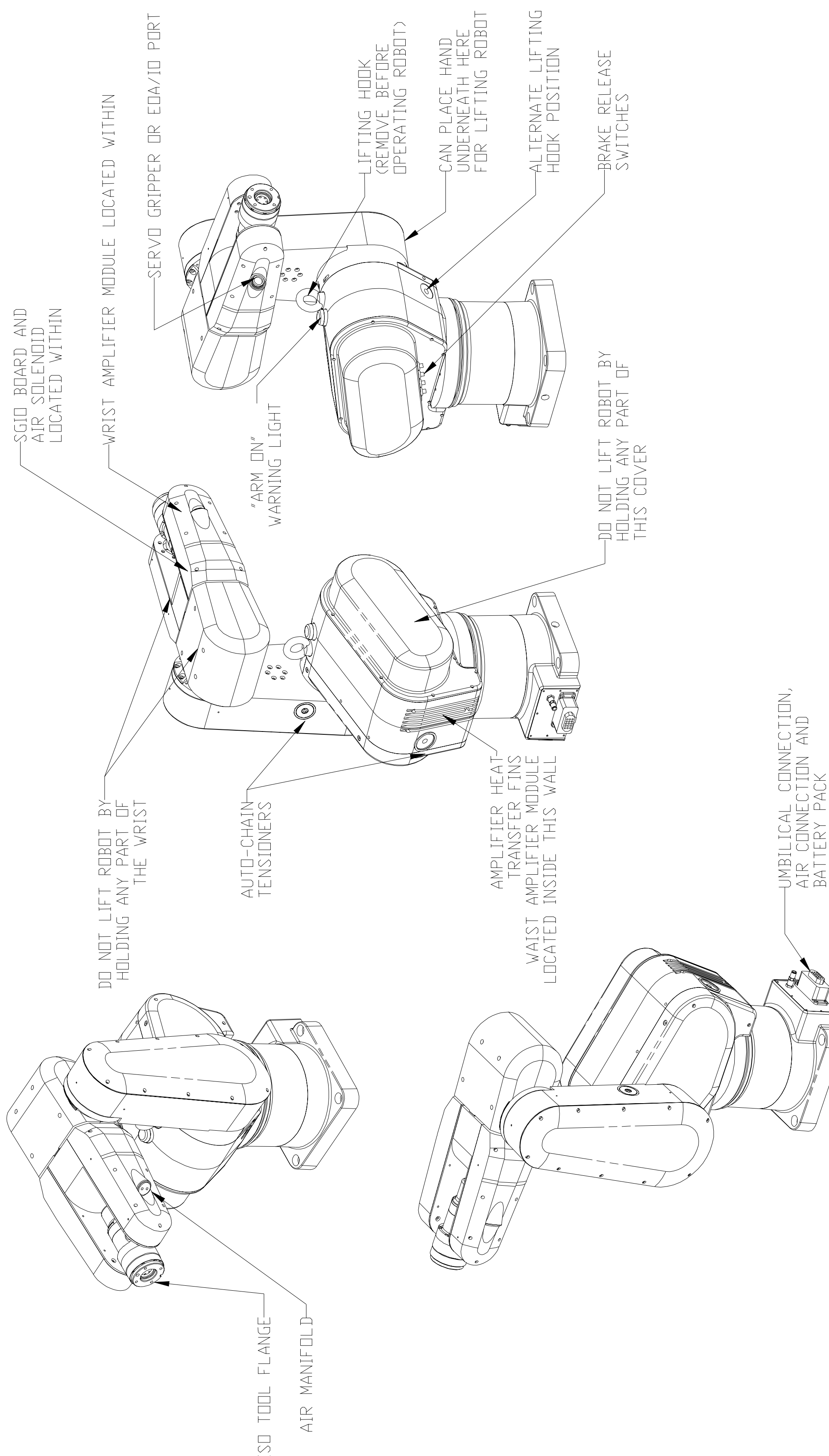
F3 Robot Arm
for C500C Controller
User Guide

UMI-F3-310

CRS It's all about time

F3 Robot Arm for C500C

Revision		
Number	History	Date
001	First issue as F3 for C500C controller (UMI-F3-310).	99-05


SGIO BOARD AND
AIR SOLENOID
LOCATED WITHIN
WRIST AMPLIFIER MODULE LOCATED WITHIN
SERVO GRIPPER OR EOA/IO PORT
LIFTING HOOK
(REMOVE BEFORE
OPERATING ROBOT)
CAN PLACE HAND
UNDERNEATH HERE
FOR LIFTING ROBOT
ALTERNATE LIFTING
HOOK POSITION
BRAKE RELEASE
SWITCHES
"ARM ON"
WARNING LIGHT
DO NOT LIFT ROBOT BY
HOLDING ANY PART OF
THIS COVER
DO NOT LIFT ROBOT BY
HOLDING ANY PART OF
THE WRIST
AUTO-CHAIN
TENSIONERS
AMPLIFIER HEAT
TRANSFER FINS
WAIST AMPLIFIER MODULE
LOCATED INSIDE THIS WALL
UMBILICAL CONNECTION,
AIR CONNECTION AND
BATTERY PACK
ISO TOOL FLANGE
AIR MANIFOLD

Preface

About This Guide

This user guide accompanies the CRS Robotics F3 robot system. It contains general information, system specifications, safety precautions, installation instructions, and basic operating instructions for the F3 robot arm and controller.

In this guide, there are references to the layout drawing of the robot on page iii of this guide. A larger copy of the same drawing is included in the envelope on the exterior surface of the shipping crate.

To obtain additional copies of this guide, installation guides in other languages, or other CRS literature, contact the Sales Department or the Customer Support Department of CRS, or contact an authorized CRS distributor.

Other Guides

For additional information, refer to the following documentation:

- Application Development Guide
- RAPL-3 Language Reference Guide
- F3t Track User Guide

Training

This user guide is not intended as an independent training tool, but rather as a guide for those who have received CRS training and have a basic knowledge of the F3 robot system.

Training is offered at CRS headquarters in Burlington, Ontario, Canada, or can be conducted at your facility. For additional information, contact the Training department.

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How to Use This Guide

This user guide is organized so that each chapter covers a different topic. The following guidelines will assist you in reading through the chapters.

- Refer to the layout drawing for reference to physical parts of the robot.
- Read the chapter on Safety Precautions before installing and using the robot.
- If you are working with an F3 robot for the first time or wish to review pertinent information about the system, read the chapters on Specifications and Installation.
- If you are installing the robot yourself, read the chapters on Installation and Commissioning.
- If CRS or a distributor has installed the robot, read the chapters on Commissioning and Operating Basics.

Before attempting to follow any procedure or examples provided in this or any other manual on CRS products, 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, work pieces, loss in robot memory, or system errors.*

Failure to unpack, install, use, and maintain the F3 robot system as instructed in this user guide may lead to problems including failures and injuries for which CRS Robotics Corp. cannot be held responsible.

This user guide describes the F3 robot system and only operating instructions specifically pertinent to this system. *You should attend a CRS training course and read the appropriate documentation before programming the robot to execute any type of command or application beyond the simple examples offered herein.*

Contents

Important Tips

Work Safely

Follow all safety information.

Work Safely in the Workspace

Always stay within reach of an e-stop button when you are in the arm's workspace. There is an e-stop on the teach pendant.

Back-up Calibration

Keep the calibration file that was delivered on the calibration diskette. Do not lose it.

If you re-calibrate the robot, update the backup file.

Maintain the Robot

Keep to the recommended inspection and maintenance schedule. Keep a log of all maintenance and service activities as well as the number of working hours.

For maintenance, use the same chain lubricant that was applied at CRS during initial assembly.

Replace the encoder backup batteries 12 months after receiving your robot. Use only nickel-metal-hydride batteries. Contact CRS Customer Support for more detailed specifications or purchase of replacement units.

Lift the Robot Carefully

Do not lift the robot without assistance of a crane or other persons.

Design the Workcell

Always design your workcell to be serviceable.

1. Teach at least one robot location where it is easy to access the arm and the drawer at the base of the arm. Teach at least one robot location that gives ample room for mounting and dismounting the robot.
2. Install the controller so that it can be easily relocated to an open area for service.
3. Provide adequate clearance at the base of the robot and at the rear of the controller for the umbilical cable.

Get Trained

Attend an F3 training course.

Use Correct Tool Frame of Reference

The tool frame of reference on the F3 is defined according to the ISO convention. This is different from earlier models of CRS robots.

Use Correct Power with GPIO and SYSIO

Do not use the internal 24V power supply for any functions when interfacing to the GPIO or SYSIO. Use an external power supply.

Shut Down Properly

To shut down the system:

1. Turn off arm power by hitting an e-stop.
2. Properly shut down the operating system with the command shutdown now.
3. Turn off the controller at the controller's main power switch.

CHAPTER 1

Getting Started Quickly

This chapter gives a quick overview on how to install and begin using the F3 robot system. It is intended for those who are experienced with robots in general and have received training with the F3 system.

For full instructions on installing and starting up the robot, and for users inexperienced with the F3 system or robots in general, read the entire user guide before proceeding with any action.

After completing quick installation and startup, reading through the entire user guide is still necessary for users with any level of experience.

Brief Installation and Startup Instructions

Detailed installation and startup instructions are found in Chapter 5. If you do not possess real experience with robots, preferably specific F3 experience, patiently read through the detailed instructions.

Minimum Installation Requirements

- As a minimum, the F3 robot should be mechanically secured by four M12 x 1.75 fasteners to a rigid platform. Each fastener should have at least 2 cm (or 0.8”) of thread engagement. For precise location, two M6 dowel pins should be used. A drawing of the base with the relevant dimensions is found in Chapter 5.

Warning: The F3 robot’s compact size is not indicative of its significant power. *Failure to use four fasteners as recommended may result in unstable installation.*

- Remove the eyebolt.
- Do not turn on the controller until the umbilical cable has been connected to both the robot and the controller.
- The umbilical cable connects to the back of the robot base. There should be at least 45 cm or 18 inches of clearance in this area to provide adequate strain relief for the cable.
- There should also be 45 cm or 18 inches of clearance at the back of the controller to provide adequate strain relief for the cable at that end.
- The umbilical cable has a minimum bend radius of 23 cm (9 in).
- Verify that the controller is properly configured for the local AC power supply.

Turning On the System

Do not forget to observe guidelines listed here prior to powering on the robot.

Warning: *Do not turn the controller on until the umbilical cable has been connected at both ends.*

If you are starting up the robot system for the first time, it is recommended that you connect a host computer to the controller via a RS232 serial cable. If you are using only a teach pendant, refer to the *Teach Pendant* section of the *Application Development Guide*.

The host computer should be a PC operating Windows 95 or higher, or Windows NT 4.0, with Robcomm 3 or a compatible terminal emulator installed.

- Start up Robcomm 3 or the terminal emulator.
- Turn on the controller by striking the black power switch on the left side of the front panel of the controller.

The controller will display a number of messages on the terminal window at startup.

When startup is successful, you see the following message as one of the last messages displayed:

Amplifier status

1……OK 2……OK 3……OK

4……OK 5……OK 6……OK

This message reports the results of a diagnostic test performed by the controller on the in-robot electronics. In its absence, or if an error message is displayed, refer to Chapter 9 for instructions on troubleshooting.

After successful startup of the controller and before turning on arm power, you should note whether the HOME indicator light on the front panel is lit. This light indicates whether a proper calibration file was found in the controller memory. If not, go to Chapter 9 for instructions on troubleshooting.

Turning on Arm Power

Warning: *Ensure that no one is in the workspace of the robot before turning on arm power.*

Warning: *Ensure the e-stop button on either the front panel or the teach pendant is easily accessible before turning on arm power.*

- Press the Arm Power button at the top right hand corner of the front panel of the controller.
- Verify that the light on the Arm Power button is lit.
- Verify that the amber beacon on the robot arm is flashing.

If either of these indicators fails to turn on, turn to Chapter 9 for instructions on troubleshooting.

You are almost ready to start moving and programming using the robot. The following guidelines will be helpful:

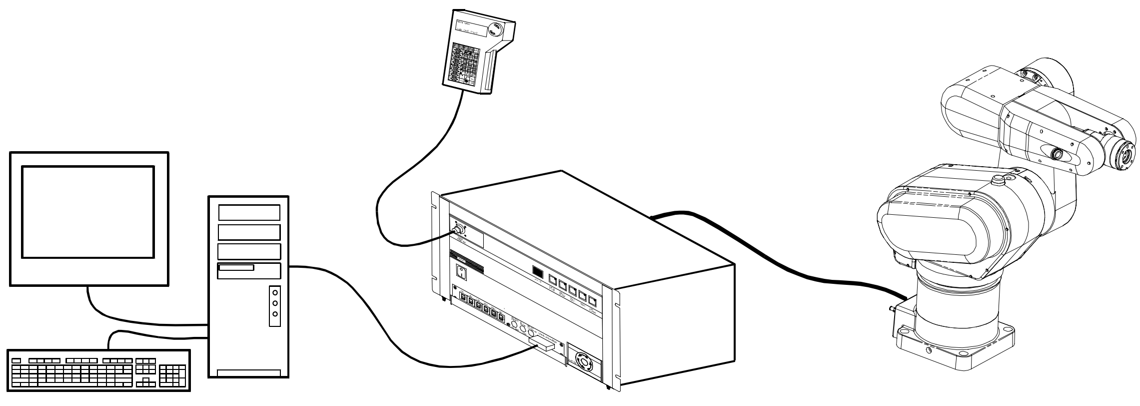
- Verify that you have removed the eyebolt before commanding robot motion.
- Read the sections of application development in the documentation set supplied with your system:
    - The *Application Development Guide*, particularly the sections on ASH and CROS, as well as the *RAPL-3 Language Reference Guide*.
- Always move the robot slowly at first when starting up the system for the first time.
- Keep the e-stop button accessible at all times.
- Ensure there is no one in the workspace of the robot while arm power is on.
- If you have not read the rest of this user guide or received training on the F3 system, limit your use of the robot to simple commands from ash at a speed below 20%.

CHAPTER 2

Introduction

The F3 robot system has been designed to automate tasks such as machine loading, specimens handling, product testing, dispensing, polishing and deburing.

The system consists of a six-axis robot arm, teach pendant, gripper or other tool, a controller running ash, as well as an umbilical cable. The cable conducts communications between the robot and controller as well as power for the electronics embedded in the robot.



An F3 system: computer, teach pendant, controller, and arm.

The F3 robot is run by a program that can be developed either on the controller with a terminal or teach pendant, or off-line on a computer using Robcomm 3 or equivalent tools. From the teach pendant or a terminal you can move the arm and teach locations. The robot can also be operated with limitations using the front panel of the controller.

Component Parts

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

- If you did not order options, the robot system is packaged in two containers.
- Options may be shipped in separate containers and may include: gripper, teach pendant, user guides, diskette(s), cable extensions, spares, etc.

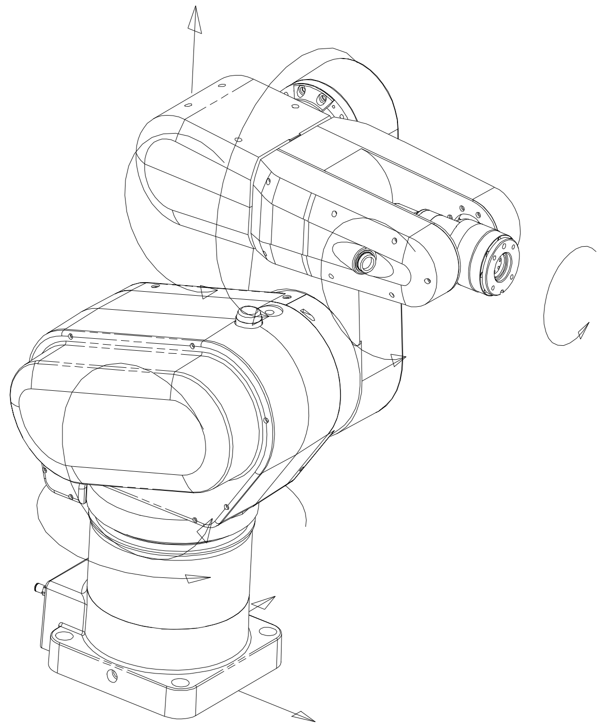
- Use the following table to check off the components, which have been ordered and received.

Component	Check if ordered	Delivery date	Serial number
• F3 arm • hex key			
• C500C controller • umbilical cable • fuse kit with AC power cable • teach pendant override plug • SYSIO override plug • CROS diskettes (2) • calibration diskette • F3 User Guide • Application Development Guide • RAPL-3 Language Reference Guide			

Option	Check if ordered	Delivery date	Serial number
• Robcomm 3 diskettes			
• teach pendant			
• servo gripper			
• end-of-arm i/o kit			

F3 Arm

The F3 robot arm has six rotational degrees of freedom. This allows it to move a gripper or any other tool of choice to the desired location defined by three coordinates for position in the workcell and three coordinates (angles) for orientation at that position.



Axes

The F3's six axes of motion (joints) are: waist (1), shoulder (2), elbow (3), wrist rotate (4), wrist pitch (5) and tool roll (6).

Umbilical Cable

An umbilical cable connects the F3 arm to the C500C controller. Inside the cable, there are two optical fibres (for communications between the robot and controller) and five copper conductors (for +12VDC, 2 x +24VDC, +77VDC and two ground lines) enclosed inside a black polyurethane jacket.

The umbilical cable has the following properties:

Properties	Ratings
abrasion resistance	excellent
heat resistance	good
flame retardancy	good
water resistance	good
dielectric strength	3000VDC
operating rating	300 V
operating temperature	0°C to 65°C
weight	222 g/m(0.15 lb/ft) plus weight of connectors
minimum bend radius	230 mm (9 in)
cable diameter	13 mm (0.5 in)

F3 Options

The following F3 options are available from CRS or an authorized distributor.

Off-Robot Hardware

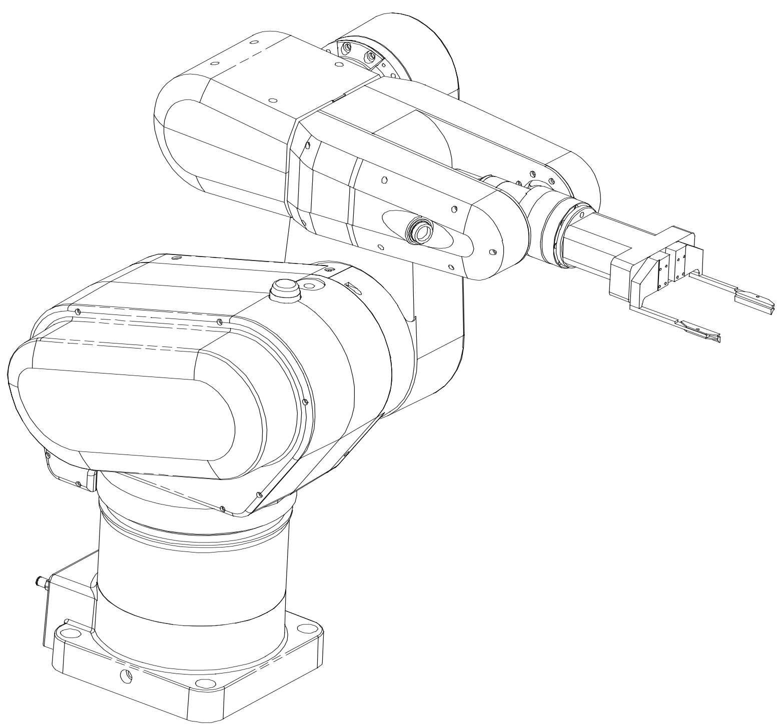
- teach pendant
- track
- long umbilical cable
- long teach pendant cable
- GPIO termination block
- external +24 V power supply for GPIO
- spares kit.

End-of-Arm Tools

With the attachment of different types of tools or grippers to the end of the tool flange, a wide range of high-speed, high precision applications are possible.

Custom designed grippers and other tools are available from CRS.

- Servo gripper



This is an electric, servo-controlled, parallel motion, two-fingered gripper capable of measuring objects between its fingers. Finger travel is 50.8 mm [0 – 2 in.] with programmable position and force. This gripper can be mounted coaxial with, or orthogonal to, the tool flange. It is available with standard or microplate fingers. For more details, read the insert on the servo gripper.

- Pneumatic gripper

  This is a two-jaw, double-actuation air gripper with 76.2 mm [3 in.] long angular motion replaceable fingers. Fingers can be machined to meet specific needs. Travel is limited to 0 — 10° per finger.

- Force sensor

  This is a six-axis force-moment sensor used in applications requiring monitoring or real-time control of contact force.

End-of-Arm I/O

- The standard configuration of the robot includes an SGIO (servo gripper I/O) board inside the wrist. This board provides four each of opto-isolated input and output channels (2 of the output lines are used to control the pneumatic solenoid in standard configuration but can be freed up if air is not needed).
- Early F3 robots are equipped with end of arm I/O boards, which control the solenoid but not the servo gripper. Users with this version of the robot wishing to add a servo gripper should contact sales or customer support group at CRS.
- To utilize the other I/O channels of the SGIO board, it is necessary to purchase the end of arm I/O package which comprises an internal cable, a connector and a custom wrist cover.
- The end of arm I/O network is expandable (additional SGIO boards can be added to provide more I/O channels, either at end of arm or within the controller). Contact CRS to learn more about this option.
- An external 24V power supply is required if more than 250 mA of current is required for I/O devices. This is provided by CRS as an add-on option.
- There are built-in RAPL-3 functions to support control of the air solenoid, servo gripper, and I/O lines.
- The I/O features and the servo gripper option cannot be used simultaneously.

CHAPTER 3

Safety Precautions

This chapter provides a brief guide to designing a safe workcell, including some considerations for safeguarding the workcell and precautions for the safe use of the F3 robot system. It is recommended that the system integrator and the end user be aware of the robotic safety standards currently applicable. They provide valuable considerations for the safe design of your workcell. Two good references are:

- UL1740 - Safety Standard for Robotic Equipment
- ISO10218 - Safety Standard for Manipulating Industrial robots

Warning! 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 system failure.

Safety Principles in Operating Robots

In the design of the F3, careful consideration was given to safety; however, risks associated with the operation of robot systems can only be minimized and not eliminated. System integrators and end-users have the responsibility of assessing these risks and providing additional safeguarding measures in the workcell.

Prevention of accidents around robot systems is based on the following fundamental principles:

1. A barrier or equivalent alternative should be set up to safeguard the workspace of the robot or the entire workcell.
2. There should be no one in the safeguarded space during automatic operation.
3. The design of the workcell should allow the maximum number of personnel-tasks to be performed from outside the safeguarded space.
4. Extra attention to safety is warranted during teaching and program verification phases when it may be necessary for someone to be present in the safeguarded area. There should be easy access to an e-stop button inside the workcell.

F3 Safety Features

The safety measures implemented by CRS include:

1. hard-stops in joints 1 to 5 to restrict its range of motion;
2. a Cartesian speed limit of 250 mm/s when the teach pendant is used in manual mode;
3. an e-stop button on the teach pendant and one on the front panel of the controller;
4. an amber warning light mounted on the robot to indicate that the robot is powered and capable of motion (see p.46);
5. fail-safe brakes on the main robot axes to prevent motion due to gravitational load (see p.46);
6. brake release switches located on the underside of the robot shoulder to permit the main robot joints to be manually moved with the motor power off (see p.46);
7. continuous fault detection during operation, including collision, runaway, over-temperature, over-current, network time-out and encoder faults;
8. prevention of automatic start-up of the robot after a power failure.

Known F3 Hazards

1. The space between moving linkages of the robot introduces a crushing/pinching hazard; these are labeled as pinch points on the robot.
2. System operation is not affected in any way by failure of the amber arm-power light. In other words, this light warns that the robot is capable of motion while it is flashing but the absence of light does not indicate arm power is definitely off.
3. The brakes in the robot are designed to prevent motion against gravity. While they can also provide some dynamic braking, they do not have sufficient power to overpower the motors and instantaneously stop robot motion.
4. No detection or safeguard exists for the loss of air pressure; therefore, any pneumatic tooling that can become hazardous as a result of loss of air pressure must be given special consideration.
5. Ingress of liquids into the arm can result in short circuiting of the electronics and consequently unpredictable arm behavior.
6. A fire hazard can result from mounting the robot arm to a piece of equipment that is at a different ground potential than that of the controller. Ensure that both systems are connected to the same system ground to prevent such a situation.

Safeguards and Safety Measures in Workcell Design

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

Incorporate safety measures into your work cell design to reduce the risk of hazard. The following list represents baseline measures which should be taken:

- Train all personnel to keep out of the workcell when the robot arm power light is on.
- Follow the instructions for installation and operation in this manual.
- Use a diverse and redundant set of safety measures including those recommended herein to provide an adequate level of safety.
- Design the measures so that the activation of one safety measure against a hazard does not create a new hazard elsewhere.
- Install barriers outside the total radius of the robot arm, gripper and payload.

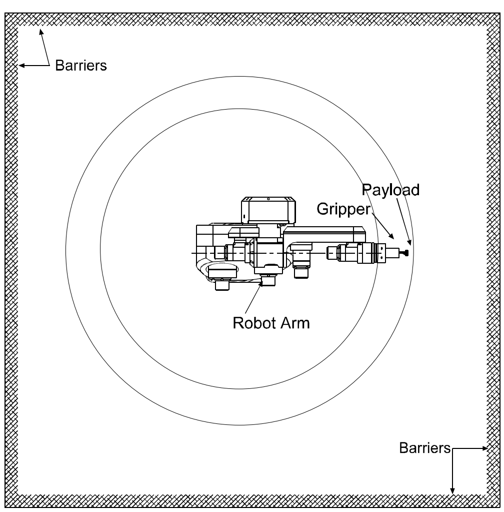
Danger! Never enter or obstruct the workspace while the robot is in use. *The robot arm is capable of fast movement without warning. Install safeguards to prohibit access to the workspace when the robot is in use.*

Physical Barriers

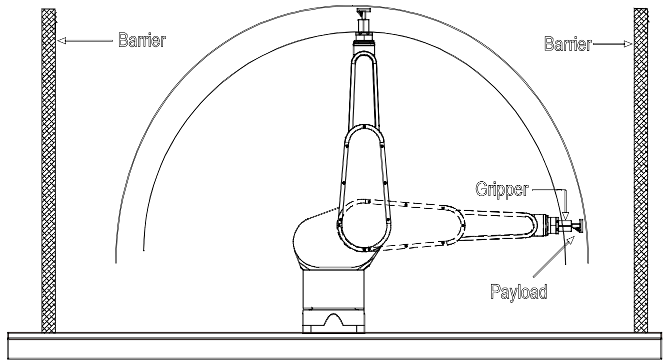
Physical barriers inhibit or prohibit access to the arm's workspace.

Install barriers:

- beyond the total limit of the arm's possible workspace, 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.



$$\text{Radius}_{minimum} = 710 \text{ mm [28 in]} + \text{Length}_{gripper} + \text{Length}_{payload}$$



$$Radius_{minimum} = 710 \text{ mm } [28 \text{ in}] + Length_{gripper} + Length_{payload}$$

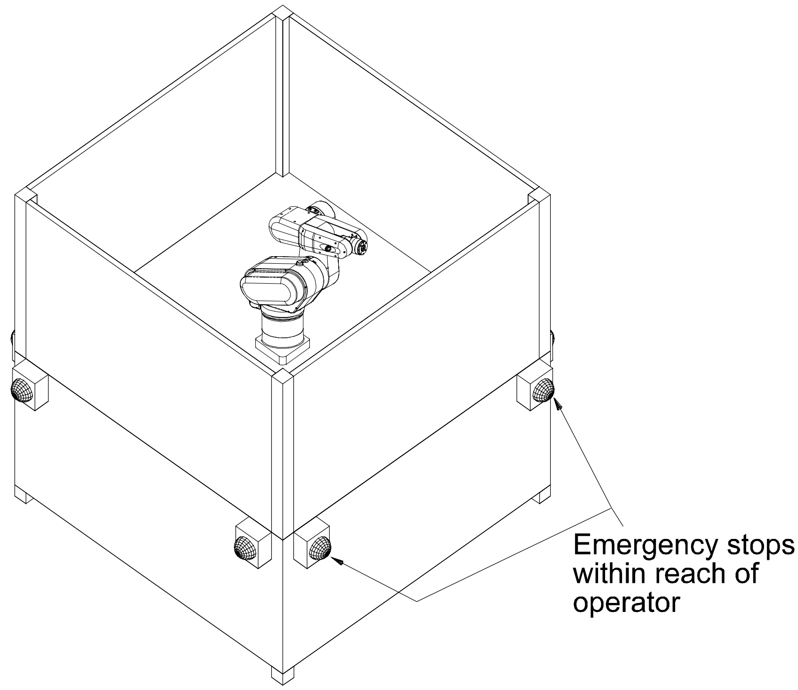
Emergency Stops (E-Stops)

An emergency stop (e-stop) button is a conspicuous, red, mushroom-shaped button. When struck, it cuts off arm power. It must be manually reset.

E-stops are part of the controller's single, continuous e-stop chain. Pressing an e-stop breaks the chain, resulting in the immediate removal of arm power. When arm power is removed, fail-safe brakes engage to prevent the robot from moving due to gravity or inertia. The F3 robot has a category 0 e-stop (as defined by the European standard EN 418). This is classed as an uncontrolled stop, since power is immediately removed from the robot motors and brakes are engaged on the main drive axes. As an added safety measure, the control software is designed to decelerate the speed of the motors to zero at a rate so as to minimize any resultant jerk.

Resetting the e-stop does not result in automatic actuation of arm power. A separate action is required to re-initiate robot motion. In this case, the arm power button must once again be pressed.

The C500C controller provides an e-stop input. Expanding the e-stop chain allows you to stop the robot system by striking external e-stop buttons. The C500C controller does not have an e-stop output. As a result, striking the e-stop buttons on the controller or teach pendant will not stop other systems in the workcell.



Example of typical barriers and remote E-Stops.

Pressing an e-stop does not turn off power to the controller. Processes that are running on the controller continue to run, except for those (without structured exception handling or other error checking) requiring robot motion, which will terminate when arm power is removed.

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 other 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:

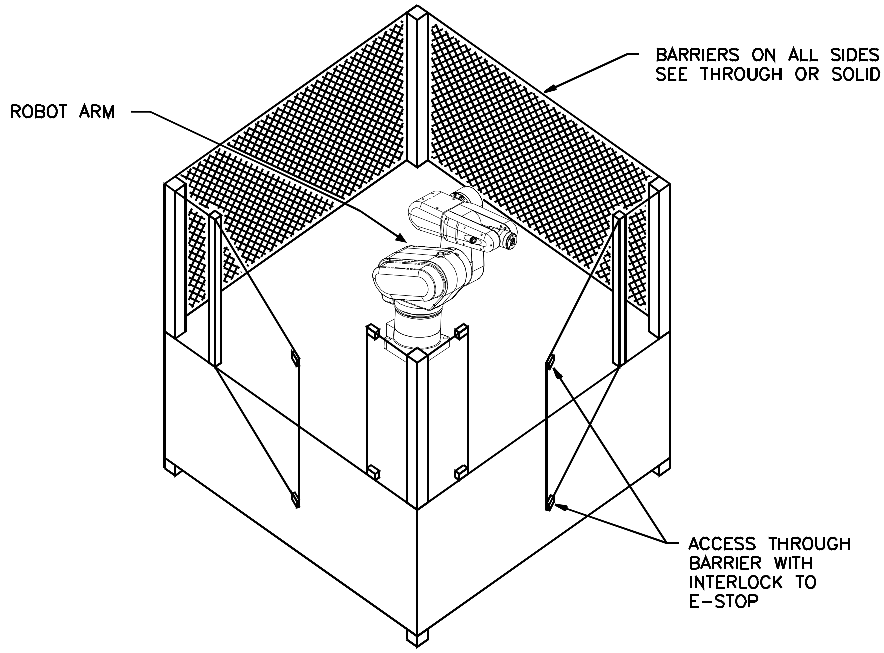
- All e-stop buttons are unobstructed.
- Personnel can reach and activate each e-stop button without difficulty.
- All e-stop buttons are outside the total safeguarded space of the robot arm, its gripper, and any payload.

Presence Sensing Interlocks

Install a presence-sensing safety interlock at any point of access through a barrier into the robot workcell. Design the interlock as part of the robot 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 is broken, and permits arm operation when the door is closed and contact is restored.

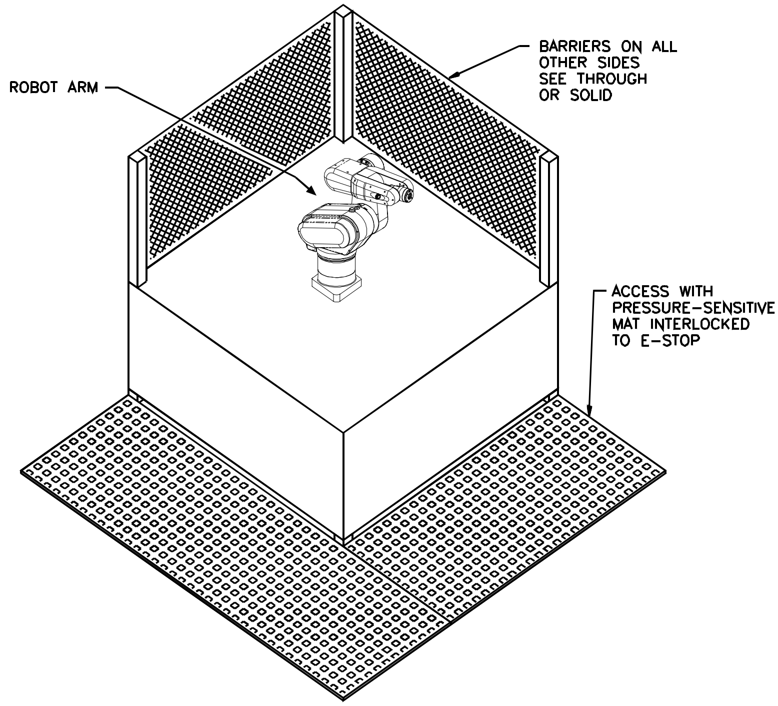
Presence sensors include:

- Contacts on doors
- Light curtains
- Pressure-sensitive floor mats

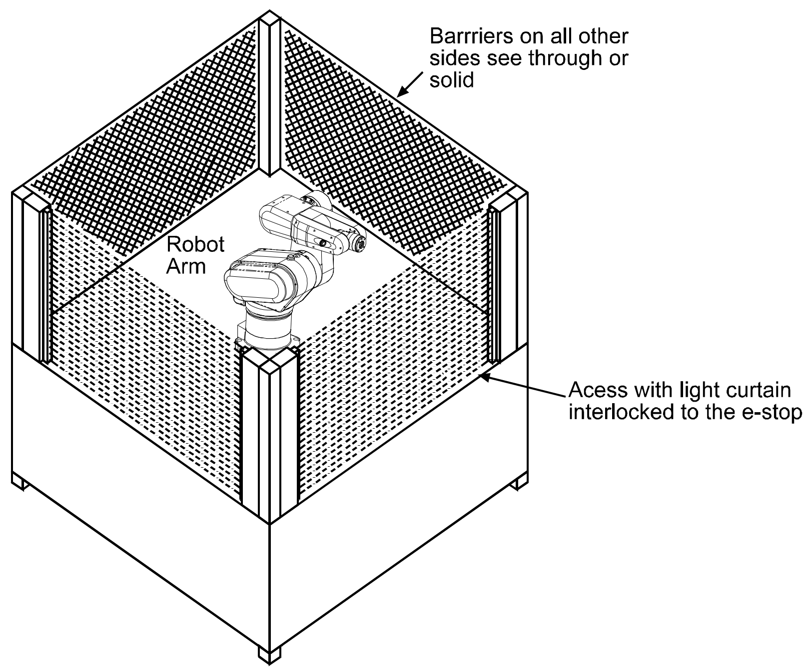


Example of barriers and interlocked contacts on doors

All presence-sensing devices should be designed and constructed to fail safe in the event of a component failure. Also, the design should place the presence-sensing envelope far enough from the arm so that arm motion stops before the intruder reaches the arm workspace.



Example of barriers and interlocked pressure mats



Example of barriers and interlocked light curtain.

Other Safety Measures

In addition to physical barriers, e-stops and presence sensors, safety measures 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 of their proximity to the workspace, but is not sufficient to prohibit access into the workspace.

- **Passive warnings**
  Passive warnings include markings on the floor or tabletop. An example is black and yellow stripe tape along a floor.

- **Beacon light**
  A prominent light which lights up 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.

Local Regulations

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

Environmental Requirements

The robot has been designed and tested to meet the European Community (EC) EMC requirements pertaining to industrial, scientific, medical (ISM) work environments, and to the safety requirements as prescribed by ISO 10218.

Indoor Use

The robot was designed for indoor applications only.

Temperature

Maintain the air temperature between 10°C [50° F] and 40°C [104°F]. Do not expose the robot to temperatures below 10°C [50° F] or above 40°C [104°F]. Do not install the robot near heating or cooling units.

Humidity

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

Atmospheric Contaminants

Do not expose the robot and controller to an environment of corrosive liquids or explosive fumes. Neither is rated for exposure to these harsh environments, and could result in hazardous situation.

The controller electronics are more sensitive to corrosion than the arm. If the arm operates in a harsh environment, place the controller in a separate and controlled environment.

Ingress Protection

In general, do not expose the robot and controller to an environment where exposure to liquids or dust is possible. Contact CRS regarding applications requiring ingress protection.

Vibration and Shock

The robot has not been rated for operation in an environment of excessive vibration or impact.

Electromagnetic Interference

The F3 robot has been tested to the European EMC requirements, and meets the industrial rating. The robot should not be exposed to excessive electrical noise or plasma.

Power Requirements

AC Power Supply

Power supplied to the controller must be stable. If the power supply is prone to surges or fluctuations in frequency, a regulating system in the power supply is recommended.

- Do not exceed voltage fluctuations ±10% of the nominal voltage.
- If the AC power is below the nominal value of 115VAC or equivalent, the robot may not be capable of moving at full speed.
- For variations in voltage only, install a regulating transformer. A more complete regulating system, such as a non-interruptible Power Supply (UPS) can be used for all robot systems.

Specification	Value
Nominal AC Input Voltage	100/115/230 VAC
Input Current/Fuse Rating	10/10/5 A
Inrush Current	7/8/16 A
Power System	Grounded, Single Phase
Maximum Power	1000 VA

Other Energy Sources

The F3 robot has provision for actuating pneumatic tooling. The following table specifies the pneumatic requirements.

Specification	Value
Air pressure, maximum	6.89 Bar, 6.89 kPa, 100 psi
Air flow, maximum	TBD
Air flow, minimum	TBD
Nominal input hose diameter at base	6 mm
Nominal output hose diameter at wrist	3 mm

Power Distribution

The following table lists the power requirements of the various subsystems of an F3 Robot System.

		Power Consumption	
Component	Power Source	Typical	Peak
F3 Arm	electrical	500 W	800 W
Controller	electrical	75 W	100 W
Servo Gripper	electrical	3 W	5 W
Pneumatic Gripper (optional)	electrical pneumatic	1 W	1W
Teach Pendant	electrical	1 W	1 W
Track Axis	electrical	150 W	300 W

Power Failure

If a power failure occurs, the robot controller automatically removes arm power.

After a power failure, you must restart the robot controller and manually turn on arm power. It is recommended that general diagnostics are carried-out to ensure that the controller and robot are functioning properly.

Electrical Ground

Ensure that the AC power supply is properly grounded. The incoming AC plug has three wires: live, neutral, and a safety ground. All three wires must be connected. The safety ground line provides the operator protection against the exposure to dangerous voltage levels in the case of a fault. In addition, the safety ground is required to reduce electromagnetic emissions.

The safety ground line of the controller is directly connected to the robot via the umbilical cable. As a result, it is important that the robot be mounted on a station that is at the same voltage potential as the ground of the controller. Ground the station or equipment that the robot arm is mounted onto, to an industrial grounding rod that is common to the AC ground of the controller, or to the same utility ground used for the controller. Failure to do so may result in the risk of fire due to the high currents that may flow in the chassis ground line of the umbilical cable as a result of the difference in ground potential.

The C500C controller was designed to be used with a grounded AC system. *Failure to provide a grounded AC input may result in electric shock, and damage to the controller.*

The F3 Robot must be mounted on a station, which is grounded to the same voltage potential as that of the controller ground. *Failure to do so may result in the risk of fire due to the high currents that may flow in the chassis ground line of the umbilical cable as a result of the difference in ground potential.*

Cables and Circuitry

- The umbilical cable should be routed out of the path of vehicle traffic (e.g. forklifts) and people. Damage to the fibre optics will occur if sufficient pressure is applied to the cable.
- All cables and connectors should be shielded from exposure to extreme temperatures, chemicals, ultra-violet light, humidity, and vibration.
- Operational failure of the robot system will result if the prescribed bend radius for the umbilical cable is not followed.

Robot Handling

The F3 robot and controller are precision instruments and must be handled with care. During handling, avoid any impact.

Relocating the Robot

Warning! Avoid manually lifting the robot. *The mass of the robot is approximately 53 kg [115 lb]. If you must manually lift the robot, at least two people should work together to lift the robot.*

In certain positions, the robot is unstable. Before unbolting it, place the robot in a tucked position. A recommended position is the packing position, which can be reached by running the \diag\f3pack command from any shell. In earlier versions of the F3, this was \diag\pack. In the earliest versions, this was pack. Alternatively, if robot power is off, but the controller is still attached, use the brake release switches and move the robot into a more suitable position before moving it.

Warning! Avoid entering the work cell while the robot is powered. *To move the robot, it is not necessary to be in the work cell while the robot is capable of motion.*

Once the robot is in a tucked position, turn off the controller power, and disconnect the umbilical cable.

Attach the eyebolt provided into the socket located beside the amber light on the robot.

A crane or hoist with a lifting capacity of at least 100 kg is recommended to lift the robot. An eyebolt is provided to assist in this process. Lift the robot only as high as necessary to clear obstacles. This will reduce the possibility of injury, and damage to the robot should the robot fall. Do not spin the robot while it is hoisted. This may cause the eyebolt to unscrew.

If manual lifting is unavoidable, first read the following points:

- Two or more persons are necessary.
- Grasp the robot under the cast aluminum base, the underside of the lower section of the lower link, or the eyebolt using the strap provided.
- Do not grasp the robot under the motor covers on the side, by the wrist, or by gripper.
- Do not drop the robot.
- Have a cart or platform ready. Do not manually carry the arm any distance.
- Lift the robot only as high as necessary to clear the obstacles.

Do NOT lift the arm by:

- using the shoulder covers on the sides of the shoulder casting, or
- using any link further out than the shoulder casting that is joined to the waist.

Live AC Power

Disconnect the AC power cord from the controller when accessing the inside of the controller. The controller should only be opened by trained personnel.

Electrically Conductive and Live Objects

- Do not allow electrically conductive objects or any liquid to come into contact with the controller circuitry.
- Do not allow anything electrically live to come into contact with the arm and controller.

Static Electricity

Warning! Static electricity can damage the electronic components in the controller, robot and teach pendant. *Wear an electrostatic discharge (ESD) wrist strap which contains a resistor connected to a ground when handling electronic components or working inside the controller.*

For best results, your electrostatic discharge (ESD) protection should be grounded to an industrial grounding rod dedicated to electrostatic discharge.

If a dedicated ground is not available, you can connect your wrist strap to the controller chassis, which must be properly grounded.

1. Unplug the AC power cable and remove the two main AC power fuses from the AC power module. This disconnects the line and neutral sides of AC power while leaving the controller's ground connected to the utility ground.
2. Plug in the AC power cable.
3. Connect the ESD wrist strap to the controller chassis.

Operator Safety

Warning! While the amber light on the robot is flashing, the robot is capable of motion. *If entering the workcell is required, always carry the teach pendant or another device with an E-Stop. Maintain an attitude of respect to the robot, and be alert to any unexpected motion. Unpredictable behavior may result due to human error in coding, or a fault in the system.*

Awareness of Robot

Maintenance personnel and programmers required to work near the robot should always be aware of the arm's position and motion.

- Be aware of the amber power light on the robot. Exercise extra caution when it is flashing. This is an indication that the robot is powered, and capable of motion at any time.
- While in the workcell, avoid any location that confines you between the arm and another object.
- For occasional close approach to the workspace, have a second person observe the arm and prepare to activate an E-Stop.
- If continuous or frequent presence in the workspace is necessary, install presence-sensing devices interlocked with the E-Stop circuit.

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 safety precautions stated in this chapter
- can identify the control devices and their functions
- test and ensure that the safeguards and interlocks function properly
- have a clear definition of their assigned task
- have procedures to safeguard against identified hazards
- know the safety systems of the robot, such as the brake release.

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 page 53 for mounting and installation procedures.
- the electrical connections are correct and that the power supply (voltage, frequency) are correctly set on the controller, and are within the specified ranges. Refer to page 22.
- all changes or additions are properly done, if you have modified your system, added hardware, software, or serviced your robot.
- user memory is intact. Errors should not appear in your programs or variable files.
- 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 are set as intended.
- interlocks, E-Stops, and other safeguards 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

Activities covered in this section require personnel to be in the restricted space of the robot while arm power is on.

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 robot malfunctions or injury to personnel.
- Test the teach pendant controls 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.
- Test the E-Stops to ensure they are functioning correctly.
- While programming or teaching locations:
    - program the robot with all personnel outside the safeguarded area whenever possible.
    - use the teach pendant whenever working within the safeguarded area.
    - when two programmers work together, one teaching and one programming, the teacher should always carry the teach pendant so that an E-Stop is available; use reduced robot speeds (25% and lower).
- While servicing the robot arm:
    - the service person must have control of the robot, and the machinery in the workcell.
    - ensure that the robot is off-line. The arm must not be paused within, 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 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

Specifications

This chapter describes the following characteristics about the F3 robot arm:

- Physical Characteristics
- Dimensions
- System Control
- Robot Performance
- Workspace
- Reach
- Torque Ratings
- Joint Speeds and Acceleration Rates
- Resolution
- Load
- Location Characteristics
- Path Characteristics
- System Features

Physical Characteristics

F3 Arm

Weight	• 53 kg [115 lb]
Reach	• 710 mm [28 in] from joint 1 axis to tool flange
Configuration	• Articulated • Six degrees of freedom
Motor	• DC brushless motors
Transmission	• Harmonic drives on all joints • Roller chains on joints 2, 3 and 5
Gripper Controls	• Servo gripper connector (optional) • Double actuation pneumatic solenoid (standard)

Electrical Power

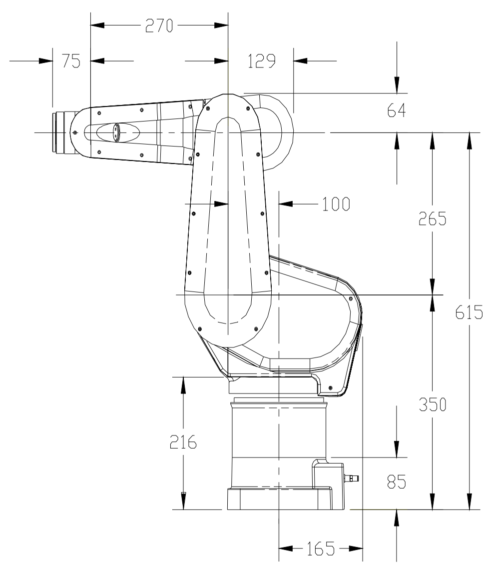
Maximum Load	• 1000 Watts

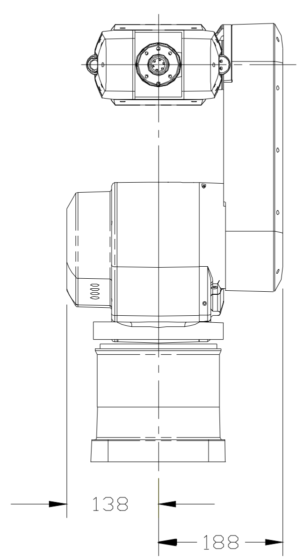
Dimensions

Arm

The dimension of each joint is measured from axis to axis.

Section	Dimension	
	mm	in.
Base (mounting surface) to shoulder	350	13.8
Shoulder offset (horziontal displacement from J1 axis to J2 axis)	100	3.9
Shoulder to elbow	265	10.4
Elbow to wrist pivot	270	10.6
Wrist pivot to tool flange	75	3.0





System Control

Software	• CROS - multi-tasking operating system • RAPL-3 - programming language
Robot Location Representation	• Joint angles • Cartesian (X, Y, Z, Z-rot, Y-rot, X-rot) • Variable tool transform • Variable base offset compensation
Motion Control	• 701 Hz PID servo loop rate • 100 Hz command generation rate
Motion Modes	• Joint interpolated (point to point) • Cartesian-interpolated (straight-line) • Continuous path • Relative motion • Blended motion (ONLINE mode) • Circular interpolation
Velocity Profile Types	• Trapezoidal • Parabolic
Teaching	• Off-line • Teach pendant

Robot Performance Summary

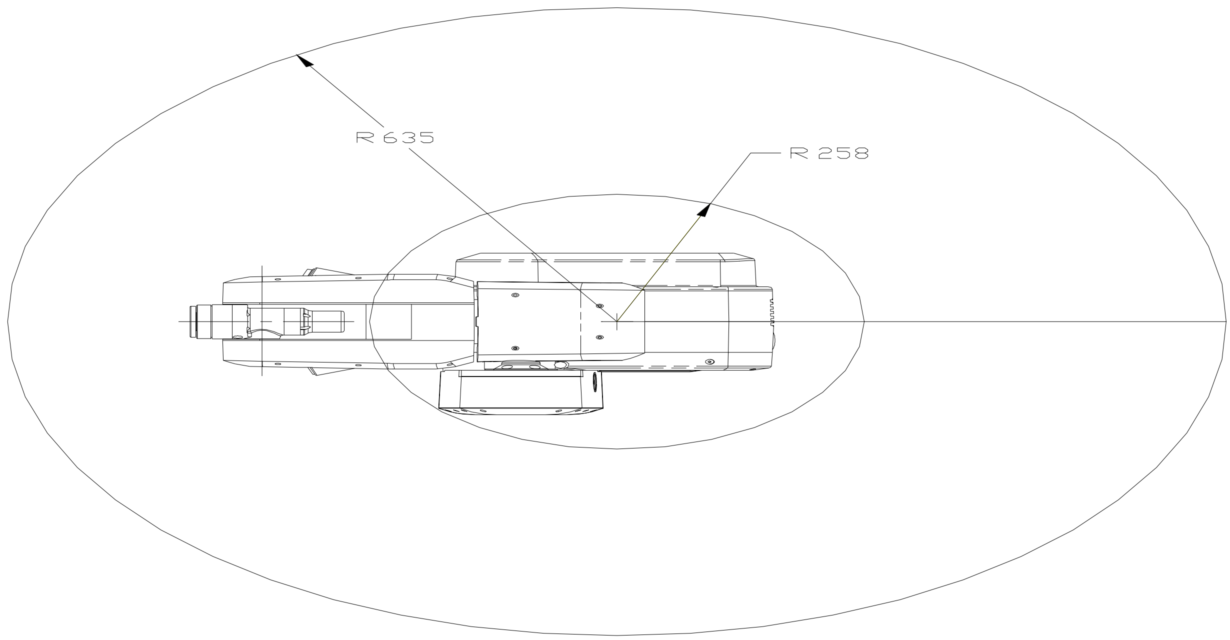
Payload	• 3 kg (6.6 lb)
Reach	• 710 mm [28 inch] nominal • 810 mm with gripper
Joint Speed	• Joint 1 - 240 °/s • Joint 2 - 210 °/s • Joint 3 - 240 °/s • Wrist rotate - 375 °/s • Wrist pitch - 300 °/s • Tool roll - 375 °/s
Joint Range	• Joint 1 ±180° • Joint 2 -135° to +45° • Joint 3 ±135° • Joint 4 ±180° • Joint 3 ±135° • Joint 6 ±51 turns or ±18,432°
Signal Performance	• 10 ms motion command update rate • 20 ms I/O scanning • 701 Hz servo update • 2^{24} position range (encoder counts per move) • serial encoder feedback
Repeatability[1]	• ± 0.05 mm (0.002”)

[1] Repeatability is the ability to return to a given location from a fixed starting location with all operating parameters fixed including speed, acceleration and control gains. It is quantified by the radius of a sphere.

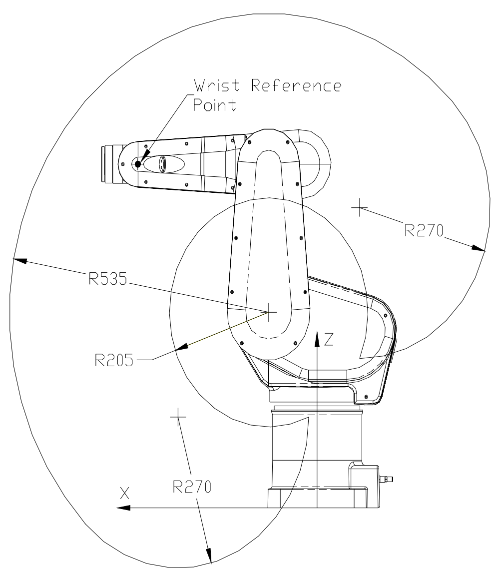
Workspace

Workspace is defined as the space that can be swept by the wrist reference point (the center of the wrist joint) plus the range of rotation or translation of each joint in the wrist (ISO 9946).

The following diagrams define the F3 workspace calculated from the wrist reference point.



The work envelope of the F3 arm: plan view (dimensions in mm.)

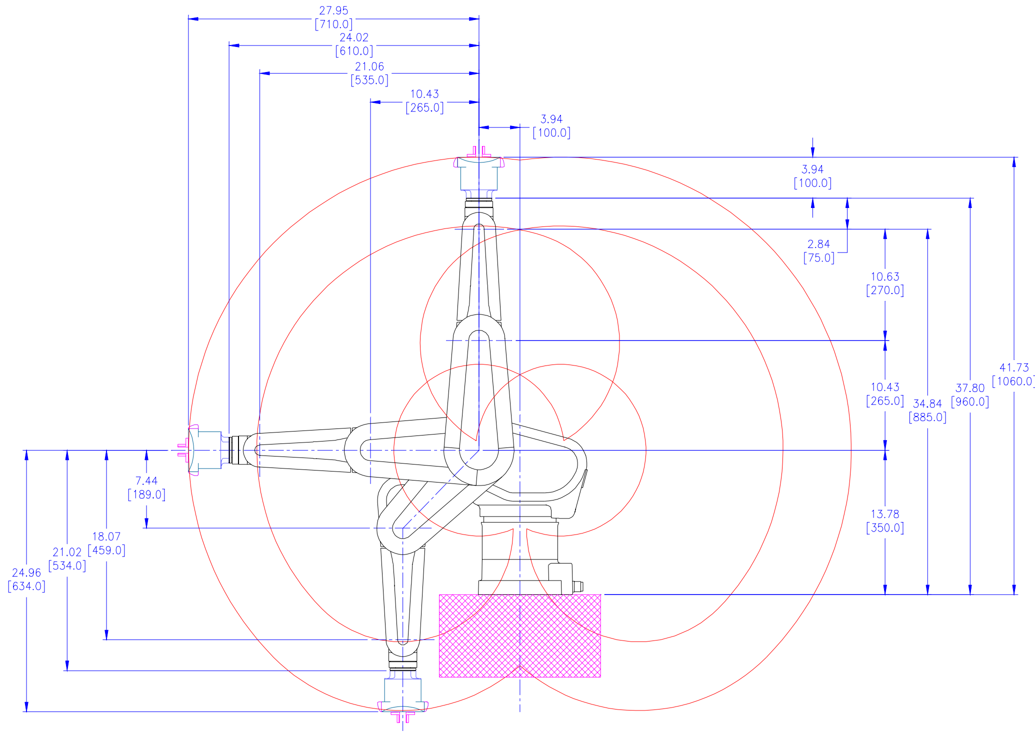


The work envelope calculated from the wrist reference point (dimensions in mm.).

Reach

The maximum reach of the arm is calculated horizontally forward and backward from the waist axis and vertically upward from the bottom of the base. The arm can reach points below the level of the bottom of the base.

F3 Maximum Arm Reach		
Horizontal Forward from the waist axis in the X-Y plane	to tool flange	710 mm [27.9 in]
	to finger platform of servo gripper	810 mm [30.9 in]
Horizontal Backward from the waist axis in the X-Y plane	to tool flange	357 mm [14.1 in]
	to finger platform of servo gripper	457 mm [18.0 in]
Vertical Upward along the Z-axis	to tool flange	960 mm [37.8 in]
	to finger platform of servo gripper	1060 mm [41.7 in]
Vertical Downward below the base level	to tool flange	534 mm [21.0 in]
	to finger platform of servo gripper	634 mm [24.9 in]



Reach of F3 with servo gripper (dimensions in inches [mm])

Torque Ratings

Arm Torque

The torque rating for each arm joint is defined in the following table.

Continuous Stall Torque Rating			
Joint	Axis	Torque	
		N-m	in-lb.
Waist	1	74.5	659
Shoulder	2	74.5	659
Elbow	3	74.5	659
Wrist rotate	4	16.6	147
Wrist pitch	5	16.6	147
Tool roll	6	16.6	147

Wrist Thrust and Torque

Default tool axis	Maximum Continuous Thrust		Maximum Continuous Torque	
	±N	±lb.	±Nm	±in-lb.
Tool yaw	30	6.6	16.6	147
Tool pitch	30	6.6	16.6	147
Tool roll	30	6.6	16.6	147

Motion Specifications

The following tables list the speed and acceleration ratings of the F3 robot.

Speed at End-Effector

Maximum Speeds	
Motion	
Compounded joint interpolated motions	3.9 m/sec
Average pick and place cycle time[2]	1.2 sec
End-effector speed in teach mode[3]	250 mm/sec

Joint Speeds

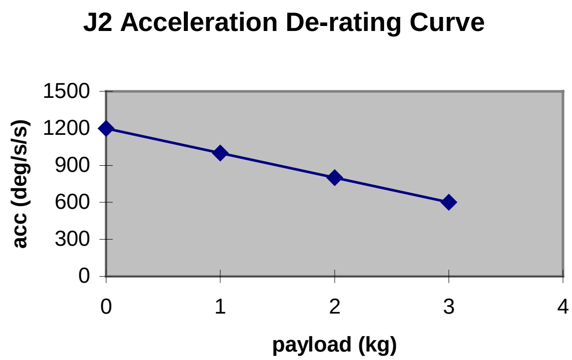
Individual Joint Speeds at 100% Program Speed				
Joint	**Axis**	**Motor rpm**	**Gear Reduction**	**Maximum Speed °/s**
Waist	1	4000	100:1	240
Shoulder	2	4000	100:1	210
Elbow	3	4000	100:1	240
Wrist rotate	4	5000	80:1	375
Wrist pitch	5	4000	80:1	300
Tool roll	6	5000	80:1	375

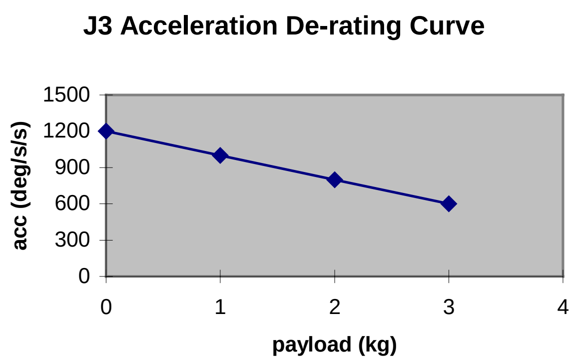
Joint Accelerations

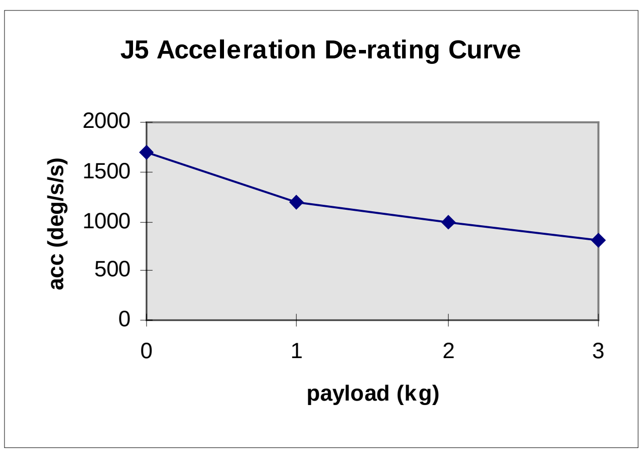
Acceleration Rates		
Joint	**Default °/s²**	**Maximum °/s²**
Wrist	879	1,757
Shoulder	879	1,757
Elbow	879	2,636
Wrist Rotate	1,098	3,295
Wrist Pitch	1,098	3,295
Tool Roll	1,098	3,295

While the above table states the acceleration limits allowable by the system's Motion Engine, the following de-rating curves are more practical guidelines for acceleration settings in order not to prematurely wear mechanical components in the robot.

[2] Based on a trajectory of one inch up, twelve inches across and one inch down.
[3] A limit imposed by regulatory guidelines.







Slew Time

Slew time is defined as the rate at which the arm can be driven from limit to limit over a dynamic range. Assuming that a joint is starting and stopping at rest, and that the acceleration profile is parabolic, slew time can be calculated as follows:

slew time = (Amax *x* Slew Angle + $Vmax^2$)/ (Amax *x* Vmax)

where Amax is maximum acceleration and Vmax is maximum joint speed.

The minimum slew time for each joint is defined in the following table.

Minimum Slew Time For Each Joint					
Axis	Slew Angle	Max. Acceleration	Max. Speed	Slew Time	Slew Speed
	°	°/s^2	°/s	s	°/s
1	360	1,757	240	1.7	212
2	180	1,757	210	-	184
3	270	2,636	240	1.3	208
4	360	3,295	375	1.1	327
5	270	3,295	300	1.0	270
6	eg. 180	3,295	375	0.6	300

Resolution

Resolution is the smallest increment of motion or distance that can be detected or controlled. Arm resolution is dependent upon the distance between the center of the tool flange surface and the center of gravity of the payload, as shown in the rotational and positional tables.

Rotational Resolution Limits		
Joint	**Axis**	**Resolution (°)**
Wrist	1	0.0018
Shoulder	2	0.0018
Elbow	3	0.0018
Wrist Rotate	4	0.0022
Wrist Pitch	5	0.0022
Tool Roll	6	0.0022

Positioning Resolution

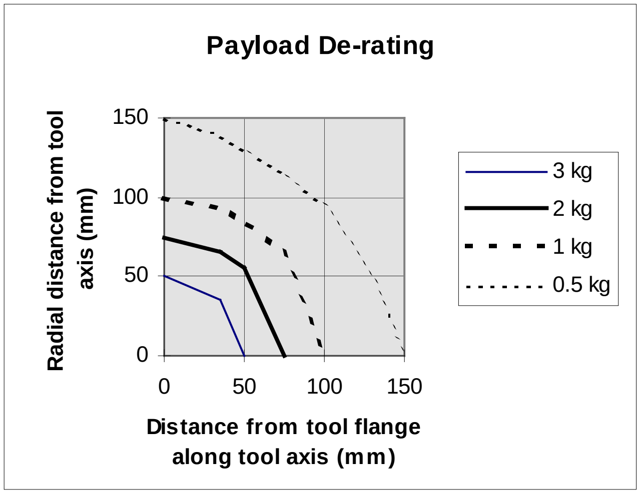
The positioning resolution for the arm is based on the rotational resolution for each joint. It is calculated at the tool flange with the arm in the ready position, pointing down.

World Coordinate	Positioning Resolution at the Tool Flange		
	degrees	mm	inch
X	-	0.008	0.0003
Y	-	0.014	0.0006
Z	-	0.011	0.0004
Z-rot	0.0022°	-	-
Y-rot	0.0022°	-	-
X-rot	0.0022°	-	-

Load

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

The following de-rating curves depict the variation of the payload capacity of the F3 robot with distance from the tool flange and axis.



System Features

Absolute Encoders

Principles of Operation

Absolute encoders are used in the F3 robot. Their design is based on using a low resolution gray scale disk in conjunction with a high resolution incremental disk to detect absolute position within one turn.

Multi-turn data - the number of turns made by the encoder shaft - is maintained by electronic counters within the encoder. When controller power is not available, a set of three (3) nickel-metal-hydride batteries located in the fibre drawer at the base of the robot provide power to the encoders. The batteries ensure that the multi-turn data is kept valid if the arm is moved when power to it is off. The batteries are trickle-charged when the controller is on.

The encoder also has an internal capacitor, which keeps the multi-turn data valid for up to 10 minutes, providing ample time to change batteries in the fibre drawer if needed.

Important Encoder Characteristics

- Single turn resolution - 11 bits or 2048 counts.
- Maximum number of turns is 8192 (13-bit count).
- Absolute position.
- Typical active battery voltage (controller on) - 4.5 V.
- Typical resting battery voltage (controller off) - 3.6 V.
- Battery alarm-on voltage - 3.1 V to 3.4 V. (See below.)
- Battery alarm-off voltage - 3.2 V to 3.6 V. (See below.)
- Battery error voltage - 3.0 V. (See below.)
- Low current consumption in battery mode - 150 µA max.
- A minimum of 6 continuous weeks in battery mode before encoders go into a state (i.e. loss of robot calibration) where they require reset of multi-turn data.
- Minimum of two days of charging with controller on after one week or longer in battery mode.
- Encoders should be reset with the robot in the *calrdy* configuration. The calibration markers are also installed while the robot is in this configuration. This facilitates *re-homing*.

Encoder Battery Issues

The encoder signals an alarm if the collective battery voltage drops below a threshold that varies between 3.1 V and 3.4 V. This alarm will be detected and reported by controller startup diagnostics. The alarm is turned off when the voltage is restored to a level above a threshold between 3.2 V and 3.6 V. Users should heed the warning and either keep the controller on continuously for at least 72 hours, or replace the batteries if they have been in use for at least 1 calendar year.

If the battery voltage drops below 3.0 V, the encoder will enter an error state and will no longer provide proper feedback. Any single encoder entering this error state will cause the system to stop providing power to the arm. Encoder fault will be reported by startup diagnostics. The amplifiers will shut down and prevent engagement of arm power.

To remedy the situation, the user should first decide whether the batteries need to be replaced (replacement is recommended if they have been in use for at least one year) or simply recharged. Recharging can be accomplished by keeping the controller on for at least 72 hours, but it is not necessary to wait for completion of this process to use the robot. Subsequently, the encoders need to be reset.

Arm Power Light

There is an amber arm power light which flashes when either:

- arm power is on, or
- the general brake release button is depressed (see below).

The light serves as a warning to stay clear of the workcell. Anytime the light is flashing, the robot is capable of motion. Extreme caution is required.

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. Brakes are installed on joints 1, 2 and 3. A 24 Volt DC signal energizes a magnetic solenoid which unloads the clamp.

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

Brake Release

While controller power is on and arm power is off, the brakes can be released by pressing the red buttons on the underside of the large aluminum cover of the shoulder casting of the robot. There is one release button for each of the lower joints, which must be engaged at the same time as the general brake-disable button. The arm power light turns on when this button is depressed.

Warning! Use the brake release buttons only if the arm power light is off. Be prepared for sudden robot motion due to gravity when brakes are released.

Note: In early F3 systems, there is an additional release-enable button which must be pressed simultaneously as the brake release button for a specific joint.

Chain Tensioners

In additional to harmonic drives on all joints, the F3 robot also has chain drives on joints 2, 3 and 5. These chains are held in tension by nonlinear springs which roughly maintain the required tension even if the chains stretch over time.

Embedded Control and Power Electronics

One of the F3's innovative features is the embedded servo control and power electronics in the robot arm. This design reduces the computational load on the controller, the volume and frequency of communications between the robot and controller as well as the number of conductors in the umbilical cable. In fact, the robot and controller communicate over a pair of optical fibres. This improves the electrical noise immunity of the umbilical cable.

The embedded electronics consists of two amplifier modules, a servo gripper I/O (SGIO) board, a double-actuation solenoid, a power conditioning module (PCM) and a fibre board.

Amplifier modules

Each amplifier module controls three joints. The waist module which can be found inside the shoulder casting provides servo control of and power to joints 1, 2 and 3. In addition, it controls the brakes of these joints.

The wrist amplifier module provides the same functions for joints 4, 5 and 6 except these joints do not have brakes. It is located in the side of the wrist without the air manifold.

Servo control in the F3 robot is based on the classical PID (proportional, derivative and integral) scheme. Absolute encoders (defined earlier) provide input to this DSP-based controller. Its outputs are current commands to the PWM (pulse width modulation) amplifier stage which switches current in the motors using Hall sensor feedback.

Warning! Make sure the wrist is kept away from liquids and collision. *Entry of liquids into the wrist may lead to shorts in the wrist amplifier module and other embedded electronics. The plastic wrist cover also cannot adequately protect the electronics from damage in case of collision. The waist amplifier module is in the shoulder casting, and is better protected, but precautions are still necessary.*

SGIO

The servo gripper input/output board consists of control electronics to provide four (4) digital input channels and four (4) output channels in addition to control of the servo gripper, if there is one (see below for more information on end-of-arm I/O and servo gripper options). In the default configuration, two of the digital output lines are used to switch a double action servo valve.

Pneumatic Valve

A double-actuation pneumatic valve is provided in the default configuration of the F3 system and maintains the state of an air-driven tool even after controller power is shut down. This mechanism is controlled by the SGIO board and supplied by an internal 3 mm air line. The outlets at the air manifold are designed for 3 mm lines. The inlet at the base next to the umbilical receptacle is designed for a 6 mm hose.

The pneumatic valve is the default end-effector. It is controlled by the first two output channels of the SGIO interface. Therefore, do not try to command these two I/O channels if the system is configured for a pneumatic tool.

PCM

The power conditioning module is located inside the shoulder casting. It converts and distributes all power lines coming into the robot. It is also the junction for the brake release lines for the lower three joints. In addition, it contains the circuit which sinks the power generated when any of the six motors decelerates rapidly (a phenomenon known as degenerative braking).

Fibre Board

The fibre board converts the optical signals from the umbilical cable to electrical serial signals conducted on two twisted pairs, one for communications from the controller to the robot and the other in the opposite direction. In addition, it serves as the first junction for incoming power lines and also includes charging electronics for the encoder backup batteries.

CHAPTER 5

Installation

This chapter describes how to:

1. Unpack the robot system.
2. Mount the robot arm.
3. Mount the controller.
4. Connect the umbilical cable.
5. Install the AC fuses and voltage selector.
6. Ground the system.

Note: Perform the above steps in sequence.

If you are customizing your installation, refer to Chapter 6 on Customizing Installations.

Unpacking the F3 System

Unpacking and packing instructions are provided herein for the sake of completeness. The F3 system is shipped with independent unpacking instructions attached to an exterior surface on the robot container, so that users have access to them prior to opening the container.

To unpack the robot, you need:

- A Philips screwdriver.
- A 5/16 inch hex key (supplied inside robot container).
- The assistance of at least one additional person.

Note: As you unpack the arm and controller, keep all packaging materials.

Keep the system together

The arm and controller you have received have been fine-tuned and burned-in together as a single system. If you have purchased multiple F3 systems, do not randomly mix and match controllers and robots.

Serial numbers

The serial numbers for the arm and for the controller are printed on the plates attached to the arm and to the controller. The serial numbers are also listed on the sheet included in the shipping containers. Keep this information in a secure and handy location as you will need it for calls to the CRS Customer Support department.

Unpacking the Arm

The plywood crate consists of three parts:

- one platform (the base of the crate holding the arm) with three (3) fixed side panels
- one removable top panel
- one removable front panel.

Along the perimeter of both removable panels, there are eight (8) Phillips screws marked by black circles.

1. With the Phillips screwdriver, remove all eight (8) black-circled screws.
2. Remove the top/side and set it aside.
3. Using the Phillips screwdriver, loosen the clamps holding down the 5/16 inch hex key.
4. Using the hex key, remove the four (4) socket head cap screws holding the arm to the platform.

Warning! The robot may tip easily after removal of the socket head cap screws*. Make sure no one and no object is in a position to be pinched by the robot.*

5. Verify that the T-nuts holding the cap screws remain embedded in the bottom of the crate.

Lifting the Arm

1. Ensure that the workcell mounting platform is ready and cleared of any debris.
2. Carefully lift the arm from the crate to your workcell mounting platform.
3. Unscrew the eyebolt from the upper bolt hole of the shoulder casting and screw it securely into the lower bolt hole on the front of the shoulder casting.

A crane or hoist with a lifting capacity of at least 100 kg is recommended to lift the robot. An eyebolt is provided to assist in this process. Lift the robot only as high as necessary to clear obstacles. This will reduce the possibility of injury and damage to the robot should the robot fall. Do not spin the robot while it is hoisted. This may cause the eyebolt to loosen.

Warning! Avoid manually lifting the robot. *The mass of the robot is approximately 53 kg [115 lb]. If a crane or hoist is not available, at least two people should work together to lift the robot.*

Warning! Check that the eyebolt is secure before using it for lifting. *The eyebolt may have come loose during shipping. To avoid injury, it is important that it is securely attached to the robot.*

Warning! Do not spin the robot while it is hoisted. *This may cause the eyebolt to loosen and result in the robot falling.*

If manual lifting is unavoidable, observe the following guidelines:

- Robot can be easily damaged from being dropped.
- Two or more persons are necessary.
- Grasp the robot under the cast aluminum base, the underside of the lower section of the lower link, or the eye-bolt using the strap provided.
- Do not grasp the robot under the motor covers on the side, by the wrist, or by gripper.
- Have a cart or platform ready. Do not manually carry the arm any distance.
- Lift the robot only as high as necessary to clear the obstacles.

Do NOT lift the arm by:

- the shoulder covers on the sides of the shoulder casting, or
- the wrist or lower link as they are held in position by brakes which cannot hold the weight of the lower part of the robot.

Danger! Remove the eyebolt. *The wrist of the arm can easily collide with the eyebolt if it is left in the upper bolt hole. The eyebolt is provided only to assist in the installation of the arm.*

Collecting the Shipping Materials

Keep all shipping materials.

Warning! Do not use the shipping cap screws to fasten the arm in your workcell. *The cap screws used to ship the arm are 5/16 inch cap screws. They are not adequate to fasten the arm in the workcell. Workcell fastening requires four M12 x 1.75 x 50 mm long cap screws.*

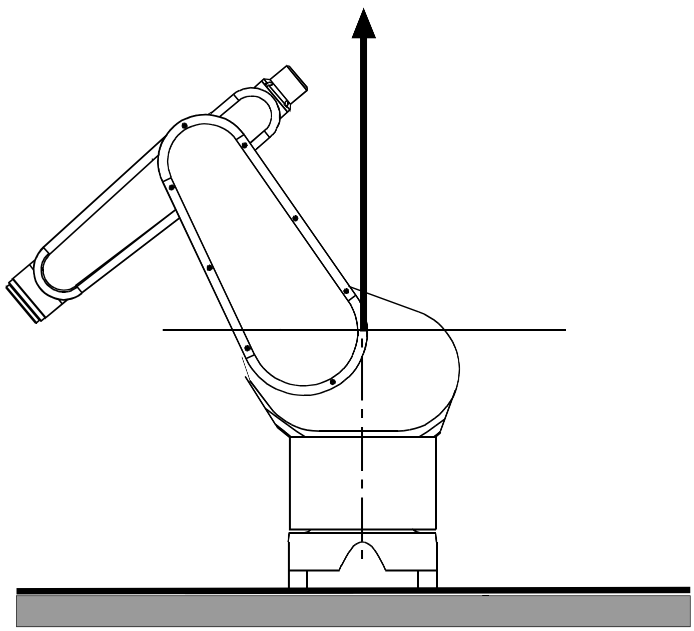
1. Replace the foam pad, four cap screws, and hex key in the crate.
2. Replace the cover of the crate on the platform of the crate, aligning the "A" marks.
3. Replace the black-circled screws.
4. Store the crate.

Mounting the Arm

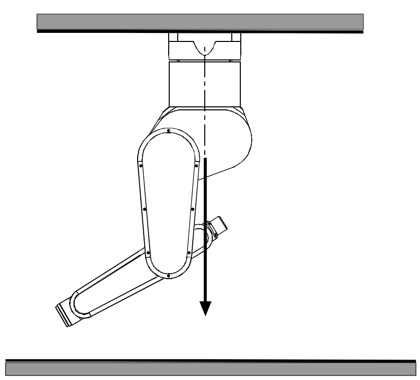
The arm should be firmly mounted on a supporting platform rigid enough to support the arm and to withstand inertial forces during acceleration and deceleration.

Positioning the Arm

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



Upright configuration



Inverted configuration

When the arm is in the upright position, its base occupies a portion of a table surface limiting the available work area.

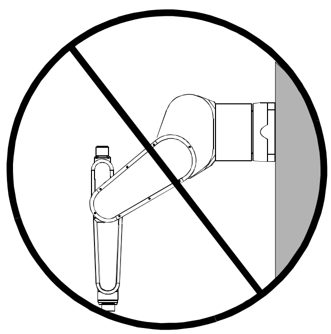
Inverted Configuration

When the arm is in the inverted configuration, a greater portion of the table surface is available as workspace. When using this configuration, a base offset is strongly recommended. See the RAPL-3 manuals for more information.

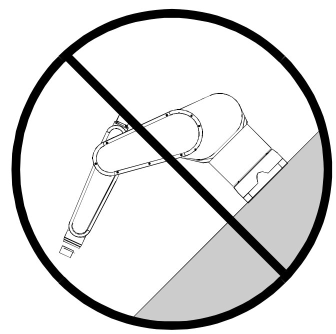
Other Mounting Positions

Do not install the arm in the following positions.

***Warning! Do not install the arm on a wall or incline**. Gravity will place excessive stress on joint 1, leading to premature failure. The brakes in joint 1 will not support the arm in this orientation.*



Wall Mounting



Inclined Mounting

Mounting Platform

There are two methods for preparing the mounting platform:

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

Tip: Use dowel pins to align the arm in case precise relocation is necessary after dismounting for service, repair or other reasons.

Procedure:

To mount the arm on a platform:

1. Prepare a mounting platform.
2. Mount the arm on the platform.

Before you begin:

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

You need:

- Machine tools to drill, tap, and ream

- A 10 mm hex key

Preparing a mounting platform

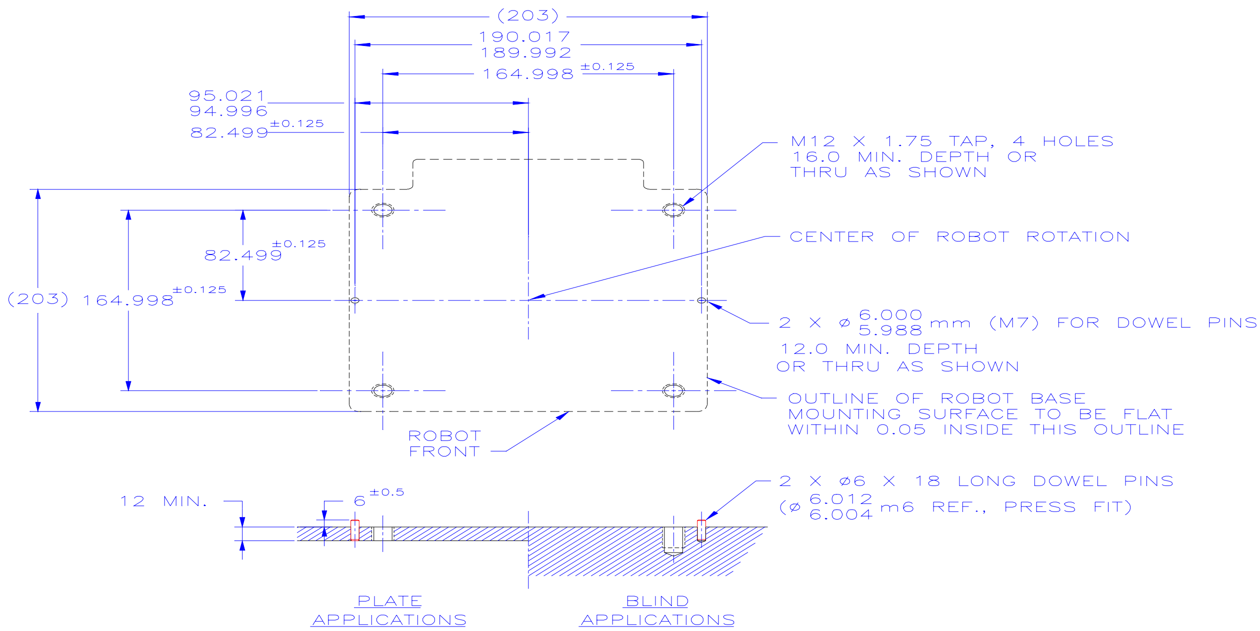
1. Referring to the drawing below, drill and tap four holes for M12 x 1.75 screws.
2. If you require precise mounting, drill and ream two holes for M6 dowel pins according to the drawing.
3. If you are using a mounting plate, prepare it following the above steps. Firmly fasten the plate to your bench, bracket or similar supporting structure. Pin the plate if necessary.

Mounting the arm on the platform

To mount the arm on the platform:

1. Install the dowel pins (if used).

   Note: The dowel pins must be in the holes of the platform before lifting the arm onto the platform.
2. With a crane or at least two people, lift the arm onto the mounting platform.
3. Secure the arm to the platform with 4 x M12 x 1.75 x 50 mm long, stainless steel 18-8 (A2), hex socket cap screw. A mounting kit consisting of these fasteners and dowel pins is available from CRS.



ROBOT MOUNTING PLATFORM REQUIREMENTS
—METRIC FASTENER VERSION
—DIMENSIONS IN MILLIMETERS

Connecting the Umbilical Cable

The umbilical cable connects the controller to the robot arm.

Before you begin:

- Ensure that the controller main power switch is off.
- Ensure the location for the cable is protected and does not leave the cable exposed to damage.
- Allow adequate clearance (30 cm or 12 in.) for connector and strain relief at both ends of the cable.

To connect the umbilical cable to the controller:

1. Align the connector with its receptacle on the controller.
2. Push the connector into the receptacle on the controller.
3. Secure the connector with the metal latch. Apply necessary but not excessive force, especially if the connector and receptacle are not properly aligned.

Disconnecting the Umbilical Cable

1. Ensure that the controller's main power switch is off.

Warning! Turn off power whenever disconnecting any cable from the controller.

2. Open the latch that secures the connector. Pull the connector straight out of its receptacle.

Grounding the System

Ensure that the AC power supply is properly grounded. The incoming AC plug has three wires: live, neutral, and a safety ground. All three wires must be connected. The safety ground line provides the operator protection against the exposure to dangerous voltage levels in the case of a fault. In addition, the safety ground is required to reduce electromagnetic emissions.

The safety ground line of the controller is directly connected to the robot via the umbilical cable. As a result, it is important that the robot be mounted on a station that is at the same voltage potential as the ground of the controller. Ground the station or equipment that the robot arm is to be mounted to, to an industrial grounding rod that is common to the AC ground of the controller, or to the same utility ground used for the controller. Failure to do so may result in the risk of fire due to the high currents that may flow in the chassis ground line of the umbilical cable as a result of the difference in ground potential.

The C500C controller was designed to be used with a grounded AC system. *Failure to provide a grounded AC input may result in electric shock, and damage to the controller.*

The F3 Robot must be mounted on a station which is grounded to the same voltage potential as that of the controller ground. *Failure to do so may result in the risk of fire due to the high currents that may flow in the chassis ground line of the umbilical cable as a result of the difference in ground potential.*

The robot arm is grounded to the controller through a dedicated chassis ground in the umbilical cable.

CHAPTER 6

Customizing Installations

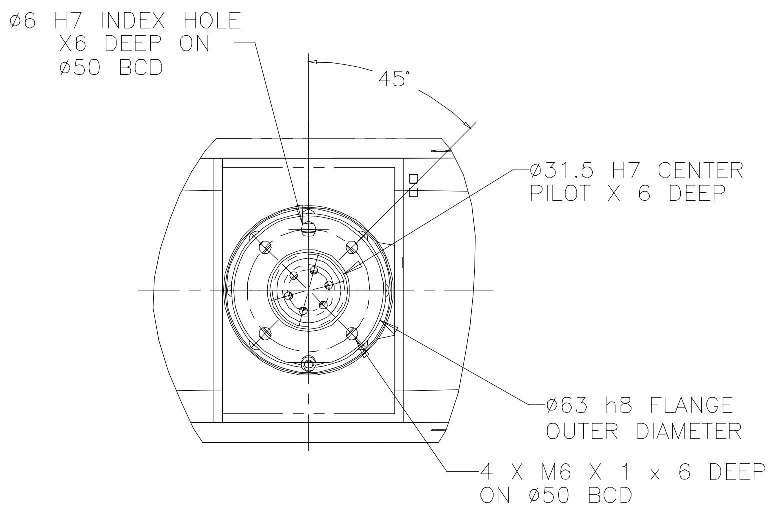
This chapter discusses how to add features to the F3 system including:

- Installing a Tool on the Robot.
- Connecting a Hose to the Pneumatic Port.

Installing a Tool on the Robot

To make a robot useful, a tool such as a gripper, grinder, deburing tool, etc. must be attached on the face of the robot's tool flange.

The tool flange of the F3 robot is designed to the ISO standard for robot tooling. The drawing shows its relevant dimensions.



The F3 robot provides a dual port pneumatic valve for driving pneumatic grippers and similar tooling. The ports are configured with opposing actuation, such that when one port is open, the second is closed and vice versa. When the controller power is off and air pressure is applied for the first time, the ports will assume one of these states. If controller power is lost, the last state of the ports does not change upon restarting the system.

RAPL-3 commands support the enabling/disabling (ON/OFF) of this air port. Refer to the *Application Development Guide* for details on gripper and tooling commands.

To install a CRS Servo Gripper, refer to the *Servo Gripper User Guide*.

Settings of the F3 Robot’s Dual Air Valve Port

State	Port A	Port B	Notes
1	open	closed	GRIP_OPEN
2	closed	open	GRIP_CLOSE
power-up	unknown	unknown	• the power-up state is unknown, however the last state will be maintained • the air valve in not powered, thus maintaing the last state • once a GRIPper command is issued, the appropriate air valve is powered
power-down	last state	last state	• at power-down, the air valve will maintain its current state; at the next power-up, this last state will be maintained. However, it will not be known to the controller • the air valve loses power, however the air pressure maintains last state of valve
E-Stop	last state	last state	• the last state of the port is maintained • power to the appropriate valve is not removed

Custom Designed Tools

Custom tooling such as a gripper should be designed and constructed so that:

- a power failure does not result in a hazardous condition such as dropping the payload (this may be acceptable if the payload is not dangerous, or the work cell is designed to contain a lost payload);
- static and dynamic forces exerted by the load and the gripper together are within the load capacity and dynamic response of the robot.

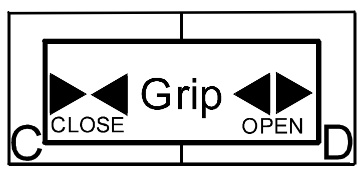
Warning! Ensure that arm power is off when entering the robot’s workspace to install the robot tooling. *Refer to the operation and safety instructions on page 29,* ***Working Within the Robot’s Workspace****.*

Warning! When attaching the tooling to the tool flange, ensure that the mounting screws do not extend beyond the depth of the flange. *Failure to do this could result in damage to the joint 6 axis motor and the tool flange.*

Connecting a Hose to the Pneumatic Port

To connect the pneumatic gripper:

1. Screw a barbed fitting into each of the two air ports of the pneumatic connector on the wrist of the robot.
2. At the arm end of the gripper's air hose, separate the two air hoses for approximately 25 mm. [1 in.] 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 3 mm [~$^1/_8$ in.] NPT air port at the rear of the robot base. Use only dry, clean, filtered, non-lubricated air at a maximum of 100 psi [689 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.
     Note: In order for these buttons to work correctly, the controller must be configured for an air gripper (default) by using the ash command **gtype air**.
   - Verify that the Open key opens the gripper and the Close key closes the gripper.



The teach pendant's gripper close and open keys.

   - 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.

Enabling the Gripper

The default gripper type is air; hence, there is no need to change the setting if a pneumatic tool is used. But if necessary, enable a pneumatic tool as follows:

1. Inside the terminal window in Robcomm 3, press <Enter>.
2. In an application shell, type gtype air or gtype 0 to set the default gripper type to an air gripper.

To enable the servo gripper.

1. Inside the terminal window in Robcomm 3, press <Enter>.
2. In an application shell, type gtype servo or gtype 1 to set the default gripper type to an air gripper.

CHAPTER 7

Commissioning the Robot

Commissioning is about starting up the robot system and testing it to ensure that it is functioning properly. The procedure should be carried out in the following sequence:

1. Verify Installation.
2. Power-up the Controller.
3. Verify that the controller is connected to a Windows PC via a RS-232 serial cable.
4. Start up Robcomm 3, or your choice of terminal emulator.
5. Start the Application Shell.
6. Check All E-Stops.
7. Move Out of the Shipping Position.
8. Check the Operation of the Live-man Switch.

Verifying Installation

Note: Refer to and follow the Safety Operation Checks on page 28 before operating the arm.

Checking Arm and Controller Installation

Verify that following:

- The robot has been mounted securely with four M12 fasteners each with at least 2 cm (0.8”) of thread engagement.
- The umbilical cable is connected at both ends, provided adequate clearance and otherwise protected from damage.
- The fuses and voltage selector have been properly installed.
- The system has been connected to a properly grounded AC outlet of correct electrical rating.
- Robcomm 3 has been installed on a PC which is connected to the controller via the front panel console port.

Note: If you do not have a computer with Robcomm 3 or compatible terminal emulator, you can test the arm using a teach pendant.

Powering Up the Controller

During the boot-up sequence of the controller, diagnostic information is displayed at the controller's front panel hexadecimal display and at the terminal window of Robcomm 3.

To check the controller power-up sequence:

1. Switch on main power at the switch located on the left side of the controller front panel.
2. Observe the ICD panel on the front panel. After about 10 seconds, the display should read "C500C CROS OK".
   - If the controller fails during the power-up sequence, the display will contain a message describing the problem.
   - If nothing appears on the front panel display, it is likely AC power is not connected, a fuse is either missing or blown or there is another power supply related problem. Refer to Chapter 10 for troubleshooting instructions.
3. Observe the messages displayed at the terminal window in Robcomm 3.
   - If you are using Robcomm 3 and a small dialog box is displayed at the beginning when the controller first starts up, just click OK.

   The boot-up sequence stops after "init: starting an interactive shell" and "connecting to ACID" are displayed and a $ (dollar sign) prompt appears. You can scroll back through all the messages using the terminal window's scroll button.

4. If you do not have a $ prompt, press the Enter key.
5. If an error message is displayed on the terminal window, or if the message below is not displayed, refer to Chapter 10 on troubleshooting.

   Amplifier status

   1……OK 2……OK 3……OK

   4……OK 5……OK 6……OK

Starting the Application Shell on the C500C Controller

Checking and operating the arm is done from an application shell (ash). Initial operation is done from the application named test.

To start the application shell:

At the $ prompt, enter:

```
ash test
```

The name test can be replaced by that of another application. Successful transfer to ash and the selected application is signaled by a change to the new prompt consisting of the name of the application plus the symbol >, for example, test>.

Checking All E-Stops

Use the procedure below to check each E-Stop device to verify that it works.

Note: Striking an E-Stop button does not remove power to the servo gripper. As a safety feature, motor power to the gripper is maintained in this situation to not release the payload.

Before you begin:

- Ensure that the controller is powered on, the operating system has booted up and the application shell has been started.

To check E-Stops:

1. Reset all the E-Stops to complete the E-Stop circuit. The E-Stop buttons on the controller and on the teach pendant are reset by twisting until they spring out.
2. Turn on arm power at the arm power switch, located near the upper right corner of the front panel of the controller. You should hear a click from the arm as the brakes release and the controller relays activate. The LED in the arm power switch is now continuously lit and the arm power beacon on the robot is flashing.
3. One at a time, test each stop or equivalent safety mechanism. Standard E-Stops are: front panel E-Stop, teach pendant E-Stop, and live-man switch. Additional E-Stops or equivalent devices may be connected through the SYSIO connector.
    a. Trigger an emergency stop by striking the E-Stop button, opening an interlocked door, interrupting a light beam, stepping on the pressure-sensitive mat, etc.
    b. When you strike the E-Stop, you should hear a click from the arm and the controller representing engagement of brakes and disengagement of relays. Check that both the LED in the arm power switch and the arm power beacon on the robot are off.
    c. Reset the E-Stop.
    d. Turn on arm power.
    e. Repeat steps a to d until all E-Stops and equivalent safety mechanisms are checked.

Scheduling Regular Checking of E-Stops

Establish a schedule of regular checks of E-Stops and other safety measures throughout the operating life of the robot system.

Moving Out of the Shipping Position

The arm is shipped in a position for unpacking and installation. Moving it into a standard configuration will facilitate robot applications. This can be accomplished from an application shell or using the teach pendant. (You may not be ready to use the teach pendant if you have not received training or read the *Teach Pendant* sections of the *Application Development Guide*.)

Warning! Move the arm carefully. *The arm is capable of a wide range of motion and can collide with itself, the workbench or other objects in the workspace. Damage and/or failure may result from any collision.*

Warning! Use the application shell (ash) with caution. *When a command is entered from* ash*, the arm continues to move until that command is completed. If a collision is going to occur, before the command is completed, hit an E-Stop.*

Before you begin, ensure that:

- the controller is powered on.
- the operating system has booted up.
- the application shell has been started.
- the teach pendant or the over-ride plug is in the teach pendant connector.
- E-Stops are reset.
- arm power is on.

To move out of the shipping position:

In ash, enter:

```
ready
```

This command results in the robot moving into the position with all joints at 0° except for joint 3 which is at -90°.

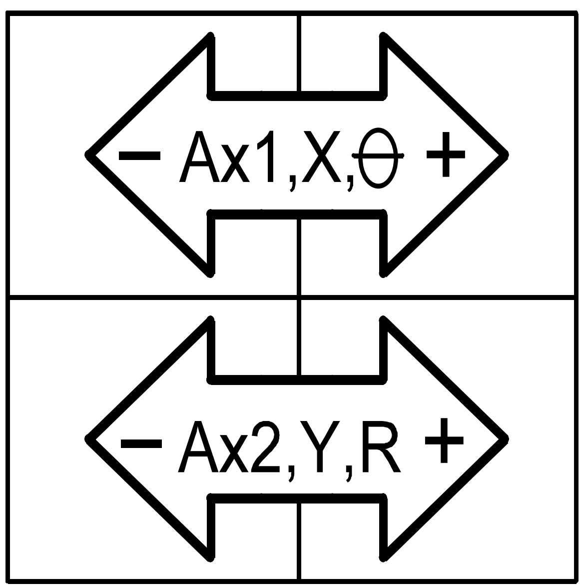
Checking the Live-man Switch

This procedure allows you to test the teach pendant live-man switch to verify that it works.

You cannot move the robot using the teach pendant without applying reasonable but not excessive force on the live-man switch. Either insufficient or excessive force will cause loss of arm power.

To operate the live-man switch:

1. Ensure that the teach pendant is connected to the controller.
2. Ensure that the pendant is active. In ash, at the prompt, enter `pendant`. The teach pendant LCD displays Application, the application name such as test and function options.
3. Navigate to a screen for motion by selecting F1 for Edit and, at the next screen, select F3 for Motion.
4. At the Motion screen, use F3 and F4 to scroll through types and modes of motion. Select Velocity and Joint.
5. Verify that arm power is on.
6. While holding the live-man switch, press on the positive or negative button of any one of six pairs labeled Ax1 to Ax6 to move one of the six joints. For example, to move joint 2 up, press on the + button of the Ax2 pair shown below.



7. Release the live-man switch while the arm is still moving. Arm power should shut off. Verify that both the LED in the arm power switch and the amber arm power light on the robot are both off. Verify also that the lower three joints are held in place by their respective brakes.
8. Restore arm power by pressing the arm power switch on the front panel of the controller.
9. Command the robot to move once again with the teach pendant. While the robot is moving, squeeze the live-man switch tightly. Arm power should shut off. Repeat the verification procedure in step 7 above.
10. Restore arm power once again.

11. Without applying pressure to the live-man switch, press an axis key. The arm should not move and there should be an audible beep indicating that the commanded motion cannot be executed.

CHAPTER 8

Operating Basics

This chapter describes how to operate the robot. Emphasis is placed on F3 specific topics, namely:

- units
- coordinate systems and reference frames
- motion modes
- system operation.

For complete instructions on development of robot applications, refer to the *Application Development Guide* and the *RAPL-3 Language Reference Guide*.

Units

For the F3 system, the default unit of distance is the millimeter (mm).

To change units in a RAPL-3 system, use the command /diag/setup.

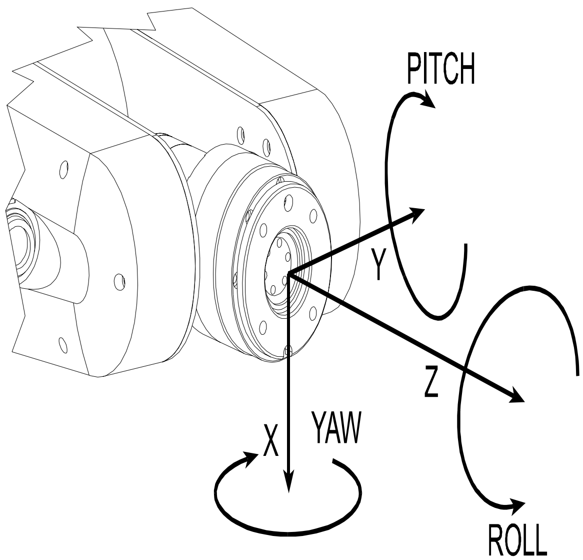
For further information, see the *Application Development Guide* and *RAPL-3 Language Reference Guide*.

The degree (°) is the only unit available for describing joint and orientation angles.

Coordinate Systems and Reference Frames

The concepts of coordinate systems and reference frames are fundamental to commanding robot motion. If you are not familiar with them, refer to the *Application Development Guide* and reference texts on fundamental principles of robotics (e.g. Craig, J.J., *Introduction to Robotics, Mechanics and Control*, Addison and Wesley Publishing Company), or contact the CRS Sales Department to inquire about training.

In general, commanding the F3 robot to move is no different than with other CRS robots. However, one significant distinction is the definition of the tool frame which, unlike other CRS systems, follows the ISO convention of aligning the tool z-axis with the default tool axis.



The F3 tool frame of reference

Motion Modes

Refer to the *Application Development Guide* for command line instructions on how to move the robot and teach locations.

F3 Joint Command

Individual joints can be commanded to move in ash using the joint command with the joint number of the displacement angle as arguments. For example, the command:

```
joint 3, 45
```

results in joint 3 moving up by 45°.

F3 Motor Control

In the motor mode, joint motion is achieved by commanding a motor to move by a desired number of pulses. For example, the command:

```
motor 3, 1000
```

moves the joint 3 by 1,000 encoder pulses.

It is important to note that the sense of direction of the motor command is not necessarily the same as of the joint command. For example, a positive motor command will move joint 6 in the opposite direction as a positive joint command. The following table summarizes this relationship.

joint	relative direction of joint and motor commands
1	opposite
2	same
3	same
4	opposite
5	same
6	opposite

In specifying the number of pulses for a motor command, the speed reduction ratio of the joint should be taken into account along with the fact that there are 2,048 encoder pulses for every full turn of a F3 motor. The following table re-states this ratio for every joint and also provides, as an example, the number of pulses equivalent to a +90° joint move.

joint	reduction ratio	number of pulses equivalent to +90°
1	100	-51,200
2	100	51,200
3	100	51,200
4	80	-40,960
5	80	40,960
6	80	-40,960

Cartesian Motion Commands in the Tool Frame

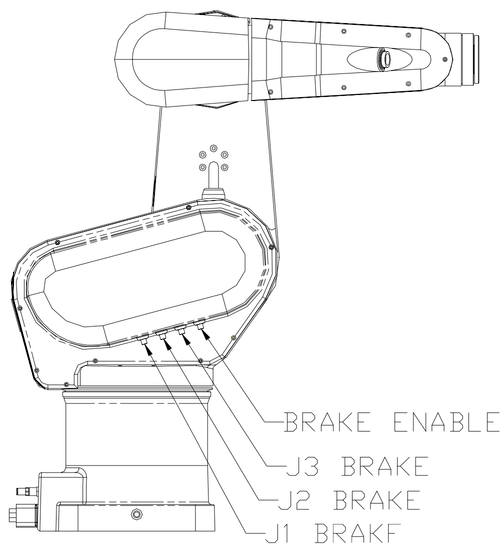
Because of the F3's distinct tool frame orientation relative to other CRS robots, users familiar with the A465 or A255 robots should be aware that tool-specific cartesian motion commands are aligned with the F3's tool axes and therefore are likely to generate different behaviour than in other systems. Programs written for the other systems may therefore not be immediately applied to a F3 robot.

System Operation

Brake Release

There are brakes in the three main joints of the F3 robot system to keep these joints in position when arm power or controller power is off. They are released automatically when arm power comes on.

When arm power is off, the brakes can be released manually by depressing the brake-release buttons on the underside of the large motor cover on the shoulder of the robot.



Drawing showing brake release buttons

Early F3 robots have four such buttons. One of them is the release-enable button while the others correspond to joints 1, 2 and 3 respectively. To release the brake of any joint, depress the enable button at the same time as one of the others.

More recent F3 robots have only three brake release buttons. A given joint can be released by depressing the corresponding button.

Warning! Do not try to press these buttons while arm power is on. *Although there is no electrical or functional consequence from such an action, it is not safe to be in the workspace of the robot when arm power is on.*

Warning! Support the arm as you release a brake. *Gravity may accelerate the descent of the wrist or outer link unexpectedly.*

Point of Control

The robot server is a process which provides all robot services to other processes running on the C500C controller. The robot server acts as the sole interface to the control of the robot and, for the reason of safety, permits only one process to have control of the robot at any time.

The teach pendant and the application shell (ash) are examples of processes running on the controller which may obtain point of control (POC) of the robot. On other words, a user may control the robot from the teach pendant or a remote computer running a terminal.

Additionally, a user-written application program may have point of control. Refer to the *RAPL-3 Language Reference Guide* for RAPL-3 commands related to this feature.

Once a process has control of the robot, other processes requesting control will receive a “Resource Busy” error until the first process releases control.

In the event that the process with point of control terminates abnormally, the robot server will not pass control to a new process until the user presses the “Pause/Continue” button on the front panel of controller. This effectively gives the front panel the highest point of control.

The purpose of this feature is to ensure that an operator cannot inadvertently take control or deliberately seize control without going to the workcell to complete the transfer of control. The act of going to the workcell forces the operator to have a clear view of the robot and any other person or potential hazard in the vicinity.

Delay after Turning on Arm Power

F3 robot motion should only be started 2 seconds after arm power is turned on. In manual operation, this is usually not an issue; however, in a RAPL-3 program, the delay() function should be used after automatic detection of arm power.

```
if (robotispowered())
delay(2000)
....
endif
```

If the recommended delay is not added in a program, the power relays in the controller may weld and lead to failure in future robot startup. This is not in itself hazardous but is nonetheless a nuisance. Future releases of software and/or hardware will address this problem.

Abnormal Process Termination

Ideally, an application will terminate naturally every time as designed. Real world experience shows that this is often not the case, particularly during the development phase.

Abnormal process termination can happen due to internal errors or at the command of a supervisory process. In addition, a user may deliberately terminate a process with CTRL-Z, CTRL-A or CTRL-E at the terminal (refer to the *Application Development Guide* for details).

CHAPTER 9

Troubleshooting

This chapter describes the serviceable problems that can occur in the F3 Robot System. Only non-invasive or minimally invasive procedures are described here. Any inspection or remedial procedure requiring major disassembly is given in the *F3 Service Guide*.

The following classes of problems are discussed:

1. Arm Power Failure
2. Amplifier Communications Failure
3. F3 Calibration & Re-Homing.

Arm Power Failure

If arm power does not come on when the switch is pressed (either the arm power LED on the controller front panel or the flashing amber light on the robot, or both, remain off), check for the following conditions and perform the corrective action.

1. **The teach pendant or its override plug is not connected.**

   Action: Close the E-Stop circuit by connecting the pendant or the override plug into the controller.

2. **The E-Stop button on either the teach pendant or the front panel is pushed in.**

   Action: Unlatch the E-Stop button.

3. **The remote E-Stop devices (connected at the controller's SYSIO) are not closed.**

   Action: Reset all remote E-Stop devices.

4. **The remote E-Stop devices are not in use but the SYSIO part of the E-Stop circuit is left open.**

   Action: Open the controller and change DIP switch 2 from OFF to ON.

5. **The arm power watchdog is disabled by the Arm Off command in RAPL-3.**

   Action: Check the program logic. Arm Off is a typical programming method for parking the robot at the end of a shift or task. Issue an Arm On command.

6. **The arm power fuse has blown.**

   Action: Replace the arm power fuse with the backup provided in the front panel tray. Remember to replace the backup fuse as well. Record this action in the maintenance log.

7. **Communications with the amplifiers cannot be established.**

   Action: See next section.

Amplifier Communications Failure

As mentioned above, the F3 system is driven by intelligent amplifier modules embedded in the robot itself. Each module, in addition to regulating the position of three joints and the current going into the corresponding motors, performs a number of diagnostic checks at startup and during continuous operations.

Upon detection of an error or failure, an amplifier module may shut down motor power as well as communications with the controller. When one module goes into such a state, the controller will shut down power to the whole system.

If an amplifier fails to communicate with the controller at startup, the error is reported on the terminal screen. During normal operations, the health status of the amplifier modules can be verified with the ampstat command.

The conditions that cause an F3 amplifier module to go into the above described failure mode are:

1. **A blown fuse**.

   Check all the fuses on the front panel of the controller using a multimeter (visual inspection may be deceptive). Replace any blown fuse with the corresponding spare provided. Replace the spare.

2. **High voltage is detected upon amplifier startup and before the user turns on the arm power switch**.

   This may be a result of the high power relays in the controller becoming welded. One way to confirm this is to turn off the controller, remove an arm power fuse and turn the controller back to verify whether the error state persists. If it does not, this confirms that one or more of the relays is welded. Contact the CRS Customer Support Group for instructions on how to release the relay(s).

3. **One of the amplifier modules, or a wire harness leading to it, has failed, but the other one remains healthy**.

   The ampstat command will indicate the health of both amplifiers. If one is reported to be working while the other is not communicating, contact the CRS Customer Support Group for further instructions.

4. **There is a breakdown in the F3 servo network, either in the umbilical or the wire harness, leading to the failure of both amplifier modules**.

   The F3 servo network consists of the two amplifier modules as well as the SGIO board which controls the end-of-arm tool (air or servo gripper) and the end–of-arm I/O channels. To assess the extent of the network failure, command the gripper to open or close. If it does not respond, the problem is a failure in the network that affects all modules.

F3 Calibration & Re-Homing

F3 Calibration

This is the process of defining a reference angle for each joint. The system uses this reference to report the current joint configuration of the robot and to carry out motion-related computations.

A calibration file is created as a result of calibrating the robot. It contains a precision location representing the offsets necessary to add to the encoder outputs in determining the joint configuration of the robot.

In F3 robot systems released in late 1997 and first part of 1998, the calibration file is generically named robot.cal during factory burn-in. In newer systems, the serial number of the robot is used as the file name - e.g. raf10035.cal. This file is located in the directory /conf and is sought by the controller upon power up of the controller.

If the calibration file is present, the message “F3 calibrated” is sent to the terminal as part of the startup report and the “home” light on the front panel is lit. If not, the absence of the file is reported and the home light is not lit.

Calibration is carried out at CRS as part of the burn-in procedure. It is typically not recommended that a user re-calibrate a robot on-site. But if absolutely necessary, contact the Customer Support Group at CRS for the recommended calibration procedure.

Restoration of Calibration File

In addition to calibration and re-homing, there may be situations which require restoration of calibration. This need arises when neither structural change nor battery problems have occurred, but the calibration file is lost from controller memory because of inadvertent erasure or change of firmware. To restore calibration, all that is required is to download the calibration file from your backups into the /conf directory. Use the **File Transfer** command in the C500 menu.

F3 Re-Homing

Although the absolute encoders in the F3 system eliminate the need for homing, it may be necessary to re-align the robot with a reference configuration represented by a given calibration file. This process of re-homing is different from the process of re-calibration.

Typically, re-homing is necessary when the encoders have to be reset because of battery error or other reasons. If there is no change in the mechanical structure of the robot, re-homing rather than re-calibration is necessary; the calibration file or its backup is available and there are calibration markers indicating the configuration in which the encoders have been last reset.

Any battery problem is typically detected and reported at startup. The necessary solution includes resetting the encoders (see step 3 in the re-homing procedure below) and leaving the controller on for at least 72 hours to recharge the batteries. Robot applications can be carried out during this recharging period.

Procedure for Re-Homing

1. Verify that the proper calibration file robot.cal is in the /conf directory. If it is not there, restore it.
2. Verify that arm power is off. If not, hit an E-Stop.
3. Verify that there is no application process running on the controller by using the ps command. CTRL-E terminates application processes started from ash, the system shell, or the teach pendant.
4. Manually back-drive the robot to align the calibration markers. (In some F3 robots, the marker is a pair of triangles on either side of a joint. The user should line up the opposing vertices of the triangles. Other robots have markers with a triangle on one side and a small alignment band on the other.)
5. Reset the wrist encoders by entering the command
   `/diag/encres`
   When prompted, enter module address
   8
   (decimal) or 0x08 (hexadecimal). If there is an error message, it indicates encoder error for one or more of the wrist axes.
6. Reset the lower arm encoders by entering the command
   `/diag/encres`
   When prompted, enter module address
   16
   (decimal) or 0x10 (hexadecimal) for the lower three joints. If there is an error message, it indicates encoder error for one or more of the lower arm axes.
7. For a track system, reset the track encoder by entering the command
   `/diag/encres`
   When prompted, enter module address
   80
   (decimal) or 0x50 (hexadecimal).
8. Turn off the controller and keep it off for at least 10 seconds.
9. Turn on the controller.
10. Test whether the robot has been correctly re-homed as follows:
    a. Turn on arm power.
    b. Start the application shell by entering `ash test.`
    c. Enter the command `calrdy`. This brings the robot into the vertical configuration.
    d. Inspect the calibration markers to ensure they are properly aligned. If any joint is mis-aligned (if a pair of markers is not exactly aligned), the markers were not properly lined up in step 4. If so, turn off arm power. Back-drive the joint to align the markers. Align the markers near to where you aligned them in step 4, but slightly on the opposite side from where they ended up when you tested them. Reset only the encoders of the mis-aligned joints. Repeat the test.

CHAPTER 10

Preventive Maintenance

This chapter covers the preventive maintenance necessary to keep the F3 system running trouble free.

All the procedures outlined in this chapter are of a non-invasive or minimally invasive nature. In other words, there is no need to disassemble the robot beyond removal of fasteners or covers. Service procedures requiring disassembly are given in the *F3 Service Guide*.

The use of a maintenance log is strongly recommended. This is particularly helpful when you call for CRS customer support. The following format is suggested:

Date	Maintenance Activity	Personnel	Notes

The maintenance intervals recommended below have been set based on normal operating conditions. For demanding applications (e.g. high payload, high acceleration, high duty cycle, etc.), more regular maintenance is necessary.

The maintenance schedule includes:

1. regular inspection
2. chain lubrication
3. battery maintenance
4. chain replacement
5. harmonic drive lubrication
6. wire harness replacement
7. cleaning the robot.

Regular Inspection

As with all machines, regular inspection ensures that the F3 robot system is running trouble-free. Frequent inspection can vary with duty cycle and operation schedule.

Weekly Inspection

Seals and Seams

The seals and other seams of the robot should be inspected for leakage of lubricant. Since many of the seals have been designed for minimizing ingress rather than egress, it may be necessary to wipe oil or grease off these seams.

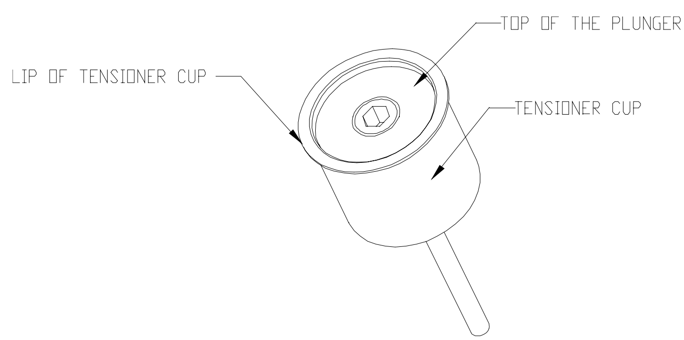
Monthly Inspection

Chain Inspection

Spring-loaded tensioners in the robot automatically take up slack in the chains resulting from stretch. Excessive load, however, may lead to prematurely excessive stretch.

Examine the movement of the robot at high speed to determine whether excessive stretch has occurred. If joint 2 or 3 moves in a jerky way suggesting chain slack, tighten the corresponding tensioner and verify whether the problem is either reduced or eliminated. Contact our Customer Support Group if the problem persists.

In factory, the plungers for the joint 2 and 3 tensioners are respectively set at 0.2” and 0.1” from the lip of the cup.



Drawing showing important parts of chain tensioner

The chain tensioners in the F3 robot have been designed to tighten the chain evenly so that the change at the output sprocket is minimized as tension is increased. This does not guarantee, however, there will be no position loss. After tightening a chain, verify that the robot continues to reach the critical locations in your workcell.

Continuous downward drift of robot position is another sign that the chains have over-stretched. In this situation, contact our Customer Support Group.

Repeatability Check

The repeatability specification of any industrial robot is typically based on testing under controlled conditions. In practice, it may vary according to environmental conditions such as temperature fluctuations.

It is a good practice to set up a mechanism in your workcell to periodically verify the repeatability of the robot. This can be based on machine vision, dial gauges or other methods.

After Collision

If you collide a robot against the workcell or any object, carry out all of the above inspections to ensure the robot can continue to operate trouble-free.

Lubricating the Chain

For optimal performance and life of your F3 robot, regularly re-lubricate the chains in joints 2, 3 and 5. It is necessary to add chain lubricant every 1,000 hours of use (roughly one and a half months). A more frequent lubrication schedule is recommended for robots moving high loads at high duty cycles.

Upright or Inverted

The procedure in the next three sections is recommended for re-lubricating the chains of an upright robot. If your robot is inverted or if your workspace does not permit the range of motion necessary to carry out the steps below, re-lubricate your robot using the same underlying principles:

1. For each joint, use one or more of the openings provided as the main entry point(s).
2. For joints 2 and 3, use at least one of the openings provided, preferably one opposite to that selected in the last step, as the drainage point.
3. Inject sufficient lubricant to lubricate one section of the chain.
4. Move the joint to expose another section of the chain to the entry point(s).
5. Repeat steps 4 and 5 until as much of the chain as possible has been re-lubricated.
6. Allow time for the lubricant to drain.
7. Move each joint around through as large a range of motion as possible at slow speed.

Re-lubricating Joint 2

Warning! *The re-lubrication procedure requires robot motion. Keep robot speed below 20%.*

To re-lubricate the joint 2 chain for an upright F3 robot:

1. Remove the five stainless M4 machine screws from the shoulder chain cover. The two top openings are for adding lubricant and the bottom three are drain holes. Prepare to collect excess lubricant from these drain holes.
2. From ash or using the teach pendant, command joint 2 of the robot to rotate joint 2 to +45° (or as high as permissible by the workspace).
3. Add no more than 5 drops of SAE 30 oil[4] (SAE 40 for a high ambient temperature) into each of the two top openings.
4. Command joint 2 to rotate by -60° (or by half of the full range of joint 2 motion permissible by your workspace).
5. Add another 5 drops of oil into the top two openings.
6. Rotate joint 2 by a final -60° (or until you reach the lower end of the permissible range of joint 2 motion).

[4] It is highly recommended that you use the same lubricant applied by the CRS production department to build our F3 robots - LPS ChainMate Chain & Wire Rope Lubricant. Contact the customer support department regarding how to obtain this lubricant. CRS Robotics Corp. cannot provide assurance that any other lubricant will be suitable for the chains or will not be harmful to other F3 components. If you are using the CRS-recommended lubricant which comes in a pressurized can, squirt once gently instead of adding 5 drops.

7. Add another 5 drops of oil into the top two openings.
8. Rotate joint 2 through its range of motion back and forth at least five times at slow speed.
9. Allow lubricant to drain while the other chains are re-lubricated.

Re-lubricating Joint 3

To re-lubricate the joint 3 chain for an upright F3 robot:

1. Remove the four stainless M4 machine screws from the lower link.
2. Rotate joint 2 to -90° (so that the lower link is horizontal). In this configuration, the two top openings are for adding lubricant and the bottom two are for drainage.
3. Rotate joint 2 to 90° (or as high up as possible so that the wrist is close to being vertically up).
4. Add 5 drops of lubricant through the two top openings.
5. Rotate joint 3 by -90° (or half of the permissible range of motion).
6. Add another 5 drops of lubricant through the two top openings.
7. Rotate joint 3 by -90° (or until the lower end of range of motion permissible by the workspace).
8. Add another 5 drops of lubricant through the two top openings.
9. Rotate joint 3 through its range of motion back and forth at least five times at slow speed.
10. Allow lubricant to drain for 5 minutes through the bottom opening at the small circular end of the link.
11. Rotate joint 2 to 0° so that the lower link is vertically up.
12. While the joint 5 chain is re-lubricated, allow lubricant to drain through the opening at the large circular end of the link.

Re-Lubricating Joint 5

To re-lubricate the joint 5 chain for an upright F3 robot:

1. Keep joint 2 at 0° so that excess lubricant in the lower link continues to drain.
2. Rotate joint 3 to -90°. If this is not permissible by the workspace, configure the robot so that the lower link continues to drain through at least one opening and the wrist is close to being horizontal.
3. Rotate joint 4 to 0°.
4. Remove the three Philips screws from the plastic wrist cover.
5. Rotate joint 5 to +135° (or to as high an angle as permissible by the tooling and the workspace).
6. Add 3 drops of lubricant through the opening on top.
7. Rotate joint 5 to 0° (or half way through the permissible range of motion).
8. Add another 3 drops of lubricant through the opening on top.
9. Rotate joint 5 to -135° (or to the lower end of its permissible range of motion).

10. Add another 3 drops of lubricant through the opening on top.
11. Rotate joint 3 to 0° so that the wrist is vertically up or close to it
12. Rotate joint 5 to +90°.
13. Add 3 drops of lubricant through the opening on the small circular end of the wrist cover.
14. Rotate joint 5 to 0°.
15. Add another 3 drops of lubricant through the opening on the small circular end of the wrist cover.
16. Rotate joint 5 to -90°.
17. Add another 3 drops of lubricant through the opening on the small circular end of the wrist cover.
18. Rotate joint 3 to -90°. The remaining opening on the wrist cover is now on top.
19. Repeat steps 5 to 10.
20. Rotate joint 5 back and forth through its entire range of motion at least five times.
21. Allow the wrist to drain for at least five minutes with joint 3 at -90°, 0° and 90° respectively.

Replace and Update

1. Replace all the screws in the lubrication openings.
2. Record the re-lubrication activity in your maintenance log.

Battery Maintenance

Background

The absolute encoders of the F3 robot rely on battery power to maintain multi-turn data when it is not connected to a live controller - i.e. the controller is turned off or the umbilical cable is disconnected at one or both ends. This backup supply consists of a pack of three (3) nickel metal hydride batteries.

The batteries are continuously charged as long as the robot is connected to a live controller. They can retain sufficient charge for the encoders for at least six (6) weeks when all power to the robot is down, provided the system has been connected to a live controller for at least 72 hours prior to the shutdown.

- Typical charging voltage is 4.5 VDC.
- Resting voltage is around 3.6 VDC.
- The encoders issue an alarm when their power is lower than 3.4 VDC.
- At lower than 3.0 VDC, the encoders cease to function properly and enter into a reset state.

Shutting Down the System for Less Than 6 Weeks

Check the battery voltage if you plan to shut down the robot system under the following conditions:

- The shutdown will be longer than five (5) days but less than six (6) weeks.
- The robot system has not been connected to a live controller for at least 72 hours prior to the shutdown.

Verifying battery voltage of systems shipped in mid-1998 or later

- With the controller turned off, remove the umbilical cable from the robot base.
- Allow the batteries to drain for at least 4 hours from the charging voltage level to the resting level.
- Use a voltmeter or digital multi-meter to measure the voltage across pins A1 and A5 in the umbilical connector at the robot base.

Verifying battery voltage of systems shipped in 1997 to early 1998

These robots may not have the battery pins installed. In this case, the following procedure is necessary to measure the battery voltage.

- With the controller turned off, remove the umbilical cable from the robot base.
- Allow the batteries to drain for at least 4 hours from the charging voltage level to the resting level.
- Use a 2.5 mm hex key to remove the seven (7) M3 socket head screws securing the fibre drawer to the base of the robot.
- Allow the fibre drawer to withdraw on its own from its cavity in the base. It will recede roughly 1 cm (0.4”).

- The black battery case on the left side of the fibre drawer assembly should now be sufficiently exposed so that the two outermost terminals of the battery pack (closest to the fibre drawer panel) are accessible.
- If not, insert the same 2.5 mm key into the air fitting and turn clockwise until the air hose inside the fibre drawer cavity is free and the drawer can be further withdrawn.
- Use a voltmeter or digital multimeter to measure the voltage across the two terminals of the battery pack closest to the fibre drawer panel.

If the measured voltage is below 3.6 VDC, the batteries may not be able to keep the encoders live for up to six (6) weeks. In that case, the robot should remain connected to a live controller for at least 72 hours to allow the batteries to recharge.

Extended Shutdown

If you plan to leave the robot off for a period exceeding six (6) weeks, it is highly recommended that you connect it to a live controller. Otherwise, it may be necessary to reset the encoders and re-home the robot after the resting period.

If it is not possible to leave a live controller connected, then the robot should be left in the calrdy configuration if possible to facilitate re-homing when the robot is started up again.

Six Month Battery Check

Even if you do not plan to shut down the F3 system, you should verify the battery voltage six months after receiving the robot.

- Turn off the controller for at least four (4) hours to allow the batteries to discharge from the charging voltage to the resting state.
- Verify the battery voltage following one of the above procedures.

Battery Replacement

The encoder backup batteries should be replaced in the following situations:

- one year after receiving the robot system.
- if at any time the combined battery voltage is below 2.8 VDC.

Warning! Use only nickel-metal hydride batteries, and NOT nickel cadmium, lithium or alkaline alternatives. *The use of unsuitable batteries may lead to hazardous failure.*

You can order replacement batteries from CRS by contacting our customer support group. The part number is R-BAT-NiMH1.2. Order at least three (3) batteries.

The procedure for battery replacement is as follows:

- Expose the battery pack by following the same steps above for verifying the battery voltage of early F3 systems.

- Remove the batteries.
- Install the new ones.
- You have up to ten (10) minutes to carry out the above steps before the encoders are no longer active and calibration is lost.

Log Update

After verifying or replacing the batteries in your F3 system, record the maintenance activity in the maintenance log.

Chain Replacement

Chains need to be replaced after 18 months of use or sooner if the load and duty cycle of the application are high. Contact our Customer Support Group to determine the best schedule for chain inspection and replacement for your application.

Harmonic Drive Lubrication

CRS Robotics Corp. uses and recommends the 4B no. 2 grease from HD Systems for the harmonic drives. This is an efficient and durable grease; it is not necessary to add new grease to the harmonic drives prior to changing it.

Grease replacement is recommended once every 1.5×10^9 input revolutions of the harmonic drives. This corresponds to 1.5×10^7 output revolutions on the lower joints and 1.875×10^7 on the wrist joints.

Consider as an example an application which moves the lower joints at an average speed of 20 rpm over three shifts per day. Grease change should be scheduled after 520 days or roughly 17 months.

For applications with high load and duty cycle or operating at a higher temperature than 60°C, more frequent grease changes may be necessary. For example, if the harmonic drives are operating at 70°C , a grease change will be necessary after 1×10^9 input revolutions. Conversely, you can wait longer between grease changes if your application has a low load and relatively low duty cycle. Contact the Customer Support Group to schedule a maintenance visit.

Wire Harness Replacement

There are four moving wire harnesses within the F3 robot:

- joint 1 harness
- lower link harness
- joint 4 harness
- wrist harness.

Like other mechanical components, copper conductors may fail after a high number of cycles of motion. To prevent such a failure during operation, it is recommended that the wire harnesses be replaced every 15 months or 10^7 cycles of joint motion, whichever comes first.

In order to minimize down time, replacement of chains and wire harnesses as well as changing of harmonic drive grease should take place at the same time - e.g. once every 12 months.

Cleaning the Robot System

All exterior arm surfaces can be cleaned using house-hold cleaning products provided care is taken not to allow such products to seep into the robot interior through any seam. Special attention is required when cleaning the wrist area near the wrist amplifier and the waist area near the waist amplifier. In addition, the use of some solvents or de-greasers may damage printed surfaces.

Ensure that liquids do not enter inside the controller. Do not immerse any part of the controller in liquid.

APPENDIX A

Umbilical Cable Connector

The connector used in the construction of the umbilical cable is an industrial connector, with an ingress protection rating of IP65. The cable is wired straight through, with no pins swapping position.

Pin on Robot	Pin on Controller	Signal Name	Rating	Signal Description
A1	A1	Return GND	10A	Signal and Power Return GND
A3	A3	Motor Power	+77V 10A	Power to motor Actuators
B2	B2	Rx from Robot	Fibre	Fibre Optic communication line
B3	B3	BRK_V	24V 1A	Power to disengage robot brakes
B4	B4	OPT_PWR	+24V 1A	Power supply for robot options (gripper + I/O), and brakes when using the robot brake release
B5	B5	SYS_PWR	+12V 3A	Power supply for the robot amplifiers, and support electronics
C2	C2	Tx to Robot	Fibre	Fibre Optic communication line
		Battery Level	5V 1A	Connection to battery pack used to maintain encoder position; not fused
GND	GND	Chassis GND	15A	Safety GND

APPENDIX B

System Fuses

The controller has fuses installed to protect various subsystems in the case of short circuit faults.

AC fuses (located in power entry module with AC power cord).

System Voltage	Fuse Rating	Type	Size
100 VAC	10 A	250 V SLO BLO	5mm x 20mm ($^1/_4$" x 1-$^1/_4$")
110 VAC	10 A	250 V SLO BLO	5mm x 20mm ($^1/_4$" x 1-$^1/_4$")
230 VAC	4 A	250 V SLO BLO	5mm x 20mm ($^1/_4$" x 1-$^1/_4$")

DC fuses (located behind front panel access cover).

Label	Function	Fuse Rating	Type	Size
F5	Arm Power (77Vdc)	10 A	250 VAC SLO BLO	5mm x 20mm ($^1/_4$" x 1-$^1/_4$")
F4	24Vdc Power	1 A	250 VAC SLO BLO	5mm x 20mm ($^1/_4$" x 1-$^1/_4$")
F3	12Vdc Power	3 A	250 VAC SLO BLO	5mm x 20mm ($^1/_4$" x 1-$^1/_4$")
F2	Relay Common Terminals	1A	250 V SLO BLO	5mm x 20mm ($^1/_4$" x 1-$^1/_4$")
F1	24V - Internal	1 A	250 V SLO BLO	5mm x 20mm ($^1/_4$" x 1-$^1/_4$")

Glossary

application

A collection of software and hardware that allows the robot to accomplish a particular task or job.

Typically, a robot application consists of robot hardware, other hardware of the workcell, and a robot program with its file of locations and other variables. It can include other programs, files, hardware, and computers running their own programs.

application shell (ash)

A utility available at the CROS command prompt that you can use to move the robot arm, teach locations, and set values to other variables. You start it by entering “ash” at the CROS command prompt ($).

arm

The mechanical, task-performing part of a robot, directed by the controller. An arm consists of 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. The joints are powered and capable of moving the links and the tool to various positions and orientations.

articulated robot

See: robot.

ash

See: application shell.

awareness signal

An audio or visual alarm 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 any of an arm’s joints about which a link or similar section rotates.

base offset

A modification to the world frame of reference that places the origin of the frame to be at a place other than the centre of the mounting surface of the base. In other words, the geometry of the arm that defines the position of the origin of the world cartesian coordinate system relative to the center of the mounting surface of the arm.

See: world frame of reference.

cartesian coordinate system

A system for defining space based on three linear perpendicular axes: X, Y and Z. The X and Y axes define a horizontal plane, and the Z axis defines the vertical dimension. Any point in space can be defined by translational coordinates specifying the distance along each axis. The orientation of a tool or nest, at that point, can be defined by orientational coordinates specifying the rotation around each axis. Cartesian coordinates are independent of any arm.

A cloc (cartesian location) holds positional data in cartesian coordinates.

See: world frame of reference.

client

A process that issues a request for a particular service.

See also: server, process.

configuring, configuration

The action of entering parameters or specific settings, to set up a component for use.

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 a robot application, the controller executes a robot software program.

coordinate system

See: frame of reference.

CROS (CRS Robotics Robot Operating System)

An operating environment that RAPL-3 processes run on.

CROS-500

The version of CROS that runs on a C500 or C500C controller. Command line access to it is through the terminal window of Robcomm 3.

When you power up the controller, CROS-500 starts up automatically.

See also: rc file.

CROS for Windows NT

The version of CROS that runs on Windows NT on a personal computer. Available only with POLARA systems.

daemon

A process that runs in the background and performs a task when necessary. In CROS-500 fastacid (fast, advanced communication interface daemon) used for terminal communication is a daemon.

See also: server.

degree of freedom (DOF)

The independent motion in which the arm can move its end effector (gripper, tool). In an articulate arm, the number of independent joints. For example, the F3 has six degrees of freedom.

directories

The default directory where the installation utility installs Robcomm 3 is
c:\crs\robcomm3\

The default directories where the installation utility installs CROS-500 and RAPL-3 components are
c:\program files\crs robotics\cros-500\
c:\program files\crs robotics\rapl-3\

electrostatic charge, electrostatic discharge (ESD)

Electrostatic charge is an electric charge that builds up on the surface of an insulated object, such as a person or an ungrounded mechanical device.

At close proximity between two objects, this charge can suddenly transfer from one object (such as a person) to another object (such as an small electronic component). Static electricity can easily damage the electronic components used in the robot controller and options. To avoid damage, anyone coming into contact with these devices should wear an electrostatic discharge (ESD) wrist strap, attached to an earth ground.

emergency stop (E-Stop)

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

encoder

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

end effector

A work-performing device attached to the tool flange for the robot's task, such as a gripper, dispenser, buffing wheel, or spray head.

frame of reference

See: tool frame of reference, world frame of reference.

free travel

The travel distance of a joint between its hardstops.

gripper

An end effector designed to grasp or hold. Sometimes called a hand.

hardstop

A hardware safety device fastened at a fixed position that determines the absolute ends of movement of a joint or track. The travel distance between hardstops is called the free travel distance. A hardstop restricts the workspace and provides some safety in the case of a runaway robot.

harmonic drive

A type of precision mechanical transmission. This device joins a motor and a joint providing smooth motion, high torque, and low backlash.

hysteresis

The amount of free play or slack in a gear or belt system.

i/o

Input/output.

installation directories

See: directories (installation).

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 system by the E-Stop circuit which breaks contact and stops the arm when the door is opened, and permits 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.

joint coordinate system

A system for defining space based on angular movement of each joint, with the knowledge of the length of the links, and referenced to a known starting position. Joint coordinates are dependent on the arm.

A ploc (precision location) holds positional data from the joint coordinate system.

limping

A method of moving the arm by disengaging the servos which normally hold the joints in place. A limped joint can be moved by hand.

link

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

location

A point in space known to the robot.

With a CRS robot, a location can be one of two types of locations. A cartesian location (cloc) stores information according to a cartesian (straight-line axes meeting at right angles) coordinate system. A precision location (ploc) stores information according to pulse counts of the joints of the robot arm.

The information about the point is placed in a location through the process of teaching.

See also: teaching, location (instrument).

MS Windows

See Windows.

nest

A position in an instrument where a container is placed.

operator

The person who uses the robot to perform work. This can include loading the workcell, running the robot, monitoring the running, and responding to any problems, but does not include designing the workcell or programming the robot. Operating work can be done from a terminal, the teach pendant, or the front panel.

See also:system integrator.

PLC (programmable logic controller)

An electronic device that reads inputs and sets outputs that are digital (on/off, yes/no, high/low). A PLC can be used to manage digitally controlled devices. The PLC is outside the controller and the computer. Communication with a PLC can be through the controller's GPIO or a serial port of the controller or a computer.

payload

The amount of weight carried by the arm and/or the amount of force the arm can exert on an object.

maximum payload

The amount of weight carried by the robot at reduced speed while maintaining rated precision. This rating is highly dependent on the size and shape of the payload.

nominal payload

The amount of weight carried by the robot at maximum speed while maintaining rated precision. This rating is highly dependent on the size and shape of the payload.

process

Within CROS, a process is a program (your robot application program, the robot server, the system shell, or the application shell) when it is executing on the system.

programmable logic controller

See: PLC.

programmer

The person who programs or re-programs the robot to do tasks.

See also: operator, system integrator.

RAPL (robot automation programming language)

The language used to program CRS robots. RAPL-3 has a completely different architecture from RAPL-II.

RAPL-3

A high-level, block-structured, compiled language, similar to C, introduced in 1997.

See also: CROS.

RAPL-II

A line-structured, interpreted language, similar to BASIC, introduced in 1993.

range of motion

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

rc file (robot configuration file)

A file that is automatically executed when CROS starts up, similar to an autoexec.bat file in DOS. The rc file starts a number of processes that run on CROS.

A robot application program can be started up by adding a line to the rc file.

See also: CROS.

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

repeatability
The ability of the robot to repeat the same motion or position a tool at the same position when presented with the same control signals (over *repeat*ed cycles). Also, the cycle-to-cycle error of the robot system when trying to perform a specific task.

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

Robcomm 3 (robot communication software)
Application software which allows a developer to: edit and compile RAPL-3 programs, transfer files between the computer and the controller, and communicate with the controller using a terminal window. Robcomm 3 runs on Windows 95, 98, or Windows NT.

robot
A device that: performs physical work; is automatic (runs without direct human intervention); is capable of performing a variety of tasks; and is programmable (the instructions directing it can be changed).

articulated robot
A robot with an arm made up of rigid links connected by rotary joints which bend at the “shoulder”, “elbow” and “wrist”. This type of robot most closely resembles a human arm.

robot configuration file

See: rc file.

safeguard device
A safeguard is a device designed to protect persons from a hazardous point or area. Safeguard devices include but are not limited to: fixed barriers, interlock barriers, perimeter guarding, awareness barriers, and awareness signals.

sever

A process that provides a service requested by a client. In CROS-500, the robot server is a server.

See also: client, daemon.

system integrator

The person or company who designs, constructs, and installs a robot system for an end-user customer.

See also: programmer, operator.

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.

teaching

A process of making a position in the workspace known to the robot.

You teach a location using the teach pendant or ash (the application shell). You move the robot to the position. You command the robot software to take the information about the position and store it in the location variable. When the information is stored, the location is taught.

All taught locations are stored in a .v3 file.

See also: location, .v3 file.

terminal

An arrangement that allows command line access to CROS on the controller. To communicate with CROS on a C500 or C500C controller, the terminal window of Robcomm 3, any terminal emulator, or a simple serial terminal, can be used.

terminal emulator

Software that emulates (produces the same functions as) a simple terminal of keyboard and monitor.

tool axis

The axis of the tool frame of reference along which the tool centre point moves, during a depart command.

See also: tool frame of reference.

tool centre point (TCP)

The point that is moved to a location, or moved between locations or moved along an axis during a straight-line move.

The tool centre point describes the point of the tool where work is performed: the tip of a dispensing head, the centre of gripper fingers, etc.

The tool centre point is defined by setting a tool transform, which modifies the tool frame of reference, from the origin at the centre of the tool flange, to the position and orientation of the actual tool.

tool frame of reference

The frame of reference with its origin at the centre of the tool flange. This frame of reference moves with the tool.

F3

The tool axes are parallel to the world axes when the arm is at the calrdy (straight up) position. The tool X axis extends forward (at calrdy) and down (at ready), the tool Y axis extends away from the side of the arm, and the tool Z axis extends vertically up (at calrdy) and forward (at ready). The relationship of axes follows the right-hand rule.

The “tool axis” is the Z axis of the tool frame.

A465/A255

The tool axes are parallel to the world axes when the arm is at the ready (tool flange facing forward) position. The tool X axis extends forward, the tool Y axis extends away from the side of the arm, and the tool Z axis extends forward. The relationship of axes follows the right-hand rule.

The “tool axis” is the X axis of the tool frame.

The position and orientation of the origin can be modified (translated and rotated) with the tool transform command.

There are motion commands that move the end-of-arm tooling relative to the tool frame.

tool tip

A physical reference point on a tool, typically the end.

tool transform

A modification to the tool frame of reference that places the origin of the frame to be at a place other than the centre of the surface of the tool flange. In other words, the geometry of a tool that defines the position of the tool centre point relative to the center of the tool flange surface.

See: tool frame of reference.

umbilical cable

A cable which connects the controller and the arm.

F3

There is one cable. Since it contains two optical fibres (in addition to five copper conductors) it cannot be bent tighter than 230 mm. [9 in.].

A465/A255

There are two cables. 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.

variable

A variable is used in a program and holds a value.

RAPL-3 has five types of variables:

cloc (cartesian location)

Holds data about a point in space based on cartesian coordinates: distances along the X, Y, and Z axes, and orientation around those axes.

ploc (precision location)

Holds data about a point in space based on encoder pulse counts of each joint of the robot arm.

int (integer)

A whole number, without a decimal part.

float (floating point number)

A number with a decimal part.

string (string of characters)

A string of characters. Used for sending information to and receiving information from an external device, another RAPL-3 process, a file, or the terminal.

teachable

Variables that are accessible outside the program. They are stored in the .v3 file and are accessed using ash.

unteachable

Variables that are used only within a program and are not in the .v3 file.

See also: .v3 file, location, ash.

.v3 file

A file that stores locations and other teachable variables. Each instrument has its own .v3 file that stores the locations for that instrument. The .v3 file is stored in the instrument's directory of the app/ directory of the CROS file system.

You use ash (the application shell) to load the contents of the .v3 file into ash's database, change values or "teach" locations, and save the new data to the .v3 file.

See also: teaching, locations.

variable file

See: .v3 file.

Windows NT, Windows 95

Computer operating systems. Robcomm 3 runs on both.

Windows NT and Windows 95 are products and registered trademarks of Microsoft Corporation.

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. Also known as the reach envelope.

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.

world frame of reference

The frame of reference with its origin at the centre of the mounting surface of the base of the arm. The world X axis extends forward from the front of the arm, the world Y axis extends away from the side of the arm, and the world Z axis extends vertically up from the base. The relationship of axes follows the right-hand rule.

The position and orientation of the origin can be modified (translated and rotated) with the base offset command.

There are motion commands that move the end-of-arm tooling relative to the world frame.

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