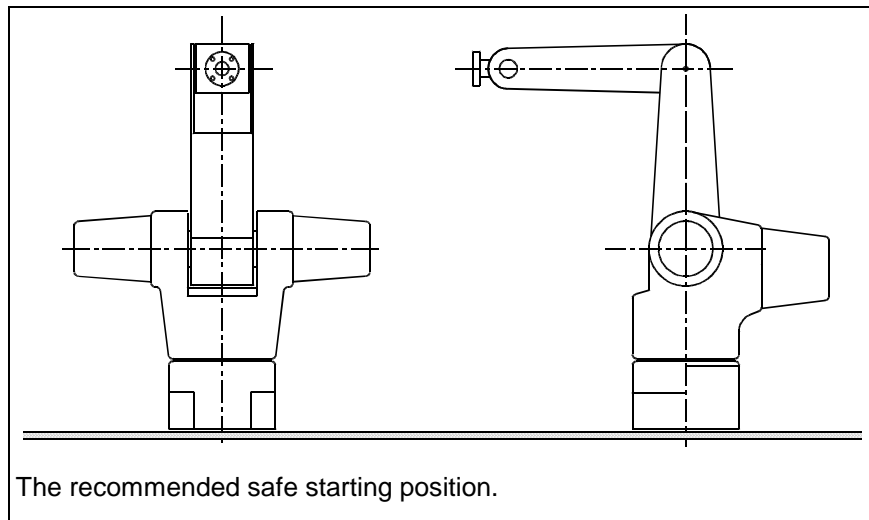
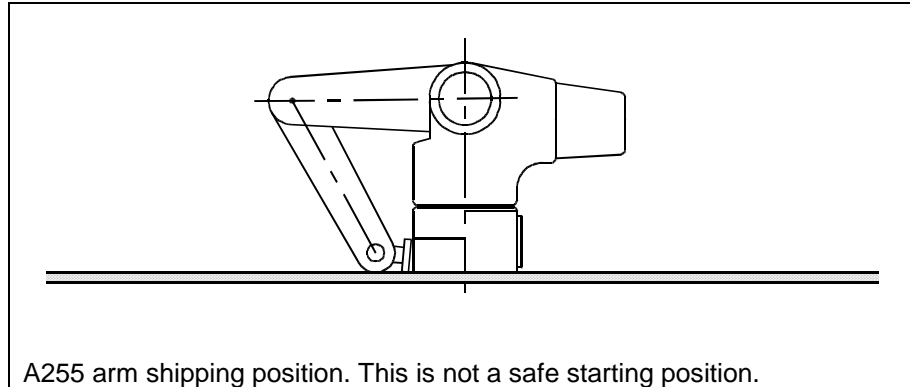
1. Ensure that the controller is powered on and displays "C500C CROS OK".
2. Re-set all the e-stops to complete the e-stop circuit. The e-stop buttons on the controller and on the teach pendant are re-set by twisting until they spring out.
3. One at a time, test each e-stop.
 - a. Turn on arm power at the arm power switch, located near the upper right corner of the front panel. You should hear a series of clicks from the arm as the brakes release. The LED in the arm power switch should be continuously lit, indicating that arm power is on.
 - b. Activate the e-stop device: strike the e-stop button, open the interlocked door, interrupt the light beam, step on the pressure-sensitive mat, etc.
 - c. When you activate the e-stop, you should hear a series of clicks from the arm as the brakes engage. The LED in the arm power switch should not be lit, indicating that arm power is off. Check the LED.
 - d. Re-set this e-stop.
 - e. Repeat steps a to d until all e-stops are checked.

Schedule Regular Checking of E-Stops

Continue to check e-stops and other safety measures throughout the operating life of the robot system. Establish a schedule of regular checks.

Move Out of the Shipping Position

The arm is shipped with the wrist positioned at the bottom of the base and the tool flange turned towards the base.



Once mounted, you can use the teach pendant or other tool to carefully move the arm out of the shipping position and into a safe starting position.

A safe starting position is any position where the arm links and tool flange are safely away from the mounting surface, base, cabling, and obstructions in the workcell. The following pose is the recommended safe starting position.

You can move out of the shipping position by using the teach pendant or the application shell. It is safer to use the teach pendant.

Using the Teach Pendant

To use the teach pendant, follow these steps.

Before you begin, ensure that you:

- Connected the teach pendant.
- Have the teach pendant (stp3) process running and have control at the teach pendant. If not, at the terminal prompt, type **pendant**.

To move out of the shipping position:

1. The teach pendant displays the Application screen with the application's name (test). Turn on arm power.

```
Application
test

1edit 2run
```

2. The bottom line of the screen indicates the selections. Press F1 (edit). This opens the Editing screen.

```
Application
test

1var          3motn
```

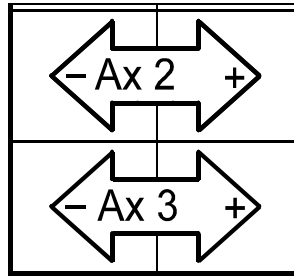
3. Press F3 (motion). This opens the Manual Motion screen. The upper right corner displays the arm power status, "ON". Since the robot is not homed, only joint mode is available. Do NOT home the robot.

```
Manual Menu
  1%    VEL  JOINT
NOT HOMED
1home   3motn
```

4. Squeeze the live-man switch.
 - Adequate pressure, constantly applied, permits arm operation.
 - No pressure, or excessive pressure, stops arm motion by shutting off arm power. To restore arm power, turn on arm power at the arm power switch.
5. As you squeeze the live-man switch, press the following axis keys to move each joint to a safe starting position. Move the joints until the arm links and tool flange are safely away from the mounting surface, base, cabling, and any elements in your workcell.
 - **Ax2+** to raise up the arm at the shoulder.
 - **Ax3+** to move out the outer link at the elbow.
 - **Ax4+** to raise up the wrist.

Note: Move each joint a little distance at a time to prevent robot damage. Notice that some axes remain stationary.

- When you are finished moving joints 2, 3, and 4 with the axis keys, the arm should be in a safe starting position, such as in the drawings on page 41.



Using the Terminal

To use the terminal, follow these steps.

Before you begin, ensure that you:

- Have a terminal running by having either:
 - A terminal emulator or the terminal window of Robcomm3 communicating through the front panel console port and having control of the robot at the terminal. (If not, at the teach pendant, press ESC repeatedly to transfer control), or
 - The Command Prompt window of CROSnt communicating through the SimSockD cable in the teach pendant's port.

To move out of the shipping position:

- Turn on arm power.
- Set the speed to a very slow value by typing


```
speed 1
```



Warning! Be prepared to strike an e-stop. When you use a command from the application shell, the robot attempts to move to the commanded position, without knowing if it is safe to do so. Use the proper joint number and distance value to avoid a collision.

- Move joint 2 by 10 degrees by typing


```
joint 2, 10
```

 Repeat this several times.
- Move joint 3 by 10 degrees by typing


```
joint 3, 10
```

 Repeat this. Continue moving the joints until the arm links and tool flange are safely away from the mounting surface, base, cabling, and any elements in your workcell.
- Move joint 4 by 10 degrees by typing


```
joint 4, 10
```

 Repeat this several times.
- When you are finished moving joints 2, 3, and 4 with the joint command, the arm should be in a safe starting position, such as in the drawings on page 41.

Check the Live-man Switch

This procedure checks the teach pendant live-man switch to verify that it works.

Note: You must hold the live-man switch with reasonable but not excessive force while you press an axis key for the duration of a robot move. Too little or too much force on the live-man switch breaks the e-stop circuit and removes arm power.

Before you begin, ensure that you:

- Have connected the teach pendant.
 - Have control at the teach pendant. If not,
 - At the ash prompt, type **pendant**
 - Have a motion screen at the teach pendant. If not,
 - At the teach pendant, press ESC until you return to the Application screen. Press F1 (edit), then press F3 (motion).
1. While holding the live-man switch and pressing an axis key during a robot move, release the live-man switch.
 - a. After releasing the live-man switch, you should hear a series of clicks as the arm brakes engage. At the same time, arm power is shut off. Check that the LED in the arm power switch is not lit.
 - b. Restore arm power by pressing the arm power switch on the front panel of the controller.
 2. While holding the live-man switch and pressing an axis key during a robot move, squeeze the live-man tightly.
 - a. After tightly squeezing the live-man switch, you should hear a series of clicks as the arm brakes engage. At the same time, arm power is shut off. Check that the LED in the arm power switch is not lit.
 - b. Restore arm power by pressing the arm power switch on the front panel of the controller.
 3. Without applying any pressure to the live-man switch, press an axis key. The arm should not move.

CHAPTER 6

Basic Operation

This chapter describes how to:

- Home the Arm
- Move the Arm Using the Teach Pendant Axis Keys
- Move the Arm Using Terminal-based Commands
- Move the Arm by Limping One Joint at a Time

The A255 is designed for stand-alone operation after homing. Stand-alone operation does not require operator intervention. RAPL-3 programs specially written for your particular application move the robot to predefined locations.

Homing the Arm

The A255 robot arm must be homed before you can teach locations or run any robot application.

Why Home the Arm

When power to the controller is off, the arm position data in the controller's memory is lost. As a result, whenever the controller is powered on, the controller does not know the position of the arm.

The "homing" procedure moves the arm to a mechanically determined position which is then retained in the controller memory. From the homing starting position, the homing procedure slowly moves each axis in sequence until the next zero pulse of its encoder is found. Afterward, during any motion, the encoders continually send position counts to the controller. Using these counts, the controller knows any position of the arm relative to the home position.

Homing Procedure

This manual describes homing the arm from the teach pendant and from the terminal. It does not describe homing the arm from a program or from the front panel's Home switch (which is disabled when shipped from the factory).

To home the arm, you must:

- 1) Move to the homing starting position.
- 2) Issue the home command.

Note: If you ordered a homing bracket and are using it to home the arm, follow the procedure in the Homing Bracket User Guide.

1) Move to the Homing Starting Position

Before you begin:

- Ensure that the arm's workcell is free of obstruction.

You can move to the homing starting position by using the teach pendant or the terminal. It is safer to use the teach pendant.

Using the Teach Pendant

To use the teach pendant, follow these steps.

Before you begin, ensure that you:

- Have connected the teach pendant.
- Have the teach pendant (stp3) process running and have control at the teach pendant. If not, at the terminal, type **pendant**.

To move to the homing starting position:

1. The teach pendant displays the Application screen with the application's name (test). Turn on arm power.

```
Application
test

1edit 2run
```

- The bottom line of the screen indicates the selections. Press F1 (edit). This opens the Editing screen.

```

Application
test

lvar          3motn

```

- Press F3 (motion). This opens the Manual Motion screen.

```

Manual Menu
  1%  VEL  JOINT

          3motn 4mode

```

- Squeeze the live-man switch.
 - Adequate pressure, constantly applied, permits arm operation.
 - No pressure, or excessive pressure, stops arm motion by shutting off arm power. To restore arm power, turn on arm power at the arm power switch.
- As you squeeze the live-man switch, press the axis keys (Ax1+, Ax1-, Ax2+, Ax2-, etc.) to move each joint. Position the joint so that its pointer sits within its starting zone. The location of pointer and zone labels are shown in the diagram.
- When you are finished positioning the joints, the arm should be in the homing starting position. The arm is now ready to be homed.

Using the terminal

To use the terminal, follow these steps.

Before you begin, ensure that you:

- Have a terminal running by having either:
 - A terminal emulator or the terminal window of Robcomm3 communicating through the front panel console port and having control of the robot. (If not, at the teach pendant, press ESC repeatedly to transfer control), or
 - The Command Prompt window of CROSnt communicating through the SimSockD cable in the teach pendant's port.

To move to the homing starting position:

- Turn on arm power.
- Set the speed to a slow value by entering


```
speed 10
```



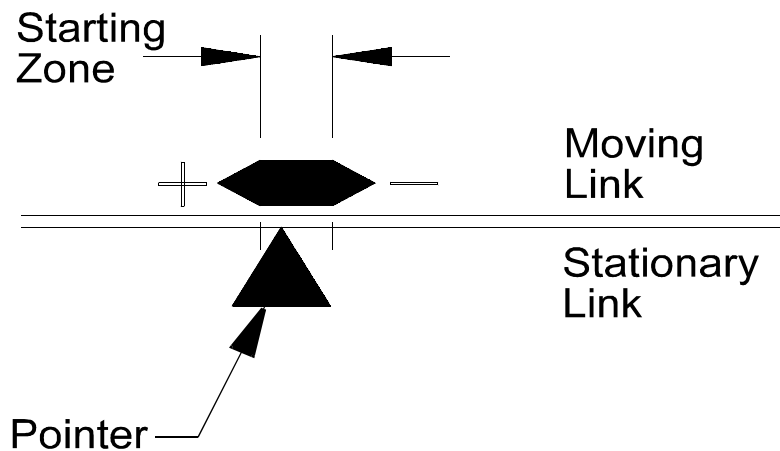
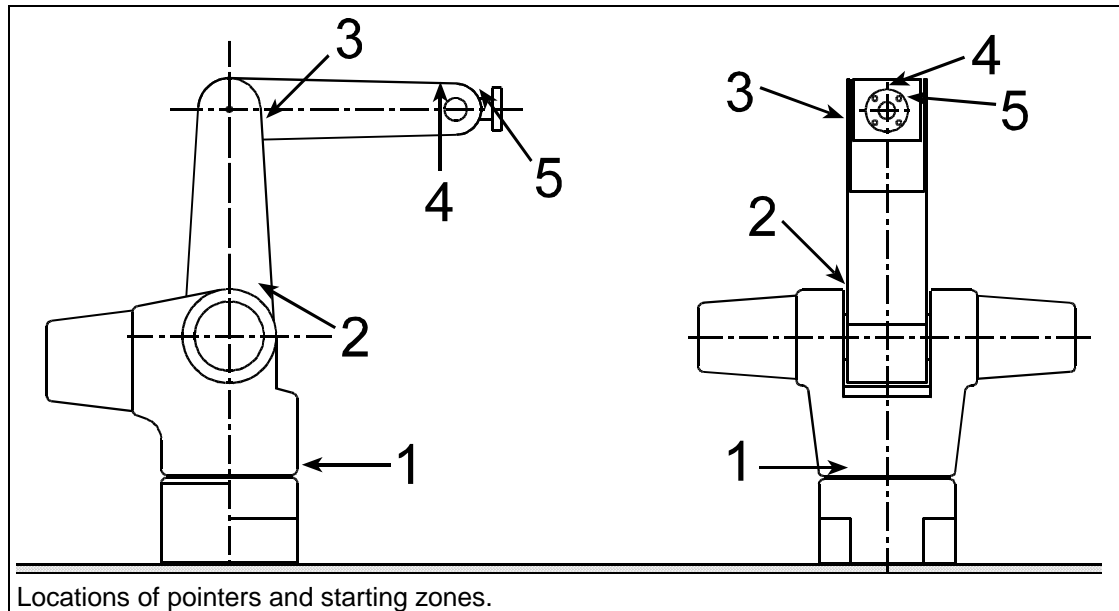
Warning! Be prepared to strike an e-stop. When you use a command from the application shell, the robot attempts to move to the commanded position, without knowing if it is safe to do so. Use the proper joint number and distance value to avoid a collision.

- Move joints with the joint command. For example, enter


```
joint 2, 10
joint 1, -5
```

For positive and negative directions of travel, examine the starting zone label on each joint as shown in the diagrams below.

4. Move each joint until its pointer sits within its starting zone. The location of pointer and zone labels are shown in the diagram.
5. When you are finished positioning the joints, the arm should be in the homing starting position. The arm is now ready to be homed.



In the starting position, each pointer is in its starting zone. The positive and negative signs corresponds to the joint's directions of rotation.

2) Issue the Home Command

Once the arm is in the starting position, you can home the arm.

You can home the arm by using the teach pendant or the terminal. It is safer to use the teach pendant. Systems with CROSnt may have to use the terminal.

Using the Teach Pendant

To use the teach pendant, follow these steps.

Before you begin, ensure that you:

- Have connected the teach pendant.
- Have the teach pendant (stp3) process running and have control at the teach pendant. If not, at the terminal, type **pendant**.

To home the arm:

1. From the Main Menu, press F2 for motion.
2. From the Homing Menu screen, press F1 or the HOME key on the teach pendant's keypad. A confirmation screen displays.

```
Confirm
start robot homing
procedure?
lyes  2no
```

3. Press the live-man switch to enable arm motion.
4. Press F1 (yes) to confirm and start the homing sequence. Maintain light pressure on the live-man switch for the duration of the homing sequence. Each joint rotates individually in sequence from joint 1 to joint 5. When arm motion stops, the homing sequence is complete.
5. Release the live-man switch. Check that the teach pendant LCD displays the message "Homed" and that the amber LED of the Home switch on the front panel of the controller is on.

```
Manual  Homed  ON

1motn 2mode 3loc 4here
```

6. Press the READY key on the keypad. Maintain light pressure on the live-man switch for the duration of the READY sequence. When the arm stops, it is in the READY position.
7. Visually inspect each homing marker. The pointer should be toward the correct end of the zone for that joint as shown in the previous drawing.
 - If any pointer is outside the range of the homing mark, repeat the procedure, making sure that the pointer starts within the starting zone, but away from the end where the pointer finishes.
 - If the arm did not home correctly, repeat the procedure.
 - If the arm refuses to correctly home for three consecutive attempts, contact you distributor or CRS Robotics.

Using the Terminal

To use the terminal, follow these steps.

Before you begin, ensure that you:

- Have a terminal running by having either:
 - A terminal emulator or the terminal window of Robcomm3 communicating through the front panel console port and having control of the robot at the

application shell. (If not, at the teach pendant, press ESC repeatedly to transfer control), or

—The Command Prompt window of CROSt communicating through the SimSockD cable in the teach pendant's port.

To home the arm:

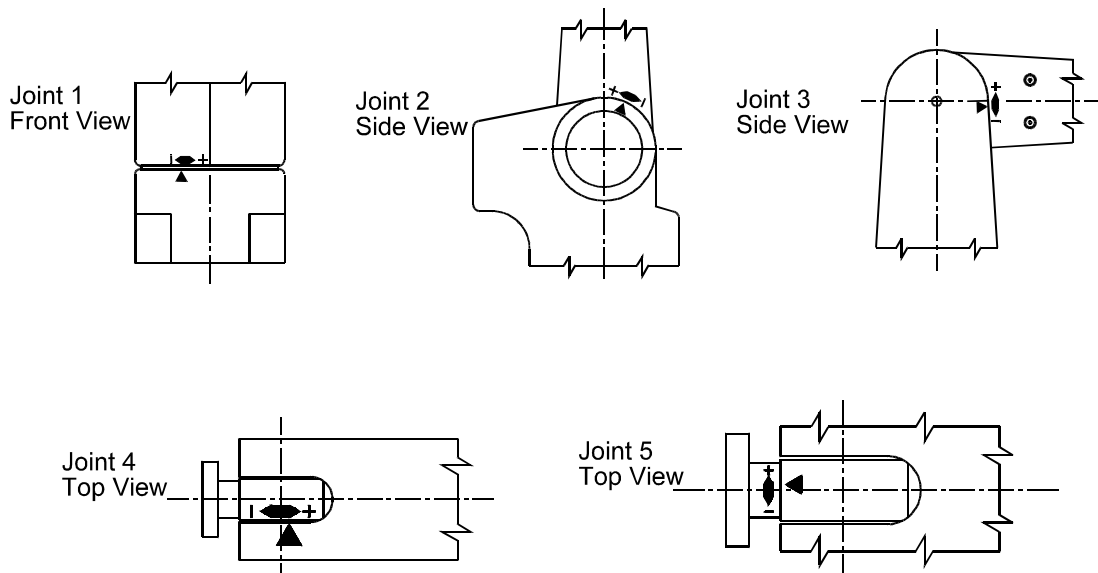


Warning! Be prepared to strike an e-stop. When you use a command from the application shell, the robot attempts to move to the commanded position, without knowing if it is safe to do so. Monitor the motion to avoid a collision.

1. Type `home`
press Enter, and at the prompt, type Y (yes). Each joint rotates individually in sequence from joint 1 to 5 and the amber LED of the Home switch flashes. When arm motion stops and the LED is lit continuously, the homing sequence is complete.
2. Type `ready`
and press Enter. The arm moves to the ready position.
3. Visually inspect the arm. The link between joints 1 and 2 should be vertical and the link between joints 3 and 4 should be horizontal. Visually inspect each homing marker. The pointer should be toward the correct end of the zone for that joint as shown in the previous drawing.
 - If any pointer is outside the range of the homing mark, repeat the procedure, making sure that the pointer starts within the starting zone, but away from the end where the pointer finishes.
 - If the arm did not home correctly, repeat the procedure.
 - If joint 1, 2, or 3 is repeatedly off by several degrees, move the arm to the ready position and move the joint by 1000 motor pulses in the opposite direction from where it was outside the homing mark using a command such as


```
motor +1000
motor -1000
```

 and then home the arm. If this solves the problem, you may need to adjust your calibration. Contact your distributor or CRS Robotics.



- If the arm refuses to home correctly for three consecutive attempts, contact your distributor or CRS Robotics.

Moving with the Teach Pendant

It is safer to use the teach pendant instead of terminal commands, since motion stops as soon as a pendant key is released, for most pendant keys. However, systems on CROSnt that do not have a teach pendant have to use terminal commands.

Motion from the teach pendant uses the axis keys. Each axis has two keys, one for motion in the positive direction, and one for motion in the negative direction. The key's function depends on the mode selected.

Motion Options

There are a number of modes and types of motion. Not all combinations of mode and type are possible.

Modes

A mode corresponds to a coordinate system. F4 toggles mode options.

Mode	Resulting Motion	Coordinates
joint	rotates around a joint axis	Axis 1, 2, 3, 4, 5 (6, 7, 8, if track or carousels)
world	moves along or around world cartesian axes	X, Y, Z, Zrotation, Yrotation, Xrotation
tool	moves along or around tool axes	X, Y, Z, Yaw, Pitch, Roll
cylindrical	moves along or around cylindrical axes	θ , R, Z, Zrotation, perpendicular-to-R-and-Zrotation, Rrotation

Types

There are four types of motion. F3 toggles type options.

Type	Resulting Motion	Usable with Modes
velocity	continuous motion while key is pressed	Joint, World, Tool, Cylindrical
jog	incremental motion for each pressing	Joint, World
align	aligns to an axis while key is pressed	World
limp	limps (and falls) when pressed	Joint

Speed for velocity type and increment distance for jog type are set using the SPEED UP and SPEED DOWN keys.

Limp is described in a later section.

Directions

Positive and negative directions, along or around an axis, are shown in RAPL-3's *Application Development Guide*.

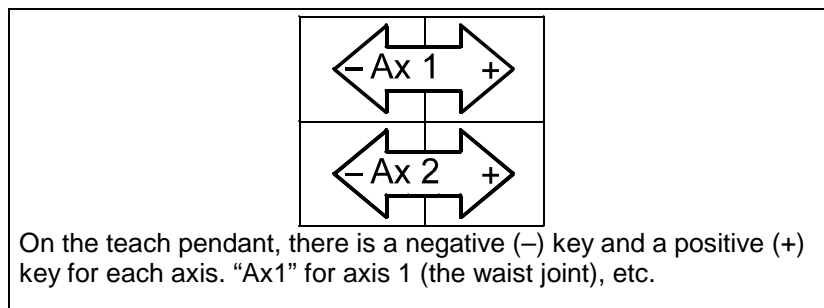
Joint mode directions are shown in the drawing on page 1 and described in the table below.

Joint	Axis	Key	Negative –	Positive +
Waist	1	Ax1	Rotates arm (right-hand rule, vertical axis upward)	Rotates arm
Shoulder	2	Ax2	Lowers arm	Raises arm
Elbow	3	Ax3	Lowers outer link	Raises outer link
Wrist Pitch	4	Ax4	Pitches wrist down	Pitches wrist up
Tool roll	5	Ax5	Rolls tool (right-hand rule, axis outward)	Rolls tool

Moving

To move using the teach pendant:

1. Repeatedly press F4 to cycle through the motion mode options, stopping at the type you want.
2. Repeatedly press F3 to cycle through the motion type options, stopping at the type you want.
3. If you selected velocity or jog type, select a speed for velocity or increment for jog, by pressing the SPEED UP or SPEED DOWN key.
4. Squeeze the live-man switch.
 - Adequate pressure, constantly applied, permits arm operation.
 - No pressure, or excessive pressure, stops arm motion by shutting off arm power. To restore arm power, turn on arm power at the arm power switch.
5. Press an axis key. For velocity and align types, hold down the key.



Moving with Terminal Commands

It is safer to use the teach pendant, since motion stops as soon as a pendant key is released. Systems on CROSnt that do not have a teach pendant, have to use terminal commands.

Before you begin, ensure that you:

- Have a terminal running by having either:

—A terminal emulator or the terminal window of Robcomm3 communicating through the front panel console port and having control of the robot at the application shell. (If not, at the teach pendant, press ESC repeatedly to transfer control), or

- —The Command Prompt window of CROSnt communicating through the SimSockD cable in the teach pendant's port. Have a terminal running by having either:

To move:

1. Turn on arm power.
2. Set the speed to a slow value such as
`speed 10`



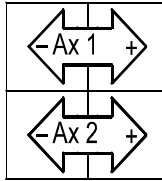
Warning! Be prepared to strike an e-stop. When you use a command from the terminal, the robot attempts to move to the commanded position, without knowing if it is safe to do so. Use the proper joint number and distance value to avoid a collision.

3. Enter motion commands with parameters.

Command	Example	Motion
joint	joint 1, 22.5 joint 3, -45	rotates a joint by degrees
wx, wxs wy, wys wz, wzs zrot, zrots yrot, yrots xrot, xrots	wx 7.5 wzs 2.5 xrots -45	moves along or rotates around a world cartesian axis by current linear units (in. or mm.) or degrees
tx, txs ty, tys tz, tzs yaw, yaws pitch, pitches roll, rolls	tx 3.5 tzs 1.5 pitch -45	moves along or rotates around a tool axis by current linear units (in. or mm.) or degrees
align	align X align -Z	aligns to a world axis
motor	motor 2, 1000 motor 3, 25	rotates a motor by pulses

Further details of these commands are in RAPL-3's *Application Development Guide*.

Moving by Limping One Joint at a Time



In limp mode, a positive (+) key limps a joint and the negative (-) axis key unlimps the joint. “Ax 1” for axis 1 (the waist joint), “Ax2” for axis 2 (the shoulder joint), etc.

“Limping” a joint disengages the servo control to the motor and makes the joint go limp. After you limp the joint, you can position the link by hand. After you position the link, you can “unlimp” the joint, which re-establishes servo control and holds the link in its new position.

Before you begin:

- Ensure that the teach pendant is connected to the controller.
 - You will be working within the robot’s workspace, observe the safety and operation checks on page 24 “Working Within the Robot’s Workspace”.
1. Power ON at the main controller switch. The teach pendant displays the Main Menu screen.

```
001:Main Menu      ON
      Not Homed
1manu  2edit  3run
```

2. Turn ON arm power. The teach pendant displays the status message “ON”.
3. Press F1 (Manual) to change to the Manual screen.

```
005:Manual  NOTHmd  ON
      VEL  JOINT
      10%
1motn  2mode  3loc  4here
```

4. Press F1 repeatedly until LIMP displays.

```
005:Manual  NOTHmd  ON
      LIMP JOINT
1motn  2mode  3loc  4here
```

5. Press the joint’s positive (+) axis key.
 - For joint 1, 4, or 5, the joint limps immediately. If you press the axis key for either joint 4 or 5, both joints limp together at the same time.
 - For joint 2, or 3, you must confirm limping.
 - a. Check that the link is supported.



Warning! Support the link. Limping will release the joint. The link will fall due to gravity. Failure to support the link can result in damage to the arm, tooling, or work pieces.

- b. Press F2 for Yes. The joint limps.

039:Confirm: ON	039:Confirm: ON
Limp robot axis?	Limp robot axis?
Axis 2: Shoulder?	Axis 3: Elbow?
1no 2yes	1no 2yes



Warning! Be careful when entering the robot arm workspace. Even though the joint is limp, arm power is ON. Hold the arm near the wrist to move the joint by hand.



Caution! Do not move the joint too forcefully. The harmonic drive is back-drivable. This allows you to rotate the joints and have that motion transferred back through the drives to the motors. Excessive force, when positioning the arm by hand, may overstress the drives.

6. Press the joint's negative (-) axis key. The servo engages and holds the joint in position.

CHAPTER 7

Gripper Installation

This chapter describes how to install the gripper.

To install a gripper, the arm must be moved out of the shipping position and the tool flange made accessible. The gripper attaches onto the arm's tool flange.

If you are installing a homing bracket (for custom homing of the arm), you will need to install a tool adapter plate with $\frac{1}{2}$ inch hex socket cap screws, see the Homing Bracket User Guide.

Installing the Gripper

Installing a gripper requires the sequence of two procedures:

- 1) Limp the wrist
- 2) Attach the gripper to the wrist tool flange

You need:

- $\frac{5}{32}$ inch ball-head hex key

Before you begin:

- For best access to the tool flange, use the teach pendant or issue joint commands to place the arm in the Ready position and rotate joint 1 so the flange is towards you.
- Move the arm by using the axis keys or by limping as described on pages 51 forward.
- When installing the gripper, you must enter the robot arm workspace, refer to and follow the operation and safety instructions on page 24 “Working Within the Robot’s Workspace”.



Caution! Do not move the joints by hand when the brakes are engaged (when arm power is off) or when under servo control. This may damage some components.



Caution! When moving while limp, do not move the joints too forcefully. Excessive force may over-stress the drives.



Warning! Ensure the controller does not move the arm. Ensure that commands are not entered at the teach pendant while you attach a gripper. Be prepared to activate an e-stop.

1) Limp the Wrist

When joints 4 and 5 are limped you can rotate and pitch the wrist and access the cap screw holes at the rear of the tool flange.



Warning! Ensure that arm power is OFF since you are entering the arm’s workspace. Refer to and follow the operation and safety instructions on page 24 “Working Within the Robot’s Workspace”.

1. With the teach pendant attached, turn ON power to both the arm and the controller.
2. At the teach pendant Main Menu, press F1 (Manual). On the following screen, press F1 (Motion) until LIMP appears.
3. Press Ax4+ (positive) and then Ax5+, the joints limp.

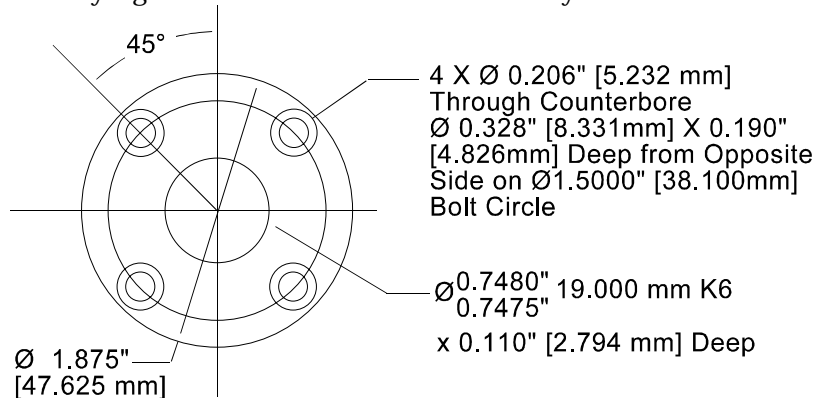
Note: Do not limp all the joints, this causes the arm to fall at joints 2 and 3 and moves the tool flange to an inaccessible position.

2) Attach the Gripper

1. Align the tool flange homing pointer anywhere near its homing zone, and position the gripper on the flange in your preferred position, either vertical or horizontal.
2. Position the gripper on the robot tool flange. Avoid straining the gripper cable, connector, hoses, and fittings.
3. From the rear of the robot tool flange, insert and hand-tighten the four #10-24 x $\frac{3}{8}$ inch socket head cap screws.

Dimensions of the tool flange for the gripper.

4. Firmly tighten the screws with the hex key.



Connecting the Cable or Hose

The electrical connector is on the left side of the arm.

The pneumatic connector is located on the right side of the arm, approximately $\frac{1}{2}$ in. [60 mm] behind the wrist axis.

Servo Gripper

To connect the servo gripper cable:

1. Line up the white dot marker on the gripper cable connector with the white dot marker on the arm connector.
2. Push the cable connector onto the arm connector until it clicks. The outer collar is spring loaded.

To disconnect the servo gripper:

1. Pull back the spring loaded outer collar.
2. Pull out the cable connector from the arm connector.

Note: Striking an e-stop does not remove power to the servo gripper. As a safety feature, motor power to the gripper is maintained so the gripper does not release its load.

For information on: specifications, testing, operating, maintenance, troubleshooting, and repair, see the Servo Gripper User Guide.

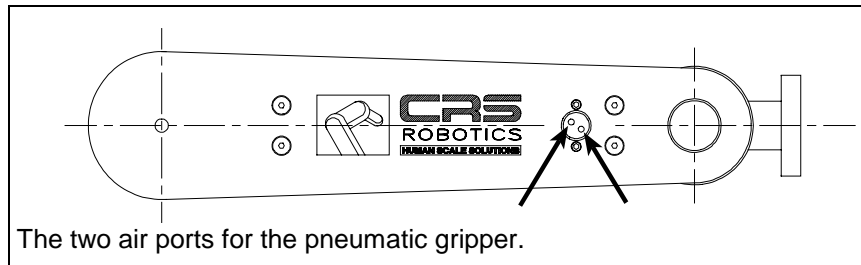
Pneumatic Gripper

The pneumatic gripper is supplied with two $\frac{1}{16}$ inch [1.6 mm] barbed fittings.

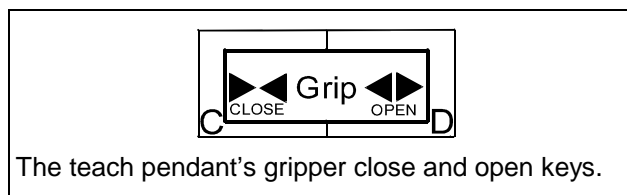


Caution! Design your pneumatic tooling so that, during a power failure, safe gripping is maintained.

To connect the pneumatic gripper:



1. Screw a barbed fitting into each of the two ports of the pneumatic connector on the right side of the arm.
2. At the arm end of the gripper's air hose, separate the two air hoses for approximately 1 in. [25 mm] of length.
3. Push one hose onto one barbed fitting and the other hose onto the other fitting.
4. Connect the workshop air supply to the $\frac{1}{8}$ NPT air port at the rear of the robot base. Use only dry, clean, filtered, non-lubricated air at a maximum of 100 psi [6.89 kPa] [6.89 Bar].
5. Test the operation of the gripper.
 - At the teach pendant, press the **GRIP** key. Press **GRIP CLOSE** and press **GRIP OPEN**.
 - Check that **OPEN** opens the gripper and **CLOSE** closes the gripper.
 - If the operation of the gripper is reversed (OPEN closes the gripper and CLOSE opens the gripper), reverse the connections of the two hoses with the two barbed fittings.



Air Ports

There are two air ports on the side of the arm.

- Pressing the **OPEN** key or issuing the open command initiates air flow from the port closest to the wrist joint.
- Pressing the **CLOSE** key or issuing the close command initiates air flow from the port furthest from the wrist joint.

Enabling the Gripper

To enable the gripper:

Use the `/diag/setup` command to choose the type of gripper (air, servo, or magnetic), refer to the RAPL-3 Language Reference Guide.

CHAPTER 8

Calibration

This chapter describes the circumstances and procedures for restoring factory calibration values or recalibrating the robot with new values.

You can:

- Reload factory calibration parameters when the calibration memory fails.
- Recalibrate the robot with new parameters when you add an extra axis, remove or replace a servo motor, encoder, or belt, etc.

Restoring Factory Calibration Values

The calibration values for your robot are unique. Reload factory calibration values if the calibration memory fails (resulting in checksum errors) when you attempt to home the arm.

You need:

- A computer with Robcomm3 software
- Your A255 Robot Arm distribution software disk or your own backup calibration disk if your system was previously recalibrated.

The distribution disk contains calibration information stored in the following file.

`cal\srs_(robot arm serial number).cal`

The .cal file contains factory defined calibration values for the robot arm.

Note: If you have previously recalibrated the arm or are using an extra axis in your application, load the calibration values from your own backup disk instead.

If lost, a copy of the factory calibration data can be obtained from your nearest distributor or CRS Robotics.

Before you begin:

- Ensure that your computer is connected to the controller front panel communication port.

To restore the factory calibration values:

1. Switch both the computer and the controller ON.
2. Switch ON arm power.
3. Transfer control of the robot from the teach pendant to your computer.
 - a. At the teach pendant, press ESC until the Terminate screen appears.
 - b. Select F1(yes), to terminate to the host point of control.
4. Run Robcomm3 and establish communication with the controller by selecting Terminal from the C500C menu. Insert the distribution disk into drive a:\.



Caution! Save your previous .cal file on a backup disk.

5. Select File Transfer from the C500C menu.
6. Select the .cal file from the a:\ drive and transfer it to the /conf directory on the C500C controller.
6. Home the arm (refer to page 46) or use your own custom homing procedure.
7. Type **ready** and press Enter to place the robot at the Ready position. All markers on the robot should align properly.

Recalibrating the Robot Arm

Recalibrate the robot when there is a drive disturbance, such as the replacement of a servo motor, encoder, chain, etc.

Note: You must recalibrate even if the replacement part is of the same type as the one removed.

The following recalibration procedures restore adequate recalibration for the majority of robot applications. Precise calibration of the robot can only be obtained when performed with the aid of a calibration fixture. If you require precise calibration contact your nearest distributor or CRS Robotics.

Procedures:

Recalibration consists of a sequence of four procedures.

- 1) Establish communication with the robot
- 2) Adjust all the joints to the Zero calrdy() position
- 3) Set and save the new calibration values
- 4) Check your locations

Note: These procedures do not calibrate extra axes. If you are adding an extra axis refer to page 67.

You need:

- Precision 24-inch square with scale
- Computer with Robcomm3 software
- Your A255 distribution disk, or your own backup, if your system was previously recalibrated. If the distribution disk is lost, you can obtain a copy from your nearest distributor or CRS Robotics.

Before you begin:

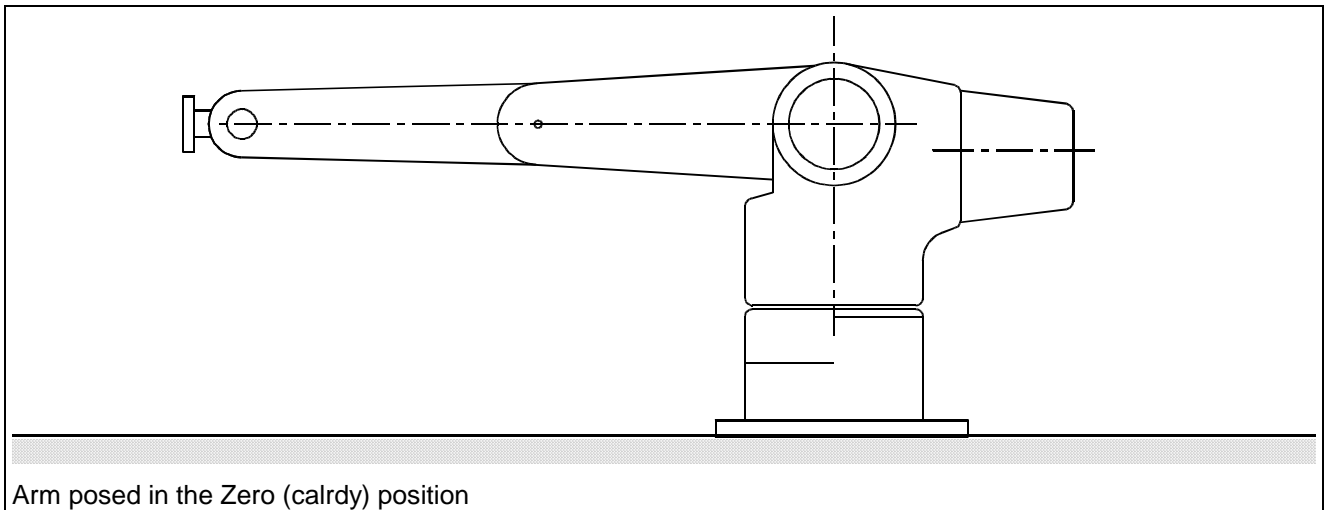
- Ensure that the arm is securely bolted down.
- Remove the gripper or other tooling attached to the arm. The tooling must be removed in order to calibrate joint 5.

Tip: Mark the position of the tooling on the arm with a pencil. Use these marks as guidelines when re-installing the tooling.

1) Establish Communication With the Robot

1. Turn ON the computer and controller.
2. Turn ON arm power.

3. Use the teach pendant to move the arm into an approximate Zero position, refer to the drawing below.



4. Transfer control of the robot from the teach pendant to the terminal.
 - a. At the teach pendant, press ESC until the Terminate screen appears.
 - b. Select F1 (yes), to terminate to the host point of control.
5. Run the Robcomm3 Terminal Emulator.

2) Adjust All the Joints in Sequence to the Zero (calrdy) Position

Adjust joints 1, 2, 3, 4, and 5, to their Zero position using the following sequence. Use the following figure as a reference.



Caution! Review the safety precautions at the front of this guide before entering within the robot's work envelope, refer to page 24.



Warning! Have someone else available to strike the e-stop when working inside the robot envelope. Working within the robot envelope when arm power is on represents a risk. In the case of a controller or arm failure, there is a danger of impact or trapping.

Joint 1

1. Type **limp 1** and press Enter, the waist joint limps.
2. Type **w1** and press Enter to display the position of the robot joints in motor pulses. The first number lists the position of axis 1.
3. By hand, rotate axis 1 until it is positioned against one of its hardstops. Do not compress the hardstop.
4. Press Ctrl+E to terminate the w1 command.
5. Type **/diag/xzero 1** and press Enter to zero the joint 1 position registers.
6. Type **w1** and press Enter and then rotate axis 1 until it is against its other hardstop.
7. Type speed **10** and press Enter.

8. Type nolimp and press Enter. Joint 1 unlimps.
9. Note the displayed motor pulse position and divide the travel value by two. This determines the value of the half-way position.
Note: The sign (\pm) must be opposite of the displayed value.
10. Type motor 1, < \pm half-way position value> and press Enter. The arm moves to the half-way position.
11. Type /diag/xzero 1 to set the Zero position for joint 1. The motor pulse count for joint 1 (W1) should now read zero.

Joint 2

1. Place the 24-inch square to measure the perpendicular distance from the robot's mounting surface to the joint 3 axle hole on the side of the arm (refer to the drawing on the previous page).
2. Use the motor command to adjust the the joint so the measured distance is ten inches. For example:

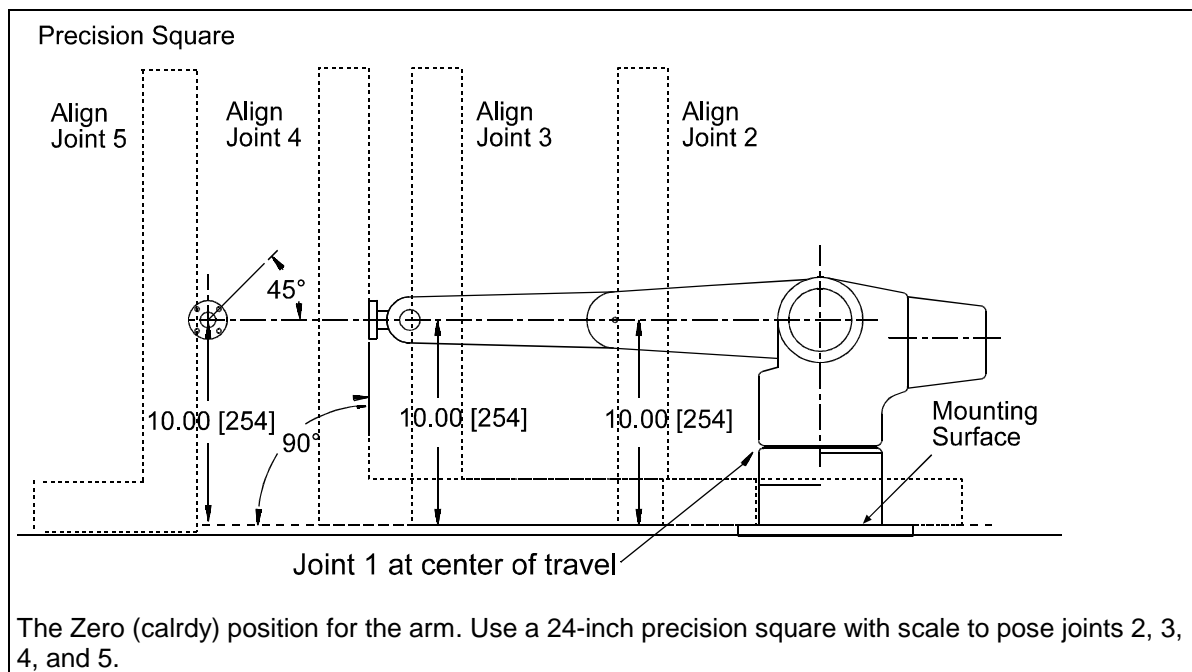
Type **motor 2**, < \pm motor pulse counts> and press Enter.

Note: Use small increments of motor pulses to move the arm (20 pulses).

Joint 3

1. Place the 24-inch square to measure the perpendicular distance from the robot's mounting surface to the joint 4 axle hole on the side of the arm (refer to the drawing on page 64).
2. Use the motor command to adjust the joint so the measured distance is ten inches. For example:

Type **motor 3**, < \pm motor pulse counts> and press Enter.



Joint 4

1. Place the 24-inch square in position to check if the tool flange is perpendicular to the robot's mounting surface (refer to the drawing on page 64).
2. Use the motor command to adjust the joint so the tool flange is perpendicular. For example:

Type **motor 4**, **<± motor pulse counts>** and press Enter.

Joint 5

1. With the joint 5 tool flange approximately at the center of its travel, use the square to align two of the tool flange screw holes so they are perpendicular to the robot's mounting surface (refer to the drawing on page 64).
2. Use the motor command to adjust the joint. For example:

Type **motor 5**, **<± motor pulse counts>** and press Enter.

3) Set the New Values

1. Type **/diag/zero** and press Enter to zero the position registers.
2. Type **joint 2,90** and press Enter to move the arm to the Ready position.
3. Type **/diag/cal** and press Enter. At the prompt, type **Y** (yes). This resets the controller's calibration data and homes the arm.
4. If required, pull off and re-apply the homing markers.

Note: New markers can be purchased from CRS Robotics.

5. Type **speed 10** and press Enter.
6. Type **ready** and press Enter.
7. Exit the Terminal Emulator.
8. Use Robcomm-3 to save the new calibration values on a backup disk.
 - Choose Calibration Receive from the Setup menu.
 - Click Save and then save the values in your selected directory.



Warning! Do not save new calibration values using the original file name. This overwrites the factory values causing them to be lost.

4) Check Your Locations

1. Re-install the plastic arm covers.
2. Inspect the homing markers and reposition if necessary.

Note: New markers can be purchased from CRS Robotics.

3. If you removed the arm tooling earlier, ensure that it is properly installed, aligned, and leveled before running your application. Installing the tooling correctly can be as important as correctly recalibrating your robot arm.

4. If you are using a homing bracket, ensure that all steps required for recalibration with the homing bracket are performed before you run your application. See the Homing Bracket User Guide.
5. Before running your application, perform the following check.
 - a. Type **speed 10** and press Enter.
 - b. Move the arm to predefined locations used in your application.
 - c. Ensure that the arm moves to those locations as expected. If not, stop arm motion and recheck your calibration.
 - d. If the problem persists after several tries, you may have to re-teach your locations.

Calibrating an Extra Axis

If you are adding an extra axis such as a carousel, use the following information to calibrate that axis. If you are adding a track axis, refer to the T265 Linear Track Option User Guide.

Use the following RAPL-3 commands to zero, calibrate, and home your extra axis.

- `xzero()`
- `cal()`
- `home()`

Glossary

Arm

A sequentially connected set of links and joints having one end, the base, attached to a platform, the other end outfitted with a tool which performs work, and the joints powered and capable of moving the links and the tool to various locations and orientations.

Awareness Signal

An audio or visual device, such as a buzzer or a light, activated by a sensing device, which makes aware the nearness of a person to the robot arm work cell or workspace.

Axis (X, Y, or Z)

A reference line of a coordinate system. In a Cartesian coordinate system, the three axes (X, Y, Z) meet at right angles, with X and Y defining a horizontal plane and Z defining the vertical dimension. Any point in the arm's workspace, i.e. any location of the gripper or tool, can be identified by this system.

Axis of Motion

A line which passes through a joint about which a link or similar section rotates.

Controller

The computerized device that controls the arm. It receives input, processes data, sends control signals to the arm, and receives feedback from the arm. During the running of an application, the controller executes a robot software program.

Degree of Freedom (DOF)

The types of independent motions in which the arm can move its end effector (grripper, tool), as defined by the axes of motion. For example, the A255 has five degrees of freedom and can move to coordinates specified by X, Y, Z, Pitch, and Roll.

Emergency Stop (E-stop)

A method that overrides robot controls, removes arm power, and stops movement of the robot arm.

Encoder

A device attached to each motor shaft which converts the movement of a joint to a signal for processing by the controller.

End Effector

A device attached to the tool flange that is used to perform the robot's task, such as a gripper, dispenser, buffing wheel, or spray head.

Gripper

An end effector designed to grasp or hold.

Harmonic Drive

A precision mechanical transmission. This device joins a motor and a joint providing smooth motion, high torque, and low backlash. A harmonic drive contains three components: circular spline, flexspline, and wave generator. The circular spline is a rigid ring with internal teeth which engage the external teeth of the flexspline. The flexspline is a non-rigid, thin cylindrical cup with external teeth

on a slightly smaller pitch diameter than the circular spline. The wave generator is a thin raced ball bearing assembly fitted onto an elliptical plug serving as a high efficiency torque converter.

Interlock

A safety device connected to a machine which prevents the machine from doing anything unless the device's integrity is maintained or restored. For example, a door-mounted contact switch connected to the robot e-stop circuit which breaks contact and stops the arm when the door is opened and allows arm operation only when the door is closed and contact is restored.

Joint

A part of an arm connecting two links and containing an axis of rotation that provides a degree of freedom.

Limping

A method of moving the arm by disengaging the servos which normally hold the joints in place.

Link

A rigid part of a robot arm between two neighboring joints.

Payload

The mass (weight) carried by the arm.

Pitch

See Yaw, Pitch, and Roll

Range of Motion

The extent of travel of a link or an arm, dependent on the limits of rotational motion of the joints and the lengths of the links.

Reach

The maximum distance that the arm can extend the tool flange or gripper. It defines the work envelope.

Resolution

The smallest increment of motion or distance that can be detected or controlled.

RAPL (Robot Automation Programming Language)

An automation-oriented, line-structured language of commands, similar to BASIC and C, used for robot applications and communication.

Roll

See Yaw, Pitch, and Roll

Teach Pendant

A hand-held robot control terminal having a keypad and LCD display. It provides a means to move the robot, teach locations, and run robot programs. It is connected by its cable to the robot controller.

Umbilical Cables

Cables which connect the controller and the arm. The motor power cable carries power to the motors. The feedback cable carries feedback from the encoders and servo gripper, as well as power for the encoders, servo gripper, brake release, and air solenoid control.

Work Cell

A station composed of the arm, the apparatus integrated with the arm (material handling, reagents, sensors, etc.), and the arm workspace.

Work Envelope

The outer boundary of the workspace. The limit of the arm's reach.

Workspace

The space or volume consisting of all points that the robot arm can reach. The outer boundary of the workspace is the work envelope.

Yaw, Pitch, Roll

The orientation of the wrist is defined by three angles: yaw (orientation about the Z axis), pitch (orientation about the Y axis), and roll (orientation about the X axis). The right-hand rule applies in determining the direction of these angles.

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