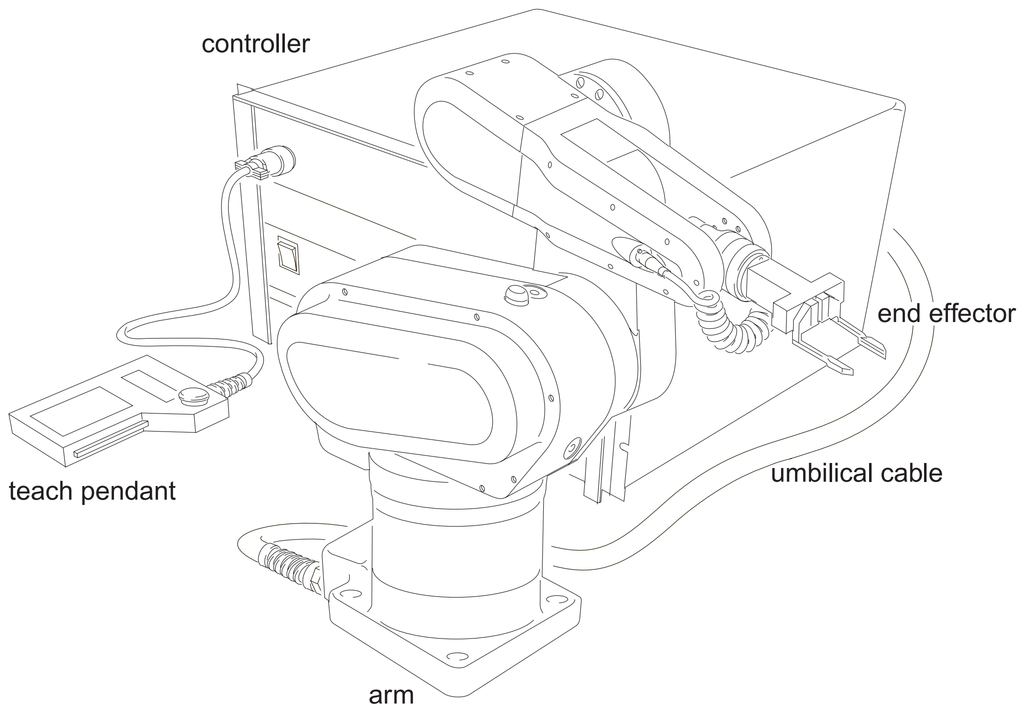
F3 Robot System User Guide

UMI-F3-400



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Rev.	Revision History	Date
001	Original Issue	00-06
001a	Updated with references to Robot Systems Software Documentation Guide	00-12
001b	Includes new calibration file instructions	01-01
001c	Corrected specifications. Missing figures restored.	01-05
001d	Corrected SIO port numbering	01-08
002	Added serial port pinouts (Chapter 7) and revised firmware installation instructions (Appendix A). First version with both ActiveRobot and RAPL-3 (all Chapters).	01-12
002a	Updated corporate logos and names.	02-07

PREFACE

About This Guide

This user guide accompanies the Thermo CRS F3 articulated robot system. It contains installation instructions, specifications, and operating procedures for the F3 arm and C500C controller.

Who Uses This Guide

This installation guide is intended for users who have already attended a Thermo CRS robot system training course. It is not intended as a self-teaching tool.

How to Use This Guide

Throughout this manual warnings are marked by a "!" symbol in the left margin. *Failure to comply with these warnings can result in system errors, memory loss, damage to the robot and its surroundings, or injury to personnel.*

This manual is task-based and uses navigational aids to help you quickly find the topics and information you need. If a technical term is not familiar to you, refer to the Glossary.

Before following instructions in a section, read the entire section first.

This guide consists of the following chapters:

- Chapter 1, Introducing the Robot System introduces the major components of your Thermo CRS robot system and provides an overview of system features.
- Chapter 2, Technical Specifications contains physical and electrical specifications, including guidelines for the nominal use of your robot system.
- Chapter 3, Safe Use of the F3 System discusses safety considerations.
- Chapter 4, Installation provides instructions for installing the robot in a work cell.
- Chapter 5, Commissioning the System explains how to load the calibration file, test basic robot functions and prepare your robot system for use.
- Chapter 6, Basic Operations describes routine system procedures.
- Chapter 7, System Connections includes detailed pinouts and configuration information to help you integrate additional devices into the work cell.

- Chapter 8, Maintenance Procedures describes how to establish a service schedule, lubricate joints, replace fuses, and perform other basic maintenance activities.
- Chapter 9, Troubleshooting helps you to resolve common problem situations that you may encounter when using your robot system.
- Appendix A, Installing New Firmware explains how to upgrade the CROS firmware on the controller.
- Appendix B, GPIO Termination Block Option provides installation and mounting instructions for the optional GPIO termination block.

Units Used in This Manual

The F3 robot system is designed to metric scale. Throughout this manual, measurements are given in metric units.

For More Information

Additional information is available in the following documents, contained on your documentation CD:

- *Robot System Software Documentation Guide*
  Guide for developing applications in an integrated way.
- *Application Shell (ASH)*
  User Guide for the controller application shell.
- *CROS and System Shell*
  User Guide for the controller system software.
- *ActiveRobot User Guide*
  Reference Guide for the ActiveRobot application development software.
- *RAPL-3 Language Reference Guide*
  Reference Guide for the RAPL-3 language.
- *Robcomm3*
  User Guide for the Robcomm3 application development tool for RAPL-3.

You can obtain copies of these documents, or other Thermo CRS literature, from the Sales department or from your distributor.

Training

We offer courses at our facility in Burlington, Ontario Canada, or on-site at your facility. For more information, contact the Thermo CRS Training Department.

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CHAPTER 1

Introducing the Robot System

At its most basic configuration, the F3 robot system consists of an F3 robot arm, a C500C controller, and an umbilical cable that provides power and communication from the controller to the arm. Commands are issued to the robot system from program applications or terminal commands, or through the teach pendant. End effectors such as grippers and other tools enable the arm to perform specialized tasks.

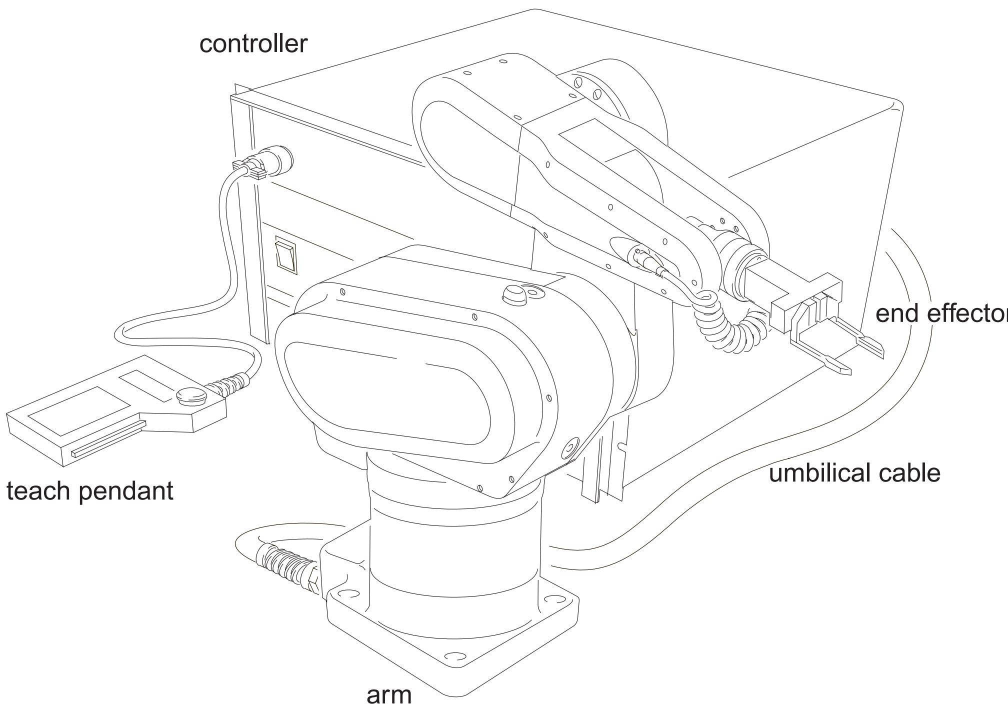


Figure 1-1: Basic components of an F3 robot system

This chapter provides an overview of the basic components of your robot system.

The Arm

The arm transports payloads and performs other motion tasks in space. A mounting plate at its base secures the arm to a fixed platform or track. You can easily mount a variety of end effectors such as grippers, dispensers, or deburring tools on the ISO-standard tool flange.

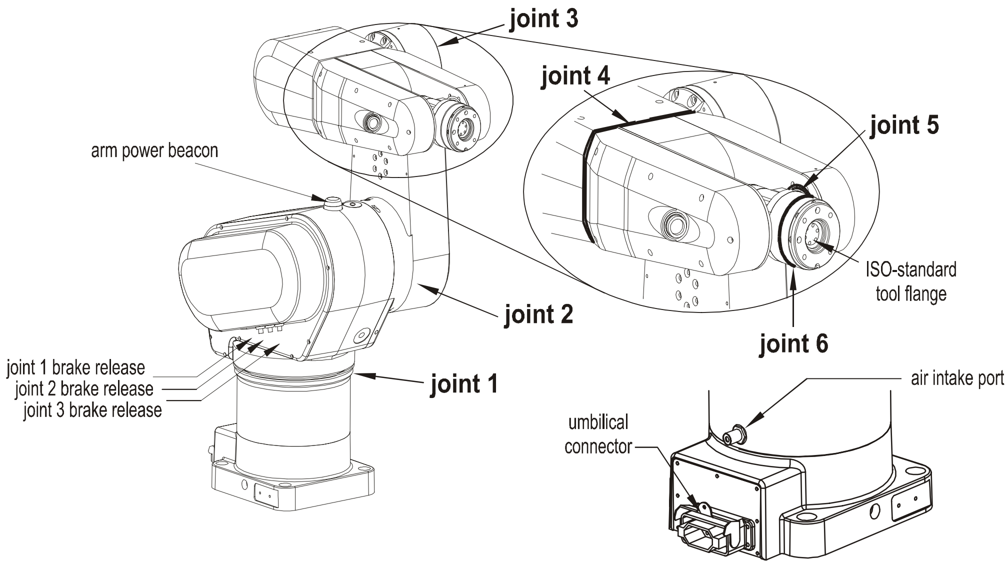


Figure 1-2: Arm features and joint numbering

Articulated joints provide the arm with six degrees of freedom, allowing you to accurately position the tool flange at any point within the work space, from any orientation.

Absolute Encoders

Absolute encoders in each joint provide continuous information on arm stance and position. When the robot system is turned off, this information is retained in memory, ensuring that the location and orientation of all axes is exactly known at all times. Under normal operation, the F3 arm does not need to be homed.

Track Robots

The F3t model of the F3 arm is mounted on a track in order to move the entire arm along an additional linear axis. For more information on how to use a Thermo CRS track, consult the *Track User Guide* on the documentation CD.

The C500C Controller

The C500C controller provides safety circuits, power, and motion control for the arm. It drives the motors in each joint, keeps track of motor position through feedback from the encoders, computes trajectories, and stores robot applications in memory. It also detects potentially damaging conditions such as robot runaway, severe collisions, overtemperature or overcurrent, loss of positional feedback, and errors in communication. If one of these conditions is detected, the controller immediately triggers an emergency stop or shutdown.

The embedded multi-tasking CRS Robot Operating System (CROS) provides process scheduling and interfaces to low-level robot system functions. It also provides basic application development tools, including the application shell (ash), an integrated environment for developing, compiling, and running robot applications on the controller. For more information on CROS and the application shell, see the *CROS and System Shell* and the *Application Shell (ASH)* guides on the documentation CD.

Note: For information on how to develop robot applications, refer to the *ActiveRobot User Guide* or the *Application Development Guide* (for RAPL-3).

The Front Panel

The front panel provides a basic interface to robot functions. Through your application, you can use the LCD status display, programmable buttons and indicator lights on the front of the controller to display status messages and request input from system operators.

Using pre-programmed button combinations, you can also shut down the controller or access diagnostic mode.

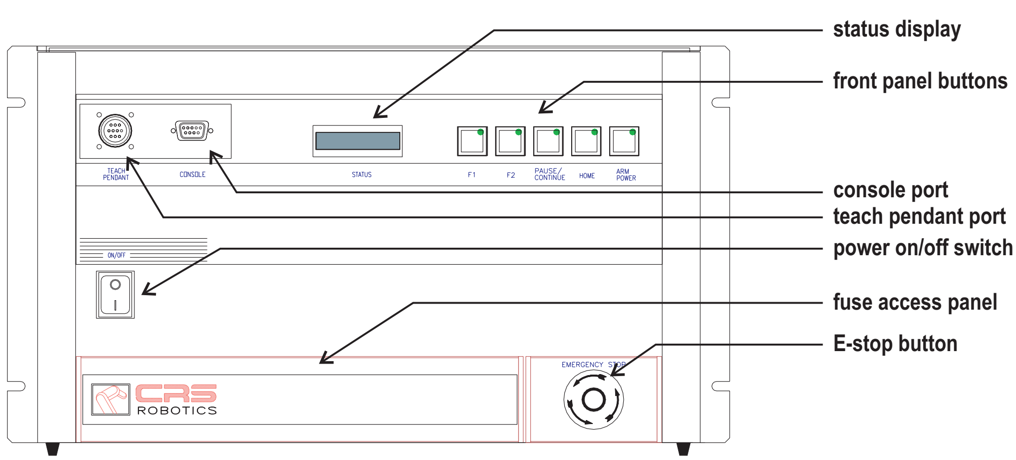


Figure 1-3: The front panel of the C500C controller

Controller Ports

Ports on the front and rear panels of the controller provide connections for external devices such as the teach pendant, the development computer, and additional E-Stops.

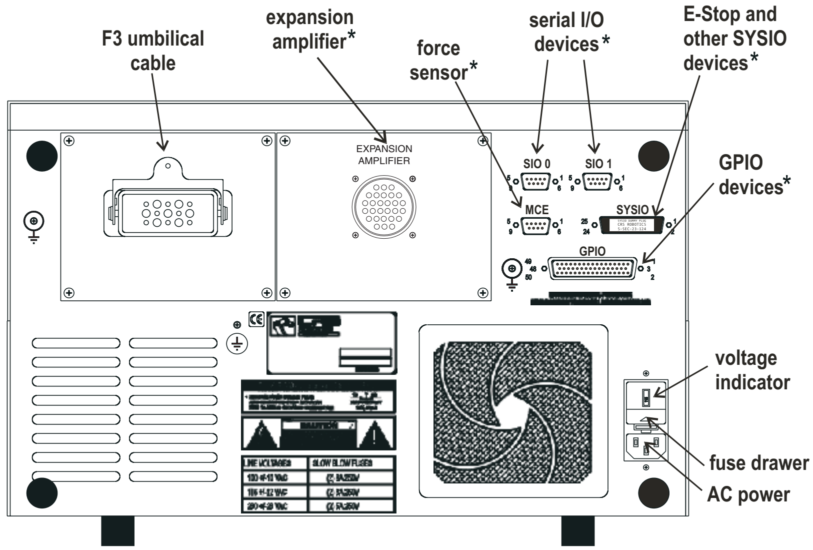


Figure 1-4: The rear panel of the C500C controller.

Note: Connections labeled with an asterisk (*) are optional.

E-Stops

Emergency stops, or E-Stops, are a safety feature designed to stop the arm in case of emergency. The E-Stop buttons provided with your system are large red, palm-cap buttons. You can also add automatic E-Stop devices such as pressure-sensitive mats or safety interlocks to your robot system.

When an E-stop is triggered, power is immediately removed from the arm motors and fail-safe brakes automatically engage to prevent the arm from moving due to gravity. To prevent the payload from being dropped, servo-operated tools remain powered and pneumatic tools retain their last state.

To ensure safety, power cannot be restored to the arm until the E-Stop device that triggered the emergency stop is manually reset.

Using the E-Stop button

- To trigger an E-Stop, push any E-Stop button. Power is removed from the arm motors and brakes automatically engage on joints 1, 2, and 3. Arm motion stops.
- To restart after an E-Stop:
  - **a** Make sure that it is safe to restart the system.
  - **b** Turn the E-Stop button until it springs out of the latched position.
  - **c** Press the Arm Power button on the controller or remote front panel to restore arm power.

The Teach Pendant

The teach pendant is an optional hand-held device used to move the robot, teach locations, and run robot programs. An E-Stop button on the teach pendant allows the operator to initiate an emergency stop at any time.

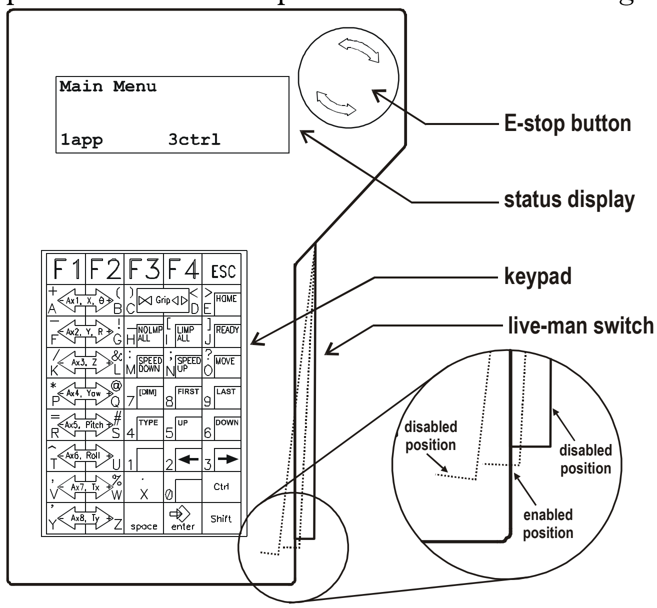


Figure 1-5: The teach pendant and live-man switch

For more information on how to use the teach pendant, see “Basic Teach Pendant Commands” on page 6-6.

The Live-Man Switch

The live-man switch is a three-position enabling switch on the side of the teach pendant. The live-man switch must be maintained in the enabled position in order to move the arm with the teach pendant.

Using the live-man switch

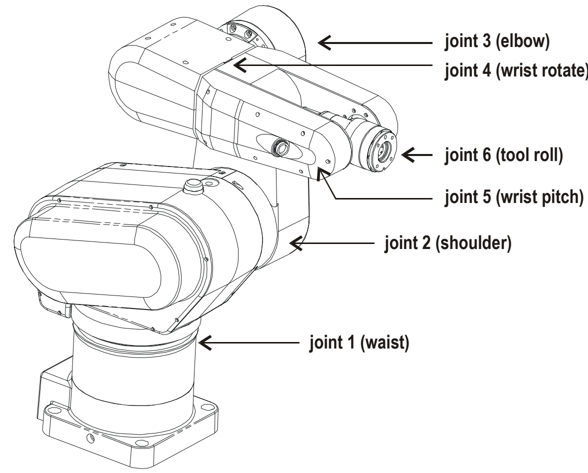
1 To enable the teach pendant, hold the pendant in one hand and gently squeeze the live-man switch in towards the pendant. You will hear a faint click as you move the switch into the enabled position.

Note: If you squeeze the live-man switch in too far, you will hear a second click as you move the switch into the disabled position.

2 While holding the live-man switch in its enabled position, press a motion command key on the teach pendant.

CHAPTER 2

Technical Specifications



Physical Characteristics

Thermo CRS Robotics F3 Arm

Number of axes	6
Weight	52 kg [115 lb]
Mounting	Upright or inverted
Nominal payload	3 kg [6.6 lb]
Reach	710 mm [28 in.] (joint 1 axis to tool flange)
Repeatability	± 0.05 mm [0.002 in.]
Encoder resolution	2048 counts per motor turn
Maximum linear speed	4 m/s (joint-interpolated motion)
Drive system	Electromechanical, brushless motors Absolute encoders in each joint
Transmission	Harmonic drives
Brakes	Brakes on joints 1, 2, and 3
Motion modes	Teach Automatic ISO-9409 compliant tool flange End-of-arm I/O (option) End-of-arm I/O with air (option)

Thermo CRS Robotics C500C Controller

Dual microprocessor design	133 MHz i486DX (system processor) 60 MHz TMS320C31 DSP (motion control)
Memory	4 MB RAM user memory 512KB NVRAM for application storage 1 MB flash memory for system firmware
User I/O	16 digital inputs 12 digital outputs 1 analog input 4 relay outputs
Front Panel interface	16x2 character, back-lit LCD display User programmable buttons and LED lights
System connections	External E-Stop control inputs 2 standard serial I/O ports 1 console serial port 1 teach pendant serial port Support for 1 additional track axis
Dimensions	482.6 mm [19 in.] x 266.7 mm [10.5 in.] Fits a standard 6U rack enclosure
Weight	31 kg [68 lb]

Electrical Specifications

AC Input voltage	100/115/230 VAC ± 10%
Line frequency	50-60 Hz
Power consumption (max)	1000 W

Operating Environment

The F3 robot system is rated for indoor use only.

Temperature	10° to 40° C [50 to 104 F]
Humidity	Keep below 80% humidity, Non-condensing environment only
Vibration	Not rated for excessive vibration or shock
Electromagnetic Interference	Do not expose to excessive electrical noise or plasma

Joint Specifications

When planning an application, refer to the following technical data to ensure that you are using your robot arm within recommended tolerances. Choose appropriate payloads and accelerations to minimize wear and prolong the life of your robot system.

Applications that regularly exceed the specifications shown here will necessitate more frequent maintenance and can decrease the life expectancy of your robot arm. For more information on maintenance, see Chapter 8, Maintenance Procedures.

Table 2-1: Joint specifications for the F3 arm

Axis	Range of Motion	Maximum Speed	Default Acceleration	Gear Ratio	Continuous Stall Torque Rating
joint 1	± 180°	240°/s	879°/s^2	-100:1	74.5 N·m [659 in.·lb]
joint 2	-135° to +45°	240°/s	879°/s^2	100:1	74.5 N·m [659 in.·lb]
joint 3	± 135°	240°/s	879°/s^2	100:1	74.5 N·m [659 in.·lb]
joint 4	± 180°	375°/s	1098°/s^2	-80:1	16.6 N·m [147 in.·lb]
joint 5	± 135°	300°/s	1098°/s^2	80:1	16.6 N·m [147 in.·lb]
joint 6	± 4096 turns	375°/s	1098°/s^2	-80:1	16.6 N·m [147 in.·lb]

Specifications in Table 2-1 are determined for a 3 kg [6.6 lb] payload carried at the tool flange.

For other payloads, or a tool carried at a distance from the tool flange, refer to the following de-rating curves:

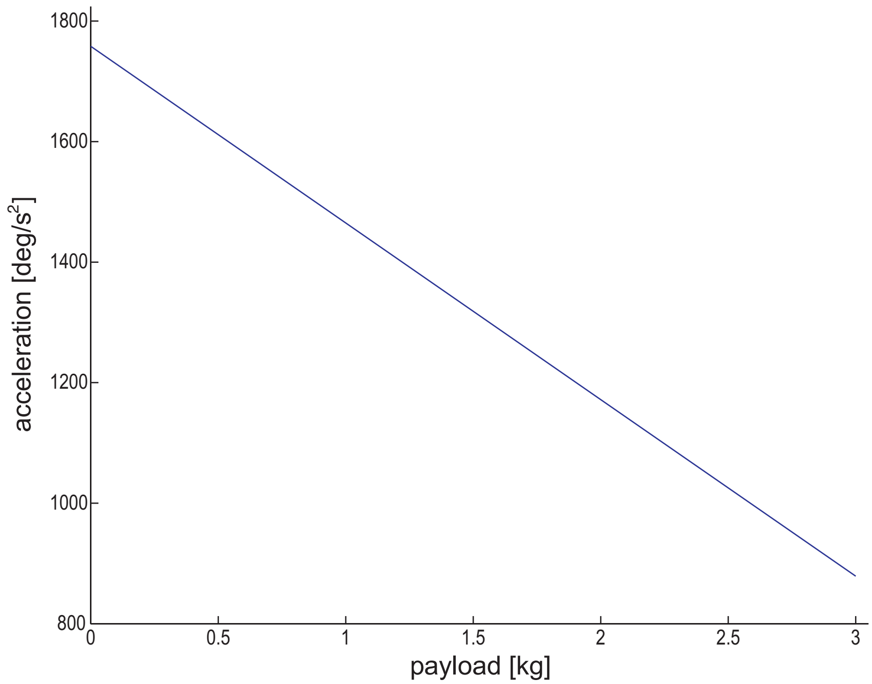


Figure 2-1: Maximum acceleration vs. payload for joints 1, 2, and 3.

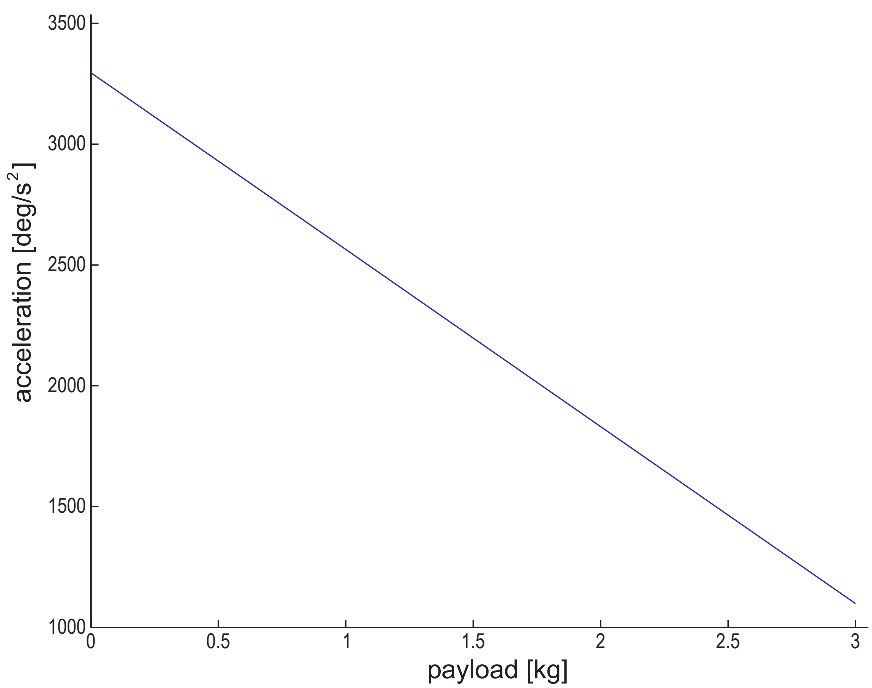


Figure 2-2: Maximum acceleration vs. payload for joints 4,5, and 6.

If the payload is carried at a distance from the tool flange, refer to the following tool offset de-rating curve:

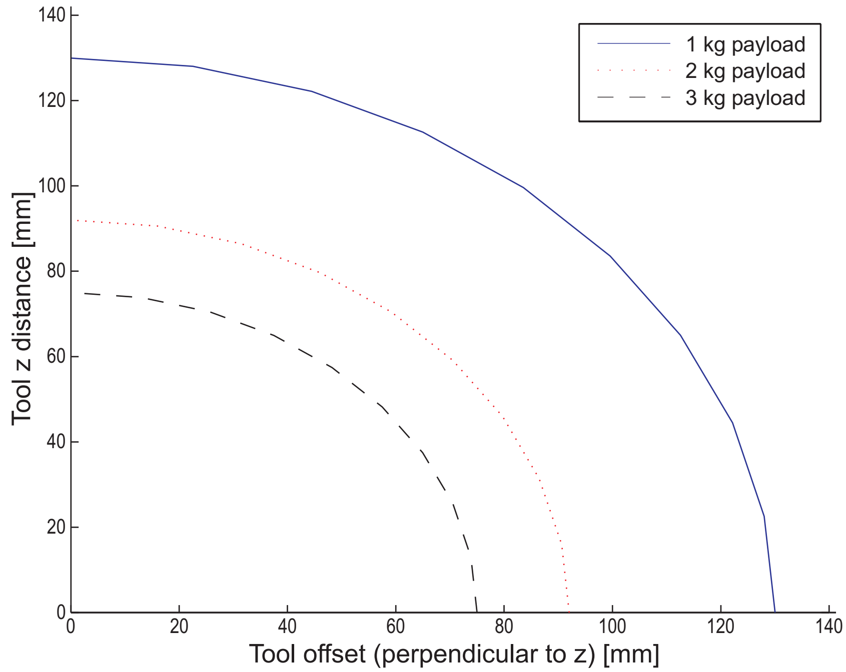


Figure 2-3: Tool offset de-rating curve.

Note: When applying a de-rating curve, you must include the mass of the end effector when calculating the payload, i.e. the *combined* mass of the end effector and payload should not exceed the maximum recommended payload mass for your application.

System Options

The following options are available for an F3 system:

- The Track option (available in 1, 2, 3, 4, 5 meter, and custom lengths) allows you to move the arm along an additional linear axis.
- Grippers are end-effectors that mount on the end of the tool flange to allow the arm to pick up objects. The Thermo CRS Servo Gripper is a servo-operated gripper which provides accurate positional and force control when gripping objects.

  Note:

- The Force Control Kit enables the arm to detect forces and adjust motion accordingly.
- The GPIO Termination Block extends the controller GPIO port to a termination block for easier access.

Contact Thermo CRS or your local distributor for more information.

CHAPTER 3

Safe Use of the F3 System

A robot is a potentially hazardous machine. Uncontrolled robot motion (robot runaway) and dropped payloads can result in serious damage to persons and equipment.

Before installing or using the robot system, ensure that you are familiar with the safety directives in this chapter. It is your responsibility to ensure that the robot system is safely installed and commissioned. You must also guarantee that all personnel operating the robot system receive adequate training and are fully aware of hazards present in and around the workcell.

Safety Conformance

Your F3 robot system has been designed and built in accordance with the following safety standards:

- UL 1740:1998 Robots and Robotic Equipment
- ANSI/RIA15.06-1992 Industrial Robots and Robot Systems - Safety Requirements
- CAN/CSA-C22.2 No. Z434-94 Industrial Robots and Robot Systems -- General Safety Requirements
- EN60204-1:1992, EN292:1991, EN954:1997 Category-1, and the Essential Health and Safety Requirements of the EC Machinery Directive
- ISO10218:1992 Manipulating industrial Robots -- Safety

Ensure that your robot application complies with all additional safety regulations and standards in effect at the site where the system is installed.

Designated Use

The F3 is designated for use in small-scale robot applications involving payloads of up to 3 kg [6.6 lb]. Typical applications include machine loading, parts handling, product testing, spraying, polishing/deburring, and laboratory automation tasks.

The F3 should not:

- operate in explosive environments
- operate in radioactive or biohazardous environments, except as part of a system that has been specifically designed for such use
- operate directly on humans (e.g. surgery)

If you are unsure whether your robot application falls within the designated use for the F3 system, contact the Technical Services Group.

Built-in Safety Features

The F3 robot system includes the following basic safety features:

- E-Stop buttons provide a means of halting robot motion in case of emergency.
- Continuous fault detection is built into the controller hardware and software. Arm power is automatically removed by faults caused by collisions, robot runaway, overheating, power surges, network time-out, or encoder faults.
- The beacon on the arm flashes when the arm is powered and capable of motion.
- Fail-safe brakes are built into joints 1 to 3.
    - Brakes engage automatically when arm power is off.
    - Brake-release switches are used to disengage the brakes and manipulate joints by hand.
- When using the teach pendant:
    - The system can only be operated while the live-man switch is engaged.
    - End effector speed is automatically restricted to 250 mm/s (Cartesian speed) or less.
- Manual input is required to transfer point of control or re-start the robot system after a power failure.

Triggering an E-Stop

In case of emergency, operators can quickly halt all robot motion by triggering an emergency stop.

To stop the arm in case of emergency

- Strike any E-Stop button.

To recover from an E-Stop

1. If necessary, press the brake-release button to release the brakes on joints 1, 2, or 3 and push the arm into a safe location. See “Releasing Brakes on the Arm” on page 5-9.
2. Remove all dangers from the workcell and verify that it is safe to power the arm.Twist the E-Stop button to reset it, or close the E-Stop device that triggered the stop.
3. Press the Arm Power button to restore power to the arm.
4. If arm power cannot be restored, see “Arm Power Cannot Be Turned On” on page 9-3 for the relevant troubleshooting procedure.

Designing a Safe Workcell

When designing your workcell, you must isolate all hazards associated with the use of your robot system.

A comprehensive risk assessment must include the following steps:

1. Identifying potential hazards associated with your robot application.
2. Estimating the severity of all identified risks and hazards, including hazards presented by the robot system itself, and by your application.
3. Selecting appropriate safeguards to control the risks. You must ensure both the safety of all persons operating near the robot work space and conformance with all applicable safety standards.

Note: If you do not wish to perform a risk assessment, you can choose instead to follow the complete Safeguarding Requirements as outlined in clause 7.2 of ANSI RIA15.06-1992.

Note: The E-Stop circuit on the C500C controller is CE rated at Category 1, which includes a single channel circuit.

For guidance in determining appropriate safeguarding measures for your workcell, consult the following safety standards:

- ANSI/RIA15.06-1992 Industrial Robots and Robot Systems - Safety Requirements
- EN775:1992 Robot Safety
- EN 1050:1997 Safety of machinery - Principles for risk assessment

Robot System Hazards

Warning! *All users of the F3 robot system must be made aware of the following potential hazards:*

- **A fire hazard may result if the arm comes in contact with a piece of equipment that is at a different electrical potential.** The arm is grounded through a chassis ground in the umbilical cable. If a charged piece of equipment is in contact with the arm for an extended period of time, the umbilical cable could overheat and catch fire.

- **Electrical shock risk: the umbilical cable carries a high voltage when the system is powered.** Route the cable so that it is protected from damage.

- **The space between moving links presents a crushing/pinching hazard.** These areas are labeled as pinch points on the robot arm. Keep well away from pinch points when arm power is on and the robot is capable of motion or when releasing brakes.

- Pinch points on the arm can trap or cut end-effector cabling or pneumatic lines. Secure external cables to the arm to prevent them from becoming trapped or cut.

- **The brakes in the robot arm do not instantaneously halt robot motion when arm power is removed.** See “Maximum E-Stop Travel Distances and Stop Times” on page 3-7.

- The beacon on the arm is not visible from all directions.

- **The arm may still be capable of motion when the beacon on the arm is off.** The robot system does not emit a warning to alert the operator if LEDs in the beacon fail. Routinely inspect the beacon on the arm to ensure that it is functioning normally.

- **Water or other liquids may cause a short circuit, which could cause robot runaway.** Water or other electrically conductive liquids must not be allowed to enter the arm or controller.

- **The F3 system does not automatically monitor air pressure for pneumatic tools.** If lack of air pressure could cause a hazard, integrate appropriate safeguards into your application via the GPIO or SYSIO ports. See “General Purpose Input/Output Port (GPIO)” on page 7-12, and “System Input/Output (SYSIO)” on page 7-17.

- **The controller front panel cannot be disabled.** If you create a remote front panel, you must ensure that the Arm Power and Pause/Continue buttons are only accessible from one location. See “Designing a Safe Front Panel Device” on page 7-17.

- **Using an unmatched controller and arm may result in collisions.** When swapping arms or controllers, or performing significant arm repairs, always ensure that the calibration file on the controller matches the arm that is connected to it. See “Loading the Robot Calibration File” on page 5-5.

Work Space

The work space is the volume of space that can be swept by all robot parts plus the space that can be swept by the end effector and the workpiece.

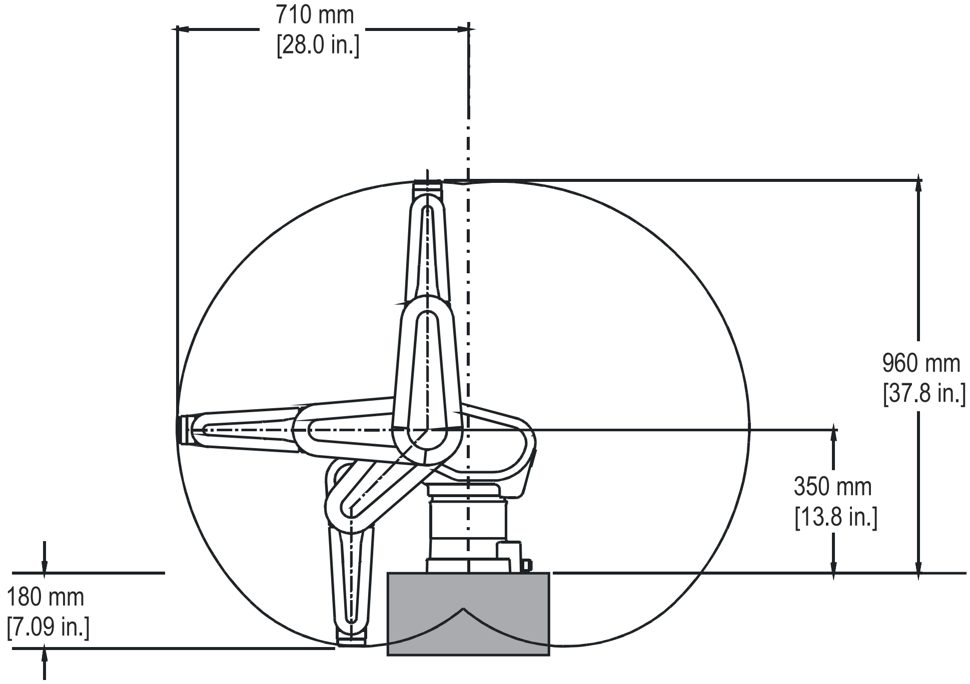


Figure 3-1: Base reach of the F3 arm (without end effectors)

To calculate the work space for your application

Add the following dimensions:

- The base reach of the arm
- The dimensions of your end effector, calculated outward from the arm
- The dimensions of the workpiece, calculated outward from the arm
- Any space required to avoid crushing/pinching hazards

The calculated distance, extended in all directions, represents the minimum work space for your application.

Establishing a Safeguarded Perimeter

Depending on the risk assessment for your application, the perimeter may be defined by a physical barrier which prevents access to the workcell, or it may simply consist of awareness warnings designed to alert operators to dangers presented by the robot system.

Note: To connect safeguards and warnings to the E-Stop circuit, see the procedures in "Installing Additional Safety Devices" on page 4-12.

Physical Barriers

When installing barriers, the following criteria must be met:

- Barriers are outside the total radius of the arm, gripper, and payload.
- Although you can use software limits to restrict arm movement to a portion of the work space, barriers must encompass the full work space of the arm. Software limits do not prevent motion during robot runaway.
- Provide sufficient clearance between the barriers and the work envelope to prevent trapping or crushing hazards.

Presence-sensing Interlocks

Presence-sensing interlocks automatically stop the arm when a door is opened or motion is detected within a defined perimeter. Presence sensors include devices such as contact switches, light curtains, and pressure-sensitive floor mats.

To increase safety in your workcell, provide presence-sensing interlocks at all points of entry into the workcell. For example, you can connect door-mounted contact switches to your robot system via the SYSIO port to interrupt arm operation when a door is open.

Note: All components used in interlocks must be safety-rated.

Note: For more information on how to connect interlocks to the robot system, see "The SYSIO Port" on page 7-18.

When designing interlocks for your workcell, keep the following points in mind:

- Interlocks must be integrated into the E-Stop circuit for the workcell and designed so that a failure automatically interrupts the E-Stop circuit and removes arm power.
- Interlocks must not interfere with other E-Stop devices in the workcell.
- The presence-sensing envelope must be larger than the work envelope of the arm. The extra volume must be sufficient to allow time for the arm to come to a halt before an intruder can enter the arm's work space.

Passive Warnings

Passive warnings are designed to alert operators of dangers presented by the robot system but do not themselves prohibit access into the workcell. To maximize safety, incorporate passive warnings into your workcell design along with physical barriers or presence-sensing interlocks.

Some examples of passive warnings include:

- Audio or visual awareness signals, such as buzzers or lights, that indicate a dangerous condition or warn an intruder to keep a safe distance.
- Awareness barriers, such as a length of yellow chain or distinct markings on the floor or tabletop.

When implementing passive warnings, ensure that all persons working with the robot system recognize the warnings and understand what they mean.

Emergency Stop (E-Stop) Devices

For safe robot use, E-Stop buttons should be readily accessible at all points where it is possible to enter the robot work space. You can install additional E-Stop devices in series via the SYSIO port on the back of the controller. For E-Stop installation procedures, see “Adding E-Stop Devices” on page 4-12.

Maximum E-Stop Travel Distances and Stop Times

After an E-Stop has been activated, the arm continues to travel a short distance before coming to a complete stop. Maximum travel distances and stop times are shown in Table 3-1 for both automatic and teach modes of operation:

Table 3-1: E-Stop travel distances and stop times

Joint	Stopping Time		Distance		Brake
	teach	auto.	teach	auto.	
joint 1	< 0.5 s	< 1 s	< 5°	48°	Yes
joint 2	< 0.5 s	< 1 s	< 5°	35°	Yes
joint 3	< 0.5 s	< 1 s	< 5°	72°	Yes
joint 4	< 0.5 s	< 1 s	< 5°	68°	N/A
joint 5	< 0.5 s	< 1 s	< 5°	45°	N/A
joint 6	< 0.5 s	< 1 s	< 5°	90°	N/A

Note: Maximum stop times in automatic mode were obtained using a 2 kg payload.

Accident Prevention

Warning! *The robot system is a potentially dangerous machine. If incorrectly installed or programmed, the arm may perform unexpected movements at high speeds.*

In order to minimize the risk of accidents around the robot system, apply the following safety principles:

- Design and test your robot application so as to ensure the safety of system operators at all times.
- Perform the commissioning procedures described in “Commissioning the System” on page 5-1 after installing, moving, or modifying any component of the robot system.
- Alert all operators to the dangers presented by the robot system.
- Prohibit or restrict access to the work space while the robot system is in use. Barriers or other safeguards should be used to establish a safe perimeter outside the reach of the arm. Train personnel to remain outside the perimeter while arm power is on.
- Make all persons entering the safeguarded area aware of potential hazards and of the need to have an E-Stop button in reach at all times.

- During automatic operation of the robot system, prevent personnel from entering the safeguarded area.
- Schedule routine inspections of all safety devices to ensure that they are functioning normally. See "Commissioning the System" on page 5-1.
- If the system is under repairs or acting abnormally, lock-out the controller to prevent the system from being used. See "Locking Out the Controller" on page 3-9.

Safety Training

Ensure that all personnel who program, operate, or maintain the robot system are adequately trained to perform their jobs safely. It is strongly recommended that you attend a Thermo CRS training course before implementing a robot application.

Ensure that all operators:

- Have a clear definition of their duties.
- Receive adequate training.
- Are fully aware of the dangers of the robot application.
- Know the location and use of all safety devices.

Working Within the Robot Work Space

During teaching and program verification, it may be necessary for an operator to enter the safeguarded area. While within the robot work space, always keep the following points in mind:

- Be aware of arm position at all times.
- Work at reduced speeds.
- Have an E-Stop device within reach at all times.
- Never work alone inside the safeguarded area.
- **Avoid crushing hazards.** Never place yourself between the arm and a fixed object.
- **Know your capabilities.** If you have not been trained, do not attempt to service the arm yourself. Only Thermo CRS-qualified service personnel should service the arm.

Locking Out the Controller

While repairing or replacing any component of the robot system, lock out the controller to ensure that the system is not used.

Note: OSHA safety procedure 1910-147 recommends locking out the AC power outlet at the main panel. If you prefer to implement the OSHA-recommended procedure, refer to OSHA 1910-147 Control of Hazardous Energy (Lockout/Tagout) for further information.

To lock out the controller

1. Unplug the AC power cord from the back of the controller.

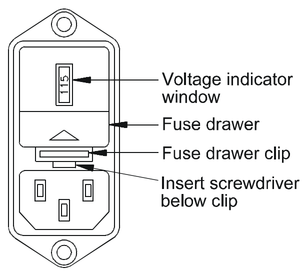


Figure 3-2: Removing the fuse drawer

2. Insert a flat head screwdriver below the clip and remove the fuse drawer from the back of the controller.
3. Create a tag labeled “**DO NOT POWER THE ROBOT SYSTEM**” and hang it on the back of the controller. The tag must be conspicuous and easy to read.

CHAPTER 4

Installation

This chapter provides instructions for installing the components of your F3 robot system. If you have not already set up a workcell, you should review "Designing a Safe Workcell" on page 3-3 before beginning the installation.

Preparing a Mounting Platform for the Arm

You must secure the arm to a supporting structure to ensure that it does not move or fall during use.

You can mount the arm in an upright or inverted position. In an upright position, the base of the arm occupies a portion of its work space, limiting the available work area. The work area is larger with the arm inverted, but the trajectories required by robot applications may be more complex.

Whether upright or inverted, the mounting platform must be rigid enough to support the weight of the arm and withstand inertial forces caused by acceleration and deceleration while the arm is in use.

Note: If you are mounting the arm on a track, see the *Track User Guide* for mounting instructions.

Platform Requirements

- The supporting structure (bench, table, bracket, or other structure) must be firmly anchored to the floor or overhead frame to prevent movement.

  Note: A welded steel frame is preferable to an adjustable frame. Adjustable frames can shift over time, decreasing accuracy.

- The platform must be level. Do not attempt to mount the arm on a wall or incline.

- If you are securing the arm to a metal plate, the metal must have a minimum yield strength of 210 MPa [30,000 psi] .

- Use four M12 cap screws cap to mount the arm. **Do not use the cap screws used to fasten the arm in the shipping crate.**

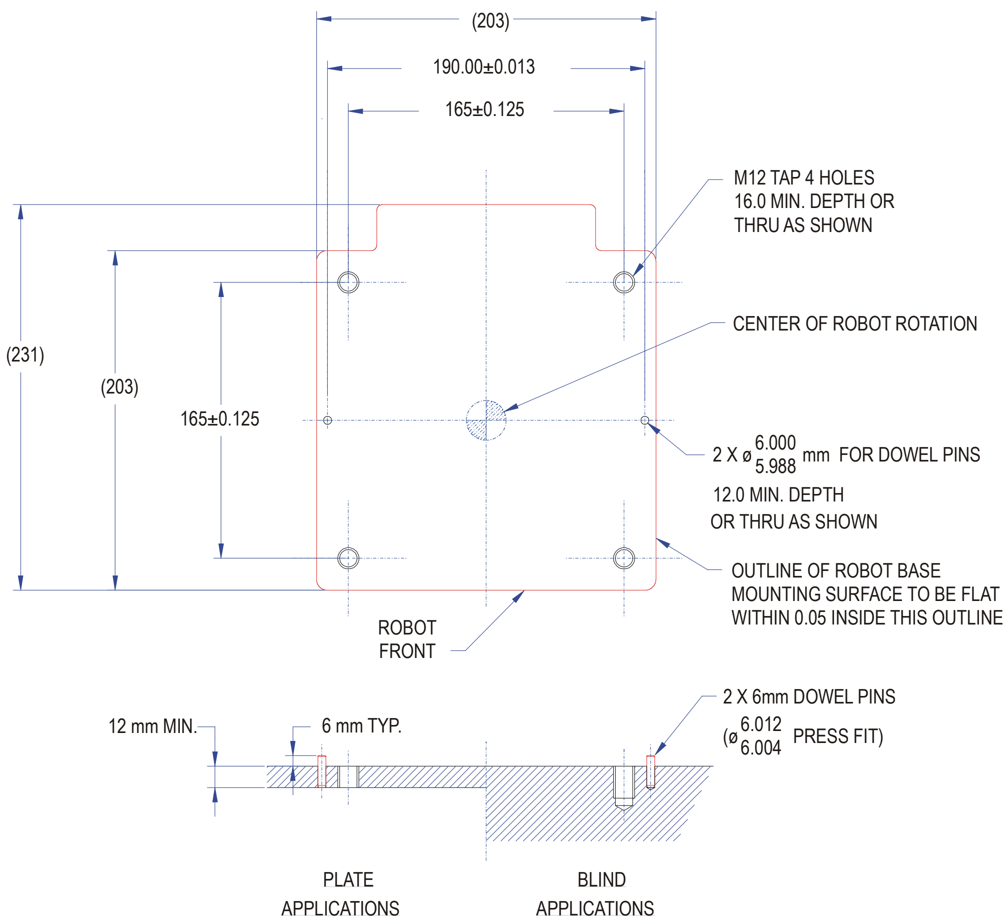


Figure 4-1: Mounting template for the F3 arm

Note: Except where noted, dimensions are in mm. Dimensions in parentheses are reference.

Note: To obtain mesasurements in inches, divide by 25.4.

To prepare the mounting platform

1 Using the template in Figure 4-1 as a guide, drill and tap holes for four M12 screws .

Note: If you are mounting the arm directly onto a tabletop, drill the holes as indicated for blind applications. If you are preparing a plate, drill the holes straight through the plate.

2 Drill and ream holes for two 6 mm dowel pins, as indicated in Figure 4-1. The dowel pins are used to ensure accurate positioning of the arm.

3 If you are preparing a mounting plate, drill any additional holes required and secure the mounting plate to the supporting structure.

Lifting the Arm

The F3 arm weighs approximately 52 kg [115 lb] and can easily be damaged if it is dropped.

Do not attempt to lift the arm unassisted. Use a crane or hoist to lift and move the arm. If necessary, the arm may also be lifted manually by two or more persons.

Lifting the Arm With a Crane Or Hoist

Use the eyebolt supplied with your robot system to securely lift the arm with a crane or hoist.

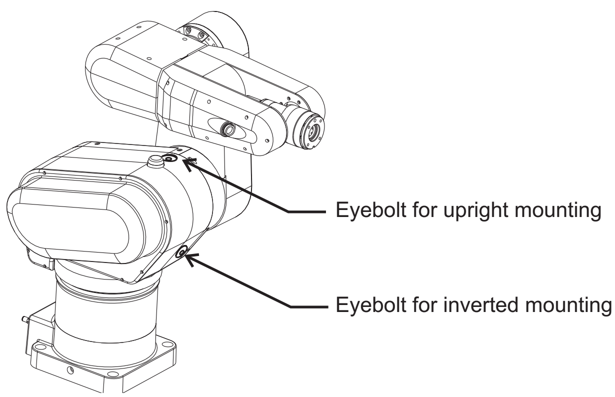


Figure 4-2: Eyebolt holes on the F3 arm.

Note: If you are unpacking the F3 system for the first time, the eyebolt is pre-installed in one of the eyebolt holes.

To lift the arm with a crane or hoist

1 Tightly screw the eyebolt into one of the eyebolt holes:

- To move the arm in its upright position, use the eyebolt hole near the arm beacon.
- To move the arm in its inverted position, use the eyebolt hole on the underside of the shoulder casting.

Note: If the eyebolt is pre-installed, verify that it is tightly screwed into place.

2 Attach a cable to the eyebolt and carefully lift the arm. Lift the robot only as high as necessary to clear obstacles to reduce the possibility of injury and damage to the robot. Do not allow the arm to spin as this will loosen the eyebolt and may cause the arm to fall.

3 Set the arm down on a clear, level surface. In its shipped position, the arm is slightly unstable and may tip over. Ensure that the arm is adequately supported at all times.

4 When you have finished moving the arm, detach the cable and remove the eyebolt from the shoulder casting. The eyebolt should only be fastened onto the arm when it is needed to move or lift the arm. **Never operate the robot system with an eyebolt in place on the arm.**

Manually Lifting the Arm

If manually lifting the arm is unavoidable, the arm can also be lifted from the base or from underneath joint 2, as shown in Figure 4-3. **Never grasp the arm by the motor covers on the side, or by the wrist.** Use a cart if the arm is to be moved over any distance.

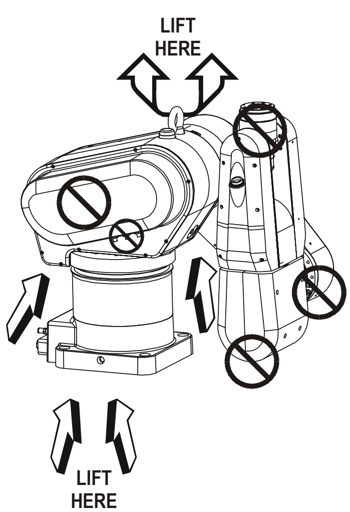


Figure 4-3: Lift the F3 arm from the base or under joint 2. Never lift the arm by the motor covers on the sides or by the wrist.

Securing the Arm to the Mounting Platform

Once the mounting platform has been prepared, you are ready to mount the arm. The arm may be mounted in an upright or inverted position.

To mount the arm on the mounting platform

1. Insert the dowel pins into the prepared holes on the mounting platform.
2. Lift the arm onto the mounting platform, taking care to line up the holes at the base of the arm with the holes on the platform.
3. Secure the arm to the mounting platform with four M12 screws. The arm should not move on the platform once it has been secured.

Do not use the cap screws used to fasten the arm in the shipping crate for mounting the arm. *The shipping screws are not sufficient to secure the arm in place during use.*

Once the robot system has been in use for a short time, re-tighten the mounting platform screws to ensure that the arm does not move.

Lifting the Controller

The controller weighs approximately 31 kg [68 lb] and has built-in handle flanges along the side edges. You can grasp the controller from underneath, or by the handle flanges.

Installing the Controller Fuse Drawer

The country kit shipped with your robot system includes the voltage selector, the fuse drawer, four fuses (two for immediate use and two spare), and an AC power cable appropriate to the standard power supply in your country.

The fuses shipped with your system should be appropriate for the local mains voltage, as shown in Table 4-1:

Table 4-1: AC fuses required for the F3 Robot System

Voltage	Required Fuses
100 VAC	10 A, 250 V, 6.3 mm x 32 mm [¼ in. x 1¼ in.], slow blow
115 VAC	10 A, 250 V, 6.3 mm x 32 mm [¼ in. x 1¼ in.], slow blow
230 VAC	5 A, 250 V, 6.3 mm x 32 mm [¼ in. x 1¼ in.], slow blow

Before using the controller, you must select the correct voltage and insert the fuse drawer into the back of the controller.

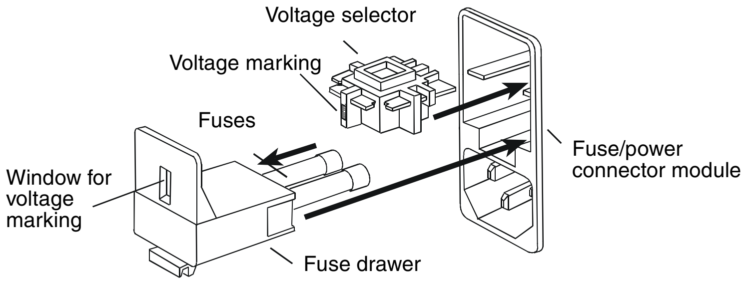


Figure 4-4: Controller fuse drawer and fuse/connector module

To select the voltage and install the AC fuses

1. Locate the fuse/power connector module on the lower right corner of the rear panel of the controller.
2. Turn the voltage selector so that the correct voltage marking faces you.
3. Insert the voltage selector into the upper part of the fuse/power connector module. Only the voltage for your country should be visible.

   Warning! The controller may be seriously damaged if the voltage is not selected correctly.

   Note: Carefully insert the fuse drawer into the connector module. Forcing the selector into place can damage the connector module.

4. Insert the two AC power fuses into the fuse drawer.
5. Push the drawer into the fuse/power connector module until it clicks.

Once the correct fuses have been installed, you can plug the AC power cable into the lower part of the fuse/power connector module.

Warning! Do not turn on controller power until you have completed the entire installation.

Mounting the Controller

The controller can be mounted on any level surface, either resting on its bottom feet or mounted in a rack.

The chassis is 482.6 mm [19.00 in.] wide by 266.7 mm [10.49 in.] high, and is designed to fit into a 600 mm [6U] rack enclosure. Holes for rack mounting are provided in the front flanges and sides, as shown in Figure 4-5.

Mounting requirements for the controller

- For safety reasons, the controller must be outside the arm's work space.
- Provide at least 225 mm [9 in.] of space for ventilation and cables at the back of the controller.
- The front panel buttons, status display, and E-Stop button must be readily accessible.
- If the controller is rack mounted, use the screws recommended by the rack manufacturer. Support the back of the controller where possible.

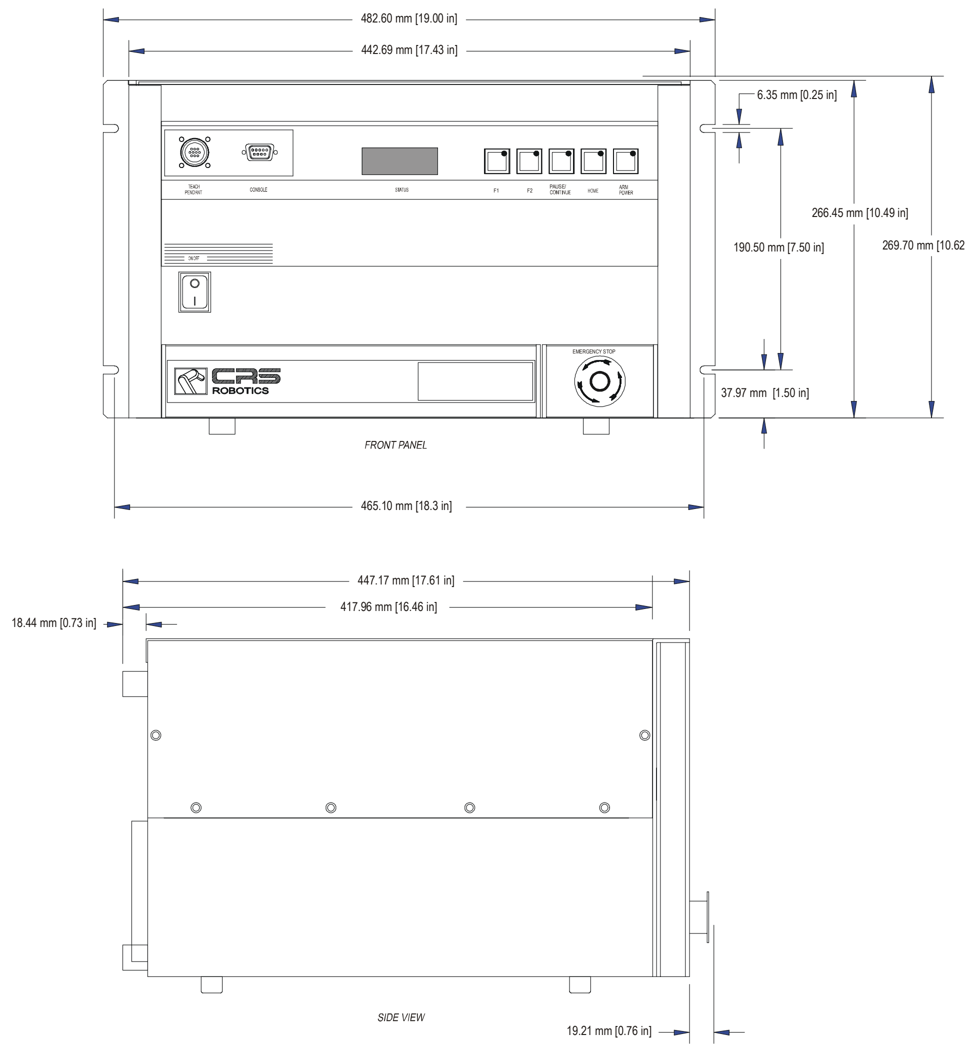


Figure 4-5: C500C controller front and side views with dimensions

Connecting Robot System Components

Connect robot system components to ports on the front and back of the controller, as shown in Figure 4-6.

Warning! *Always turn off power before connecting or disconnecting cables.*

Additional devices should be added to your robot system later, after you have performed an initial power-up and tested the system for basic functionality.

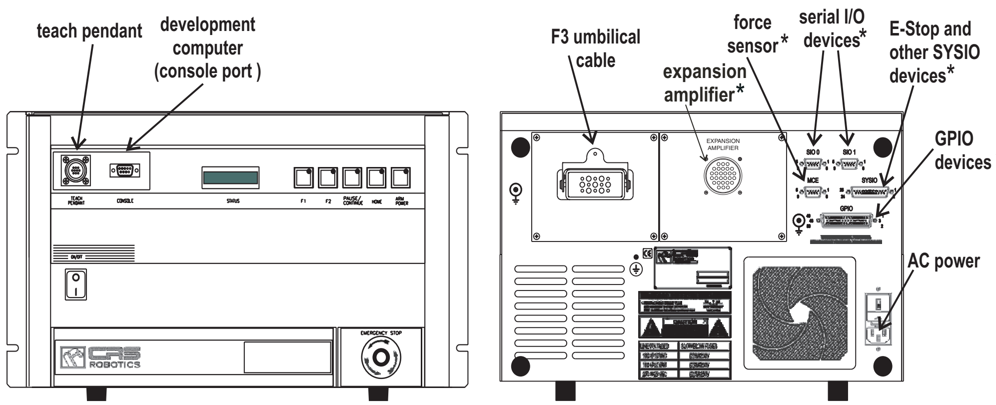


Figure 4-6: Connections to the C500C controller.

Note: Connections labeled with an asterisk (*) are optional and may not be needed for your robot system. For more detail on these connectors, see Chapter 7, System Connections.

Connecting the Umbilical Cable

The umbilical cable connects the controller to the F3 arm. It provides power and communication to the arm, and connects the arm to the same ground as the controller.

To connect the umbilical cable

1 Plug the male umbilical cable connector into the receptacle at the back of the controller, shown in Figure 4-6.

2 Press the connector in firmly and push down the latch until you hear it click shut.

Note: You will have to press quite hard on the latch to close it. This compresses a rubber gasket between the connector and the receptacle to form a watertight seal.

3 Plug the female umbilical cable connector into the receptacle at the back of the F3 arm.

4 Press the connector in firmly and lock it in place with the latch.

Connecting the SYSIO Dummy Plug

The SYSIO dummy plug is a small black and silver DB-25 connector. If you do not have any SYSIO devices connected, you must insert the dummy plug into the SYSIO port to complete the E-Stop circuit for your robot system.

Note: The SYSIO dummy plug is usually pre-installed at the factory.

For more information on the SYSIO port, see "System Input/Output (SYSIO)" on page 7-17.

Connecting the Teach Pendant

The teach pendant is used to move the robot, teach locations, and run robot programs from a handheld keypad.

Note: You cannot run ActiveRobot programs from the teach pendant.

To connect the teach pendant

With the controller shut down and powered off, remove the teach pendant dummy plug and connect the teach pendant to the port labeled *Pendant* on the front of the controller, shown in Figure 4-6.

Note: If a teach pendant is not connected to the controller, connect the teach pendant dummy plug to the teach pendant port in order to complete the E-Stop circuit for your robot system.

For more information on how to use the teach pendant, see "Basic Teach Pendant Commands" on page 6-6.

Connecting the Development Computer

In order to program robot applications and commission your robot system, you will need a development computer with ActiveRobot or Robcomm3 installed. The *ActiveRobot User Guide* included on the documentation CD explains how to set up a development computer for a robot system using ActiveRobot. If you are programming in RAPL-3, install Robcomm3 as described in the *Robcomm3* user guide.

Note: The computer must be connected via a straight-through RS-232 cable with a female DB-9 connector at the controller end.

Note: The default baud rate used by the C500C controller is 57600 bps.

To connect a development computer for ActiveRobot

1. Connect your serial cable to a serial port on the development computer.
2. With the controller shut down and powered off, connect the other end of the serial cable to the Console port on the front of the controller.
3. Using the ActiveRobot Configuration utility on the development computer, set up communication with the robot system.

Note: ActiveRobot configuration is described in the section entitled “Installing ActiveRobot” in the *ActiveRobot User Guide*.

To connect a development computer for RAPL-3

1. Run Robcomm3.
2. In the main Robcomm3 menu, click **C500** and select **COM Settings**.
3. Under **Comm Port**, select the serial port for your computer.
4. Under **Baud Rate**, select 57600.
5. Click **OK** to apply the change.

Note: Robcomm3 installation is described in the *Robcomm3* user guide.

If you cannot establish communication between the development computer and the controller, see Chapter 9, Troubleshooting.

Connecting End-of-arm Tools

Install end-of-arm tools according to the instructions provided in the manufacturer's documentation. If no documentation is available, or the documentation is not specific to the F3, refer to these guidelines:

- Secure standardized end-of-arm tools to the ISO-standard tool flange with four M6 screws.

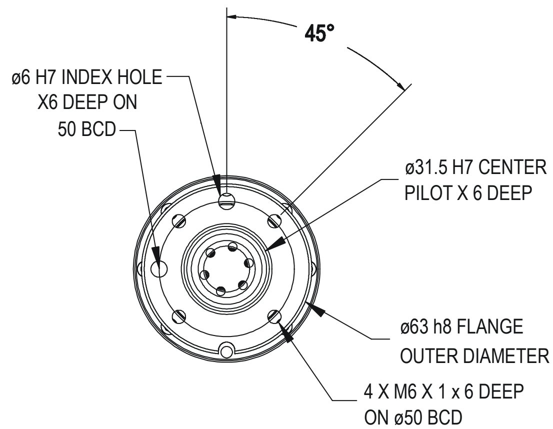


Figure 4-7: The ISO-standard F3 tool flange

Warning! Do not allow fasteners to protrude through the tool flange to the rotating part of the wrist. *When selecting fasteners, be careful to ensure that they are the correct length.*

- Use an M6 dowel pin and the pilot hole to accurately position the tool against the flange. Two index holes are provided for the M6 dowel pin. One is slightly smaller than the other in order to provide a press-fit.
- To enable pneumatic or servo control, connect the tool to end-of-arm connectors on the side of the wrist. Secure all wires to the arm in order to prevent them from being pinched.

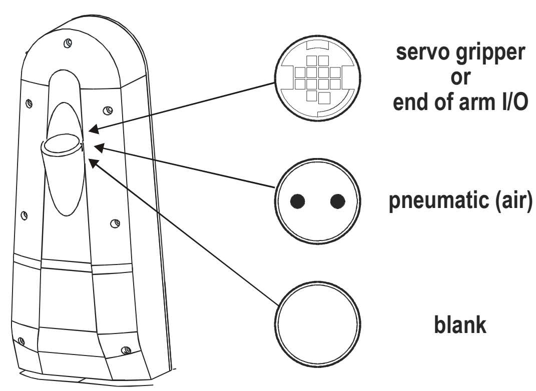


Figure 4-8: End-of-arm connectors available with the F3 wrist. See Chapter 7, System Connections for more detailed information on these connectors.

Note: If your F3 arm is an earlier model with air only, one of the two wrist covers may be blank. Some F3 models provide an optional end-of-arm I/O connector or a second pneumatic connector instead of the standard servo gripper connector.

Installing Additional Safety Devices

In order to improve safety within your workcell, you can connect additional safety devices to the E-Stop and arm power circuits via the SYSIO port on the back of the controller.

Warning! *Do not connect live voltage through the SYSIO E-Stop circuit. This can permanently damage sensitive electronic components within the controller.*

Note: The SYSIO port uses ribbon-cable numbering rather than the standard DB-25 numbering scheme. For more information on the SYSIO port pin layout, see "System Input/Output (SYSIO)" on page 7-17.

Adding E-Stop Devices

The E-Stop circuit for your robot system includes E-Stop buttons on the controller and the teach pendant, as well as a passive E-Stop device in the Live-man switch.

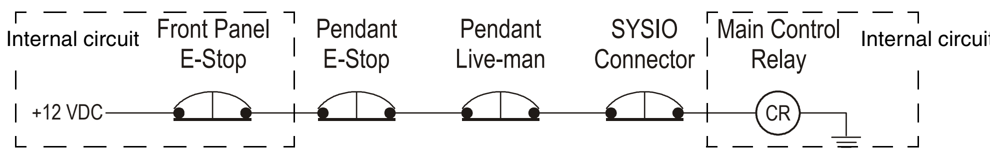


Figure 4-9: The E-Stop circuit

Note: All E-Stop devices in Figure 4-9 shown in their normal (closed) position

Design the E-Stop circuit for your system with the following points in mind:

- An E-Stop button must be a large, palm-cap, red button that has been third-party approved for use as an E-Stop. Once triggered, the E-Stop button must require a manual reset.
- In addition to buttons that halt robot motion, E-Stop devices can include passive triggers such as door latching mechanisms or pressure sensors.

  Note: All mechanisms used as E-Stop devices must be safety-rated.

- Connect all E-Stop devices in series to ensure that power is removed when any device in the circuit is disconnected or disrupted.

To connect additional E-Stop devices to the controller, see "System Input/Output (SYSIO)" on page 7-17.

Connecting External Devices to the Controller E-Stop

Danger! *If your application includes more than one power circuit, E-Stop devices must stop **all** potentially dangerous devices in the workcell.*

If your system includes the Expansion Amplifier option, you can use the ArmOn and Brake switch contacts on the expansion amplifier connector to remove power from external devices when the controller E-Stop is pressed.

To connect external devices to the controller E-Stop chain, see "Connecting to the E-Stop Chain" on page 7-11.

CHAPTER 5

Commissioning the System

After installing, relocating, or making any changes to components of your robot system or updating the version of CROS on the controller, you must check the robot system thoroughly to ensure that it is functioning correctly. This is referred to as commissioning your system for use.

When commissioning a robot system, you must:

- Establish clear boundaries around the arm's work space, whether the arm is installed as part of a workcell or mounted on a lab bench.
- Designate and adequately train all personnel responsible for commissioning and functional testing of the robot system.
- Ensure that personnel responsible for commissioning the robot system have read and understood the Safety instructions in Chapter 3, Safe Use of the F3 System.

To commission a robot system

1. Inspect the system for any dangers (page 5-2).
2. Connect the development computer and power up the robot system (page 5-3).
3. Set up the default system configuration (page 5-6).
4. Verify encoder feedback (page 5-7).
5. Turn on arm power (page 5-7).
6. Check all devices in your E-Stop circuit (page 5-8).
7. Engage and disengage the brake release mechanism (page 5-9).
8. Test joint motion from both the teach pendant and the development computer (page 5-10).

Inspecting the System

Before turning on the power to your robot system, verify the following points:

- The arm is securely bolted to its mounting platform and any installed end effectors are tightly fastened to the tool flange.
- The development computer is connected to the Console port on the front of the controller.
- The teach pendant (or dummy plug) is connected to the Teach Pendant port on the front of the controller.
- All cables are connected and properly strain-relieved.
- The arm is not carrying a payload.
- The eyebolt is removed from the arm.
- The robot work space is free of obstructions.
- The work space is clearly delineated by barriers or other safety measures.
- Operators and other personnel are outside the robot work space.
- The E-Stop circuit is closed:
    - All triggered E-Stops have been reset.
    - A SYSIO device (or the SYSIO dummy plug) is connected to the SYSIO port.
    - All other devices in the E-Stop circuit, such as safety interlocks and proximity sensors, are closed and the circuit is complete.
- If you have made any modifications to your robot system, verify the following additional points:
    - The controller AC voltage is correctly selected.
    - The arm and all components are correctly installed and stable.
    - Cables are not pinched or under strain.
    - If you are using a different arm or controller, or have serviced the arm, verify that the calibration file on the controller matches the arm. See "Loading the Robot Calibration File" on page 5-5.

Powering Up the Robot System

During power-up, the controller boots and performs diagnostic tests. For safety reasons, turning on the controller does not turn on arm power.

Caution! Turning the controller off incorrectly can cause memory loss. *Once the controller is powered on, make sure that you shut it down correctly according to the procedure in* *"Powering Down" on page 6-9**.*

To power up the system

1 If you have not already done so, connect the AC power plug from the controller to your power outlet.

2 Standing outside the robot work space, switch on the controller power. The controller begins cycling through its boot-up sequence.

Note: For more information on controller boot-up, see the *CROS and System Shell Guide* on your documentation CD.

When the controller finishes booting up, the front panel display reads:

```
C500C CROS
```

If you have a terminal window open on the development computer, you will also see the following diagnostic test results:

```
Amplifier status
1......OK 2......OK 3......OK
4......OK 5......OK 6......OK
```

If you do not see this message on the front panel display, or you encounter any errors, refer to Chapter 9, Troubleshooting.

Installing the Latest Version of CROS

The documentation CD shipped with your robot system contains the latest released version of CROS, the robot system firmware. Before using the system for the first time, you should verify that the correct version of CROS is installed on the controller.

- To verify the version of CROS on the controller, open a terminal window on the development computer and enter the command `crosver`.

If the version of CROS on the controller is lower than the version on your documentation CD, install CROS from the documentation CD.

Robot applications may not function as expected with a different version of CROS. *If you intend to use application software that has been written for an earlier version of CROS and do not want to upgrade, install the earlier version of CROS instead of the one on the documentation CD.*

For more information on how a CROS upgrade will affect application performance, refer to the CROS release notes on the documentation CD.

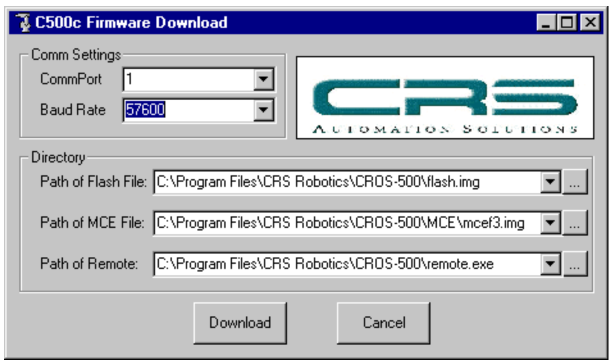
To install CROS

1. Insert the documentation CD into the CD-ROM drive on the development computer and install CROS. This installs CROS and the firmware download utility onto the development computer. The download utility is used to transfer CROS from the development computer to the controller.

2. On the development computer, start the CROS-500C Firmware Download Utility. The download utility is located in the CRS Robotics folder under Program Files on your Windows Start Menu.

   Note: If you don't see the download utility on your Start Menu, you can click Find and select Files or Folders to search for "download.exe".

   The download utility opens the following configuration screen:



3. Verify that the settings are correct for your robot system.

Setting	Required Value
CommPort	The development computer COM port that is connected to the robot system.
Baud Rate	The baud rate of the controller *Console* port. The factory default setting for the *Console* port on a C500C is 57600 bps.
Path of Flash File	The name and location of the file flash.img on the development computer. You can press the "..." button to search for the file yourself.
Path of MCE File	The name and location of the file mcef3.img on the development computer.
Path of Remote	The name and location of the file remote.exe on the development computer.

   When the settings are correct, click **Download** in the Firmware Download window. The download utility then prompts you to restart the controller in Diagnostic mode.

4. Restart the controller in Diagnostic mode:

   a. Shut down the controller by entering the command `shutdown now`.

   b. Switch off controller power.

   c. While holding down the F1, F2, and Pause/Continue buttons, switch on controller power. Continue to hold the buttons for 10 seconds.

   d. The controller boots into Diagnostic Mode. Verify that the message

   ```
   Diagnostic Mode
   ```

   is displayed on the controller LCD screen.

5. On the development computer, click **OK** to start the download.

When the download is complete, you must rebuild the controller file system.

Note: Any program application or configuration files on the controller are deleted during the rebuild. If you have any files stored on this controller, make sure they are backed up before you proceed.

To rebuild the file system

1. Switch off controller power.
2. While holding down the F2 and Home buttons, switch on controller power.
3. The controller LCD displays the message `Loading new MFS from Flash` while the file system is being rebuilt. When the process is complete, the controller continues with its normal bootup sequence.

Loading the Robot Calibration File

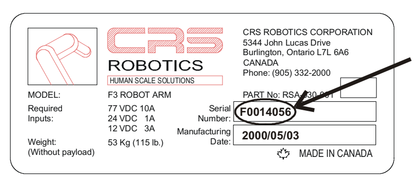
Before you can use an arm with a new controller, you must load the correct robot calibration file for the arm. Each F3 is shipped with a calibration disk that contains the specific calibration file for that arm. The calibration file determines where the zero position is for each of the arm's encoders.

You only have to reload the calibration file after a recalibration, a service procedure which affects the encoders (in which case, you will receive a new calibration disk), or when using a different arm with the controller.

Warning! Collisions may occur if you attempt to use the arm with an incorrect calibration file. *When replacing the arm or controller, always ensure that the calibration file on the controller matches the arm in use.*

To load robot.cal onto the controller

1. Locate the arm serial number on the decal at the base of the arm.
2. Locate the calibration disk shipped with your arm and verify that the number on the disk matches the number for the arm.



Note: If you have lost your calibration disk, note the serial number for the arm and contact the Technical Services Group for assistance.

3. Transfer the calibration file robot.cal from the calibration disk to the /conf directory on the controller connected to your arm.
4. Shut down and restart the controller.
5. Verify that the LED on the Home button is lit, showing that the arm's position has been correctly read from the calibration file on the controller.

   Note: The F3 arm retains positional information. Under normal use, you should not need to home the arm.

   If the Home light does not come on, you must restore the calibration file. See the Troubleshooting procedure "Joint N Is Limp" on page 9-1.

Updating After Repairs to the Arm

After servicing and re-calibration, the robot.cal file on the controller must reflect the changes made to the arm.

If the arm and controller were re-calibrated together, the file on the controller is already up to date. If the arm was re-calibrated separately, you must update the calibration on the controller with the new calibration file.

To update robot.cal after service and re-calibration

1. Locate the appropriate robot.cal calibration file for your arm. If a new calibration file was not provided with your arm after servicing, contact the service technician or representative who performed the repairs.
2. Copy the robot.cal calibration file for the arm to the /conf directory on the controller connected to your arm.
3. Shut down and restart the controller.

Setting up the Robot Configuration File

If you are setting up the system for the first time, use the command `/diag/setup` to configure default parameters such as measurement units and the number of axes for your robot system.

Note: Robot system configuration parameters are stored in robot configuration file, `/conf/robot.cfg`.

To configure the system

1. Open a terminal window on the development computer.
2. Enter the command `/diag/setup`.
3. You will be prompted to answer a series of configuration questions. If you answer a question incorrectly, simply run `/diag/setup` again.
4. Once setup is complete, shut down the controller by entering:

   ```
   $ shutdown now
   ```
5. Reboot the controller to apply the new configuration.

For more information on configuration parameters, see `cfg_save` in the *RAPL-3 Language Reference Guide* and the *Application Shell (ASH)* guide, or ConfigSave in the *ActiveRobot User Guide* on the documentation CD.

Verifying Encoder Feedback

With arm power off, make sure that the controller is receiving feedback from all encoders.

To test encoder feedback

1 If necessary, remove arm power by pressing an E-Stop button. The LED on the controller Arm Power button should now be off.

  From ash, enter the command `w1` to display the position of each encoder. If your arm is in the ready position, the motor pulse count display will look something like this:

```
-1     +0     +51200    +1     +0     +1
```

  Note: A variation of a few motor counts is normal.

  Note: For more information on the application shell, ash, please refer to the *Application Shell Guide* on your documentation CD.

2 Starting with joint 1, push against each joint with your hand and observe the display. The number of counts should change in response to the movement.

  Note: Although brakes prevent joints 1, 2, and 3 from moving, the encoders will register a small movement when each joint is pushed.

3 Press **Ctrl+E** to return to the ash prompt.

Turning on Arm Power for the First Time

Before turning on arm power for the first time, make sure that an E-Stop button is in reach and that operators and other personnel are well outside the robot work space. Because the system has not yet been checked for safety, be especially cautious when commissioning the robot system.

Warning! An undiagnosed problem with your robot system can cause the arm to move unpredictably when power is applied. *You should always be prepared to strike an E-Stop button when applying arm power for the first time.*

To turn on arm power

1 While standing outside the robot work space, press the Arm Power button on the front panel of the controller.

  The LED on the Arm Power button should light and the beacon on the arm should flash, indicating that the arm is powered on.

2 If you cannot turn on arm power, check for triggered E-Stop devices and make sure that the teach pendant and SYSIO ports are properly terminated with either a device or a dummy plug. Reset any triggered E-Stop devices and press the Arm Power button again.

If you still cannot turn on arm power, see the troubleshooting procedure “Arm Power Cannot Be Turned On” on page 9-3.

Checking Devices in the E-Stop Circuit

Devices in the E-Stop circuit must remove arm power to protect the operator in case of an emergency. Before putting the robot system into routine use, make sure that all devices in your E-Stop circuit are functioning correctly.

To check E-Stop devices

1. If it is not already on, turn on arm power by pressing the Arm Power button on the controller. The LED on the Arm Power button should be lit.
2. Verify that the beacon light on the arm is flashing on and off, indicating that the arm is powered.

   Note: If the beacon light is very dim or stays off while arm power is on, there may be a more serious problem with your arm. Lock out the system and contact the Customer Support Group for assistance.

3. For all E-Stop buttons, perform the following test procedure:
   a. Trigger an emergency stop by pressing the E-Stop button. You should hear a click as the brakes engage and relays in the controller remove power from the arm.
   b. Verify that both the beacon light on the arm and the LED on the controller Arm Power button are now off. If you have installed an additional beacon light, verify that it is off as well.
   c. Reset the E-Stop button. Turn the button until it springs out.
   d. Turn on arm power again by pressing the Arm Power button.
4. If you have a teach pendant, test the pendant live-man switch as follows:
   a. If the pendant is not yet active, transfer control to the pendant by entering the ash command `pendant` from the development computer.
   b. Without engaging the live-man switch, press an arm motion key. Verify that this triggers an emergency stop and removes arm power.
   c. Turn on arm power.
   d. While squeezing the live-man switch just enough to engage the first safety trigger, press one of the arm motion keys. Verify that the arm can be moved from the pendant without triggering an emergency stop.
   e. While moving the arm from the pendant, release the live-man switch. Verify that this triggers an emergency stop and removes power from the arm.
   f. Turn on arm power.
   g. Squeeze the live-man switch to its full extent (past the second safety trigger) and press one of the arm motion keys. Verify that this also triggers an emergency stop and removes power from the arm.
   h. Turn on arm power again.
5. Test any additional safety devices (such as pressure-sensitive mats, interlocked doors, or other devices) connected to the E-Stop circuit for your workcell. Ensure that all devices safely remove power from the arm.

Releasing Brakes on the Arm

Brakes on joints 1, 2, and 3 on the arm prevent the joints from moving or falling due to gravity when arm power is off. Each of these joints has a release button to allow you to disengage the brake. Before using your robot system, test the brakes to ensure that they release and engage normally.

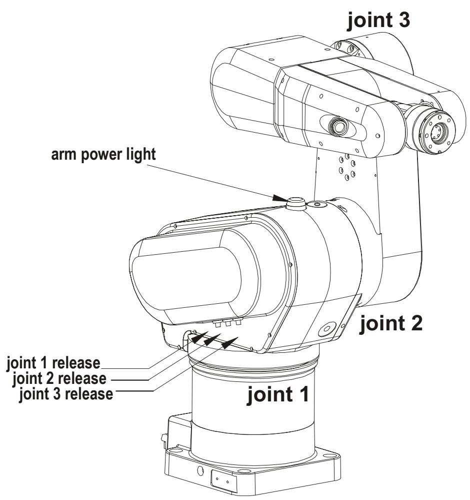


Figure 5-1: The arm power light flashes when the brake release buttons are pressed

Warning! When the brakes are released, spaces between moving links can present a pinch hazard. *Stay clear of labeled pinch points on the arm when releasing brakes.*

Warning! Due to gravity, joints may move faster than expected when released. *Take care to support joints when releasing brakes on the arm.*

To test the brakes

1. Make sure that arm power is off. If necessary, remove arm power by triggering an E-Stop.
2. Remove any payload from the arm.
3. Press in the brake release button for joint 1 and manually rotate joint 1. Joint 1 should rotate with some resistance.
4. Now release the brake release button and attempt to move joint 1 with the brake engaged. You should not be able to move joint 1.
5. Press in the brake release button for joint 2. Joint 2 should slowly begin rotating downwards due to gravity.
6. Release the brake release button. Joint 2 should stop moving.
7. Press in the brake release button for joint 3. Joint 3 should slowly begin rotating downwards due to gravity.
8. Release the brake release button. Joint 3 should stop moving.

If all three brakes do not engage and disengage normally, contact the Customer Support Group for assistance.

Testing Joint Movement

As part of commissioning your robot system, test each joint to verify that the full range of motion is available. If you have a teach pendant, perform this test from the teach pendant and the development computer to ensure that both are functioning normally. Always test arm motion at reduced speeds to decrease the risk of injury.

Warning! Avoid collisions when moving the arm. *If you have just unpacked the arm, you should limp the arm and move it into a safe starting position (such as the ready position, shown in Figure 5-2) before beginning this test.*

To test arm movement from the teach pendant

1 Make sure that arm power is turned on.

2 Using Manual mode on the teach pendant, set the arm speed to 10% by pressing the speed up or speed down buttons.

Note: For a description of other teach pendant functions, see “Basic Teach Pendant Commands” on page 6-6.

3 Taking care to avoid any other elements in the workcell, move each joint through approximately 5° in the positive and negative directions by pressing the Ax + or - keys for each joint.

To test arm movement from the development computer

1 Make sure that arm power is turned on.

2 On the development computer, open a terminal window and start an ash session with the command `ash test`.

3 In ash, set the arm speed to 10% by entering the command `speed 10`.

4 Taking care to avoid any other elements in the workcell, move each joint through 5° in the positive and negative directions using the `joint` command. For example, enter:

```
test> joint 1, 5
```

to rotate joint 1 counterclockwise by 5°.

Each joint should move smoothly and quietly. If you encounter any error messages or other problems, consult Chapter 9, Troubleshooting.

Verifying Robot System Positioning

You need to verify whether the arm is correctly moving to programmed locations.

1 Move the arm to the ready position using the teach pendant READY key or the ash command `ready`.

Note: If you cannot move to the ready position because of obstructions in the workcell, you can use any taught location for this test. In this case, you would move to the location using the `move` command.

2 Verify that the arm is correctly positioned. In the ready position, the arm should be in the orientation shown below:

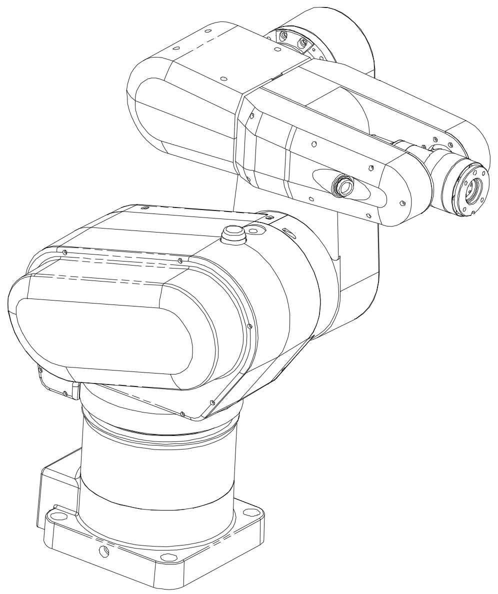


Figure 5-2: The F3 arm in the ready position

If the arm does not correctly move to programmed locations, see Chapter 9, Troubleshooting.

Re-Commissioning the System

Schedule tests at regular intervals to ensure that your system keeps functioning normally, and always re-commission your system whenever you make a change to any workcell components. Once the system has been set up and successfully commissioned, you can follow a much simpler procedure, described in “Basic Operations” on page 6-1.

CHAPTER 6

Basic Operations

This chapter describes routine system procedures used when developing or implementing a robot application. For information on how to create or implement robot applications, see the *Robot System Software Documentation Guide* on your documentation CD.

Pre-power Checklist

Before turning on the power to your robot system, verify the following points:

- The arm is not carrying a payload.
- The robot work space is free of obstructions.
- Operators and other personnel are outside the robot work space.
- The E-Stop circuit is closed:
  - All triggered E-Stops have been reset.
  - All other devices in the E-Stop circuit, such as safety interlocks and proximity sensors, are closed and the circuit is complete.
- If you are using a development computer, the computer is connected to the console port on the front of the controller.

Powering Up the System

Always stand outside the robot work space when turning on power.

Warning! *Turning off system power without shutting down CROS may corrupt controller memory and damage files on the controller. See “Powering Down” on page 6-9 before turning off the controller.*

To power up the system

1. If you are using a development computer, turn on the development computer and open a terminal window in Robcomm3.

2. Standing outside the robot work space, switch on the controller power. The controller begins cycling through its boot-up sequence.

3. When the controller has finished its boot sequence, the LED on the Home button should be lit and the front panel display will read:

   ```
   C500C CROS
   ```

   This indicates that the controller is ready.

   Note: If you do not see the ready message on the front panel display, the home light does not come on, or you encounter any errors, do not use the system. To correct boot-up problems, refer to Chapter 9, Troubleshooting.

Turning on Arm Power

Before turning on arm power, make sure that an E-Stop button is in reach and that operators and other personnel are well outside the robot work space.

Warning! An undiagnosed problem with your robot system could cause the arm to move unpredictably when power is applied. *You should always be prepared to strike an E-Stop button when applying arm power.*

To turn on arm power

While standing outside the robot work space, press the Arm Power button on the front panel of the controller. The LED on the Arm Power button should light and the beacon on the arm should flash, indicating that the arm is powered on.

If you cannot turn on arm power, check for triggered E-Stop devices. Reset all triggered E-Stop devices and press the Arm Power button again.

To turn off arm power

Striking any E-Stop button immediately removes power from the arm and engages brakes on joints 1 to 3 to halt arm motion.

Managing Point of Control

In order to prevent accidents within the workcell, your robot system is designed so that only one device or process can control the arm at a time.

Transferring Control To or From the Teach Pendant

When you power up the system with a development computer attached, the development computer typically has control of the system.

If you want to use a teach pendant instead, you must command the system to transfer control to the pendant.

To transfer control from the computer to the pendant

At the prompt in the terminal window, enter the command:

```
$ pendant
```

The robot server transfers control to the pendant. You should see the main menu appear on the teach pendant screen, indicating that the pendant is ready for use.

To transfer control from the pendant to the computer

1 Press the Esc key on the teach pendant until you see the message:

```
 Terminate pendant
 and release robot
     control?
1 yes          4 no
```

2 Press the F1 key on the teach pendant to release control.

The robot server transfers control to the terminal window on the computer, and the pendant beeps three times before shutting off.

Transferring Control With the Pause/Continue Button

Occasionally, when transferring control to the pendant or issuing a command, the command is interrupted and the Pause/Continue button on the controller begins to flash. You may also see the terminal window message:

```
Press the Pause/Continue button to gain robot point of control.
```

or the teach pendant message:

```
Getting control...
(you may need to
 press CONTINUE.)
```

These messages indicate that the system requires direct confirmation that it is safe to transfer control. Point of control can only be transferred by pressing the Pause/Continue button on the controller.

Warning! *Always assess potential dangers in the workcell before pressing the Pause/Continue button. The robot system may immediately continue carrying out commands as soon as the Pause/Continue button is pressed. Negligence could result in personal injury or damage to your robot system.*

To transfer control with the Pause/Continue button

1. Determine whether it is safe to transfer control. In particular, ensure that the work space is free of obstructions and that all personnel are outside the safeguarded area.
2. If it is safe to transfer control, press the flashing Pause/Continue button on the front of the controller.

   Note: You may also need to press the Arm Power button to restore power to the arm.

   The robot system transfers control. Any previously commanded motion resumes.

Running a Robot Application (RAPL-3 only)

If your application does not start automatically on boot-up, you can run robot applications from the development computer or the teach pendant.

Note: The procedures in the section are for RAPL-3 applications only. For more information on how to deploy an ActiveRobot application from the development computer, refer to the *ActiveRobot User Guide* on the Documentation CD.

To launch a RAPL-3 application from the development computer

At the controller system prompt, enter the name of your compiled application, complete with its path. For example, to run a compiled application called '`test`' located in the /app/test directory on the controller, you would enter:

```
$ /app/test/test
```

Note: Compiled applications are generally located in the /app directory in a subdirectory of the same name.

The robot system should begin running the selected application. If your application does not include some way of terminating itself, you can interrupt the application at any time by pressing **Ctrl+Z**.

To launch a RAPL-3 application from the teach pendant

1 From the Main menu, press the F1 key on the pendant to enter Application mode. You should see the following screen:

```
Application: Find
myapp
1 sel   2 ↑    3 ↓
```

2 If the name of your application is not shown in the current Find menu, press the F2 or F3 keys to scroll up or down through the list of applications in the /app directory on the controller.

3 When the name of the application that you want to run is shown in the Find menu, press the F1 key to select it. If you selected an application called test, you would see the following screen:

```
Application
test
1 edit  2 run
```

4 Press the F2 key to run the application. You will see the following screen:

```
ATTENTION! Confirm:
test
Run program?
1 yes   2 no
```

5 Press the F1 key to confirm that you want to run the application. The teach pendant displays the message:

```
Press CONTINUE on
controller to start
OR hit ESC to abort
```

6 If the work space is free of obstructions and personnel, and it is safe to proceed, press the Pause/Continue button on the controller.

7 The robot system should begin running the selected application. If your application does not include some way of terminating itself, you can interrupt the application at any time by pressing the ESC key on the teach pendant.

Basic Teach Pendant Commands

This section contains basic instructions for moving the arm with the teach pendant.

Starting the Pendant

- If you boot the controller without a development computer connected, the teach pendant starts automatically.
- If you have a development computer attached to your robot system, you can start the pendant from ash or the system shell by entering the command `pendant` in the terminal window.

Moving the Arm

To move the arm, you must be in manual or homing mode.

To access homing mode from the main menu

If you have started the pendant from the system shell or booted up with the pendant active, you will see the main menu screen:

```
Main Menu

1 app   2 motn
```

Press the F2 key. You are now in homing mode:

```
Homing Menu       ON
      1%  VEL  JOINT
1 home     3 motn 4 mode
```

To access manual mode from the application menu

If you have started the pendant from ash, you will see the application menu screen for the currently selected application:

```
Application
test
1 edit  2 run
```

1 Press the F1 key. You will see the following screen:

```
Application Edit
test
1 var  2 src  3 motn
```

2 Press the F3 key. You are now in manual mode.

```
Manual Menu      ON
     1%  VEL  JOINT
          3 motn 4 mode
```

To move the arm

- Press the Ax + and Ax - keys to move the arm.

To change motion modes

- Press the F3 key to cycle through velocity, jog, limp joint, and align world motion modes.
- In jog motion mode, press the F4 key to cycle through jog world, jog tool, and jog joint modes.
- In velocity motion mode, press the F4 key to cycle through the joint, cylindrical, world, and tool frames of reference.

To change the arm speed

For safety reasons, the arm speed is limited to 250 mm/s or less when using the teach pendant.

- Increase the pendant speed by pressing the Speed Up key.
- Decrease the pendant speed by pressing the Speed Down key.

Selecting a Tool Transform

If you have entered an alternate tool transform as an application variable, you can use the teach pendant to set it as the current transform.

To set a variable as the tool transform

1 From the Application Edit screen, press the F1 key to enter the Var Find menu:

```
Var Find:
mytransform
1 sel   2 del   3 ↑   4 ↓
```

2 If the name of your tool transform variable is not shown in the Var Find menu, press the F3 or F4 keys to scroll up or down through the list of application variables until the name of your tool transform variable is shown.

3 To set this variable as the tool transform, press the Select Single key (numeric key 9).

Note: The tool transform setting is not permanently saved and resets to its default value when you shut down the controller.

Limping the Arm

In order to adjust arm position manually, it is sometimes useful to limp a joint. When limped, the joint is not under servo control and can be manipulated easily.

Warning! A limped joint may fall rapidly due to gravity. Always support the joint being limped.

Warning! Spaces between moving links can present a pinch hazard. *Stay clear of labeled pinch points on the arm when limping a joint.*

Note: When using the teach pendant, you can only limp joints 2 and 3.

To limp a joint

1 In homing or manual mode, cycle through the motion modes until limp mode is selected:

```
Manual Menu       ON
     1%   LIMP JOINT
          3 motn 4 mode
```

2 To limp joint 2, press the Ax2 + key.

3 To limp joint 3, press the Ax3 + key.

Powering Down

Always ensure that the controller operating system is shut down before you turn off the power.

***Warning!** Turning off system power without shutting down CROS may corrupt controller memory and damage files on the controller.*

Note: If the controller has been powered for less than 72 hours, or you are shutting the system down for more than a few days, verify that the batteries are sufficiently charged to maintain the encoders in the arm before powering down. See "Checking the Encoder Batteries" on page 8-7 for more information.

To power down from the development computer

1 From a terminal window on the development computer, enter the ash command `shutdown now`

Note: If you are using ActiveRobot, you can also shut down through the ActiveRobot Configuration utitlity by selecting the **Controller** tab and then clicking **Shutdown Controller**.

2 Wait until the controller LCD screen displays the message:

```
C500C CROS
System Halted
```

3 Press the E-Stop button.

4 Switch the controller power off.

If you do not have a development computer connected, you can shut the controller down manually from the front panel.

To power down manually (CROS versions 2.6.1134 or later)

1 While holding down the Home button on the front panel, press and release the Pause/Continue button.

2 Release the Home button. The controller will begin shutting down.

Note: You must complete steps 1 and 2 within a second or two. If nothing happens, simply try again a little faster or a little slower.

3 Wait until the controller LCD screen displays the message:

```
C500C CROS
System Halted
```

4 Press the E-Stop button.

5 Switch the controller power off.

Note: If you are using ActiveRobot, you can initiate a power down using the ActiveRobot shutdown method. For more information on shutdown and other ActiveRobot commands, see the *ActiveRobot User Guide*.

CHAPTER 7

System Connections

This chapter describes the pin layout and use of the connector ports provided with your F3 robot system.

When designing a connection to any robot system port, consider the following points:

- Shut down and turn off the controller before connecting any devices.

  Never connect devices while the controller is turned on. *Connecting a live device while the controller is on may damage the controller.*

- You can use either the internal 24 V power supply, or an external supply.
- If you use the internal 24 V supply, determine whether the 1 A rating is sufficient for the load required by your devices. If it is not, use an external power supply.
- Be extremely cautious when wiring connectors. Carefully verify all connections before connecting a custom-wired device.

  Warning! Incorrect wiring can seriously damage sensitive robot system components. *Verify that you have correctly matched the pin numbering scheme and that all connections are properly wired before using the connector.*

Connecting to the Servo Connector

A round RP17 Hirose connector on the wrist provides an interface for either the CRS servo gripper or the End-of-arm I/O option.

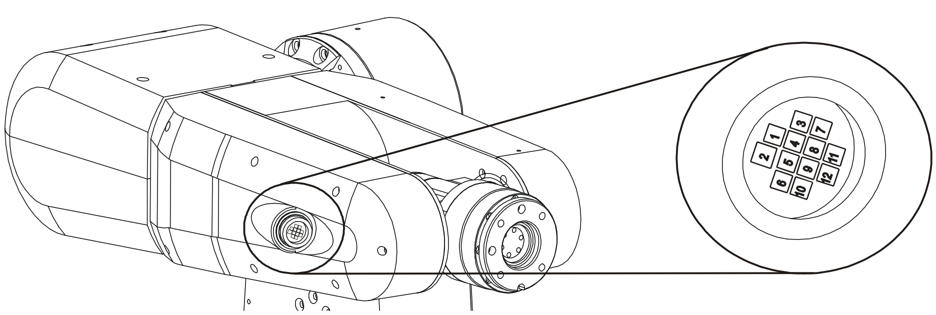


Figure 7-1: Connecting servo-operated tools or end-of-arm sensors to the wrist

Note: The connector is usually covered by a protective plug.

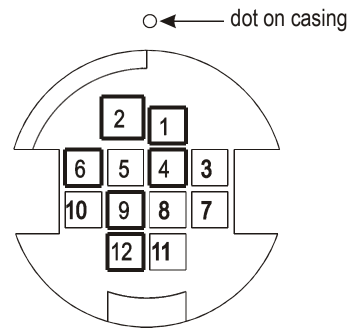
Note: You can tell whether you have the servo gripper or end-of-arm I/O configured by examining the connector and counting the number of pins in use. The servo gripper connector uses 5 of the available pins, while the End-of-arm I/O connector uses all 12.

Servo Gripper Connector (Standard)

On F3 arms without end-of-arm I/O support, the servo connector is configured for the CRS servo gripper. The pinouts for the connector are as follows:

Table 7-1: Pinouts for the Servo Gripper

Pin number	Function
1	+5 VDC
2	GND
4	Motor+ (24 V PWM)
6	Motor- (24 V PWM)
9	Gripper feedback (0 to 5 VDC)
12	Chassis GND



Enabling Servo Control

Before using servo-operated tools, you must set the gripper type.

Note: If you are using a CRS servo gripper, refer to the *Servo Gripper User Guide* for full installation instructions.

To set the gripper type from ash

1 At the ash prompt, set the gripper type to “servo” by entering:

```
test> gtype servo
```

2 Save this setting in the robot system configuration file by entering:

```
test> cfg_save
```

You can also set the gripper type and perform gripper functions uunder application control. See the *Servo Gripper User Guide* for a list of servo gripper commands in ash and RAPL-3, or refer to the *ActiveRobot User Guide* for the ActiveRobot gripper commands GripperCalibrate, GripperClose, GripperDistance, GripperFinished, GripperFinish, GripperOpen, GripperStop, and GripperType.

End-of-arm I/O Connector (Option)

If your F3 arm is configured for the End-of-arm I/O option, you can use the servo connector for custom end-of-arm tools or to relay information between an end-of-arm sensor and the controller.

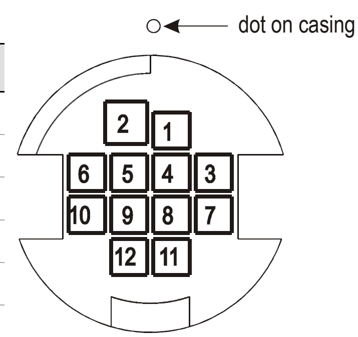
Table 7-2: Specifications for the End-of-arm I/O connector

Maximum current available from the internal power supply	150 mA
Maximum current allowed with an external power supply	1000 mA
Allowed input current (current sink, active low)	8-11 mA
Maximum input voltage	20-26 VDC
Input impedance	2500 Ω
Maximum output current for each output (current sink, active low)	75 mA
Maximum output voltage	24 VDC
Output voltage drop	1.0 V

The pinouts for the End-of-arm I/O connector are as follows:

Table 7-3: Pinouts for End-of-arm I/O

Pin number	Function
1	GND (factory default) or ISO_COM input
2	GND (factory default) or ISO_COM output
3	24 VDC (factory default) or ISO_24 VDC output
4	Input 1
5	Input 2
6	Input 3
7	Input 4
8	Air Solenoid or Output 1 (no air)
9	Air Solenoid or Output 2 (no air)
10	Output 3
11	Output 4
12	Chassis GND



Note: By default, pins 1 and 2 are connected to the controller ground, and pin 3 is connected to the main 24 V line. If you require an isolated circuit for your end-of-arm device, contact the Customer Support Group for assistance.

Connect your device to the input and output ports as shown:

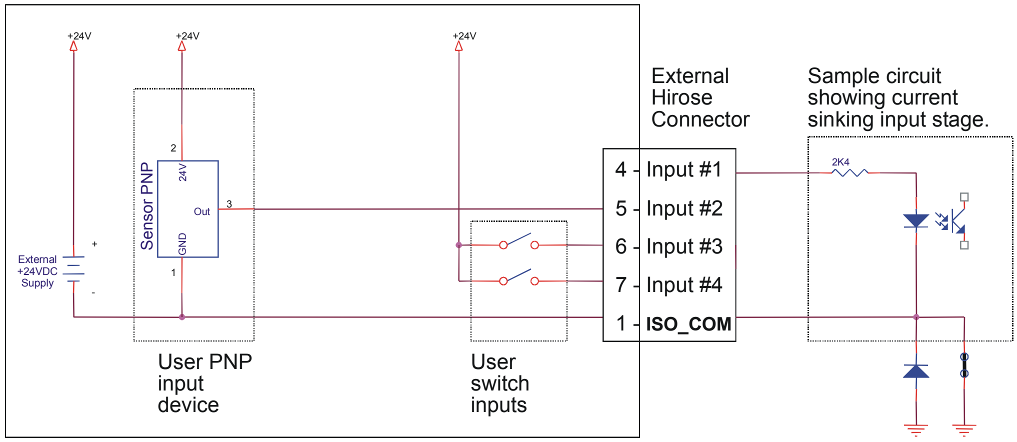


Figure 7-2: Connecting inputs to the End-of-arm I/O connector

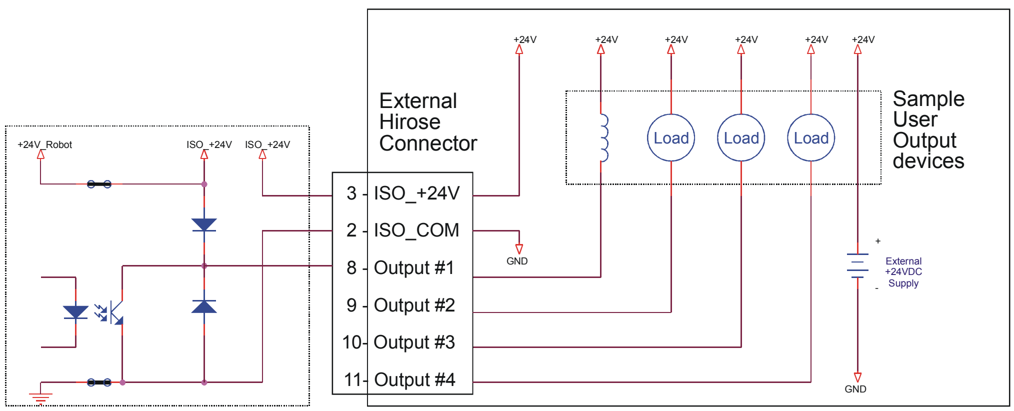


Figure 7-3: Connecting outputs to the End-of-arm I/O connector

Note: Unless you have specifically requested the *End-of-arm I/O without air support* option, pins 8 and 9 are reserved for the air solenoid. Otherwise, these pins are available as outputs 1 and 2.

For more information on input/output configuration options, see the commands `net_out_set`, `net_outs_set`, `net_outs_get`, `net_in_get`, and `net_ins_get` in the *RAPL-3 Language Reference Guide* provided on your documentation CD.

Using the Pneumatic Connector

The air connector on the wrist provides a dual port air supply for pneumatic grippers and other air-driven tools.

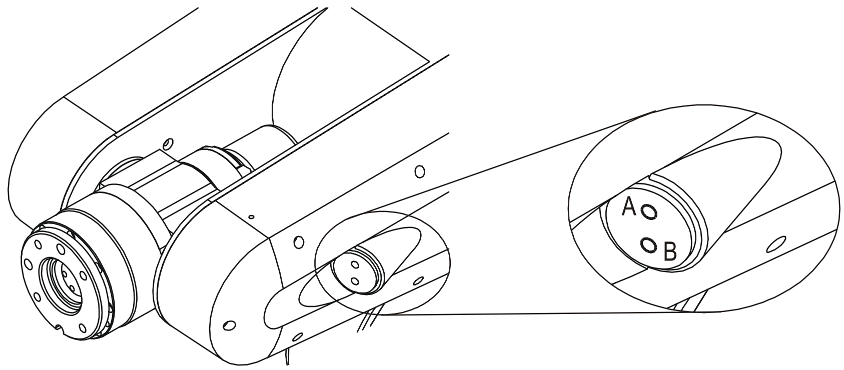


Figure 7-4: Connect pneumatic tools to the air connector on the wrist.

The pneumatic ports act in opposition so that when one port is open, the other is always closed. You control the state of the pneumatic ports with the `grip_open` and `grip_close` commands.

Warning! Loss of air pressure may result in dropped payload, or deactivation of tooling. Re-pressurization may result in tool startup. *Ensure that your pneumatic tool contains appropriate safeguards.*

Note: You can also use the Grip open and close keys on the teach pendant.

Table 7-4: Port settings for the air connector

Action	state of port A	state of port B
grip_close	off	on
grip_open	on	off
arm power removed (e.g. E-Stop interrupt)	retains last state	retains last state
controller shutdown	retains last state	retains last state

When the controller is powered up for the first time, the solenoid valve controlling the air connector ports is not powered until you issue a gripper command. Once powered, the valve maintains power for as long as the controller is on, even when arm power is off. If the controller is turned off, the state of the air valve is maintained due to air pressure in the line. When the controller is turned on again, the valve retains its last state.

Enabling Pneumatic Control

Before using pneumatic tools, you must set the gripper type for your robot system to enable pneumatic control.

To set the gripper type from ash

1 At the ash prompt, set the gripper type to “air” by entering:

```
test> gtype air
```

2 Permanently save this setting in the robot system configuration file by entering:

```
test> cfg_save
```

You can also set the gripper type using RAPL-3 or ActiveRobot commands. See the `griptype_set` command in the *RAPL-3 Language Reference Guide, or* `GripperType` and ConfigSave in the *ActiveRobot User Guide* for a more detailed explanation.

Connecting a Pneumatic Tool

To use a pneumatic tool with the F3, you must connect an air supply to the arm. The air intake port is located just above the umbilical cable connector at the base of the arm.

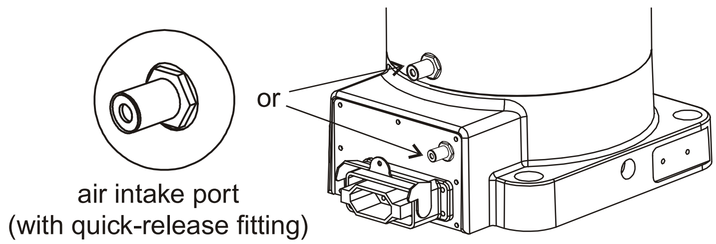


Figure 7-5: Depending on your F3 model, the air intake port may be located either at the base of joint 1, or on the baseboard cover plate.

When connecting an air supply:

- Do not exceed a maximum pressure of 689 kPa [100 psi].
- Use only dry, clean, filtered, non-lubricated air.

  Warning! The pneumatic valve exhausts inside the robot. *Humid air can cause condensation inside the arm, leading to system failure or unexpected behavior.*

To connect the air supply to the arm

1 Insert a standard tube with a 6 mm outside diameter into the quick-release bulkhead fitting on the air intake port at the back of the arm.

2 Press the tube in until it catches snugly inside the fitting.

Note: Press the black ring inward on the fitting to release the tube.

To connect your tool to the pneumatic connector

1 Screw an M5 x 0.8 (metric) or #10-32 (Imperial) threaded fitting into each of the two air ports on the wrist.

2 Connect pneumatic hoses for your tool to the fittings.

3 Secure all hoses to the arm to prevent them from becoming pinched.

Serial Ports

The C500C controller provides the following four ports for serial communication:

- “Teach Pendant” on page 7-7
- “SIO0 and SIO1 Serial Port Connectors” on page 7-8
- “Console Port Connector” on page 7-8

Teach Pendant

The teach pendant connector on the front of the controller routes communications, power, and E-stop and liveman switch connections to and from the teach pendant. If the teach pendant is not connected, a teach pendant dummy plug must be inserted in the controller’s teach pendant connector.

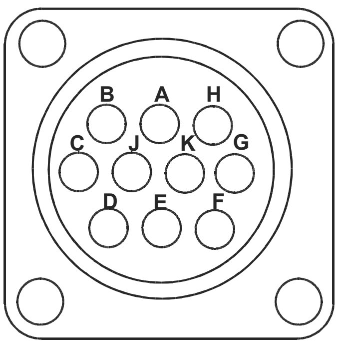


Figure 7-6: Teach pendant connector pin numbering

Table 7-5: Teach Pendant Front Panel connector

Pin #	Signal Name	Signature	Description
A	TP_INSTALLED	TTL	Teach pendant installed
B	TX	RS-232C	Transmit signal to the teach pendant
C	GND	Power	Return from the teach pendant
D	TPESTOP+	ESTOP+	Teach pendant emergency stop switch pair
E	TPESTOP-	ESTOP-	Teach pendant emergency stop switch pair
F	VCC	Power	+5 V supply to the teach pendant 100 mA max
G	LIVEMAN+	Contact	Pendant liveman switch pair
H	RX	RS-232C	Receive signal from the teach pendant
J	Not used	Not used	Not used
K	LIVEMAN-	Contact	Pendant liveman switch pair

SIO0 and SIO1 Serial Port Connectors

The SIO0 and SIO1 serial ports at the back of the controller use standard DB9 connectors and are available for general use.

Note: The **SIO0** and **SIO1** ports are configured as standard DTE ports. To connect a computer to one of these ports, you must use a null modem serial cable.

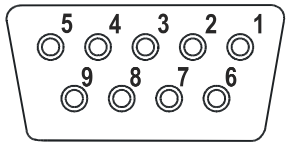


Figure 7-7: SIO0 and SIO1 connector pin numbering

Table 7-6: SIO0 and SIO1 serial DB-9 connectors

Pin #	Signal Name	Signature	Description
1	DCD	Input / RS232	Data Carrier Detect
2	RXD	Input / RS232 / ±10 V	Receive Data
3	TXD	Output / RS232 / ±10 V	Transmit Data
4	DTR	Output / RS232	Data Terminal Ready
5	GND	GND	Signal Ground
6	DSR	Input / RS232	Data Set Ready
7	RTS	Output / RS232	Request To Send
8	CTS	Output / RS232	Clear To Send
9	RI	Input / RS232	Ring Indicator

Console Port Connector

The **Console** port on the front of the controller uses a standard DB-9 connector and is used to connect a development computer to the controller.

Note: The **Console** port is configured as a standard DCE port. However, only pins 2, 3, and 5 are used.

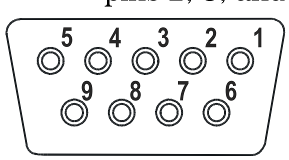


Figure 7-8: Console port connector pin numbering

Table 7-7: Console Port connector

Pin #	Signal Name	Signature	Description
2	TXD	Output / RS232 / ±10 V	Transmit Data
3	RXD	Input / RS232 / ±10 V	Receive Data
5	GND	GND	Signal Ground

The Umbilical Cable Connector

The umbilical cable connects the arm to the controller via a Harting Han 15 D connector. The cable is wired straight through, with no pins swapped.

Note that there are two models of F3 umbilical cables, with slightly different pin layouts. Compare your umbilical cable connector to the drawings below to determine which pin layout applies to your arm.

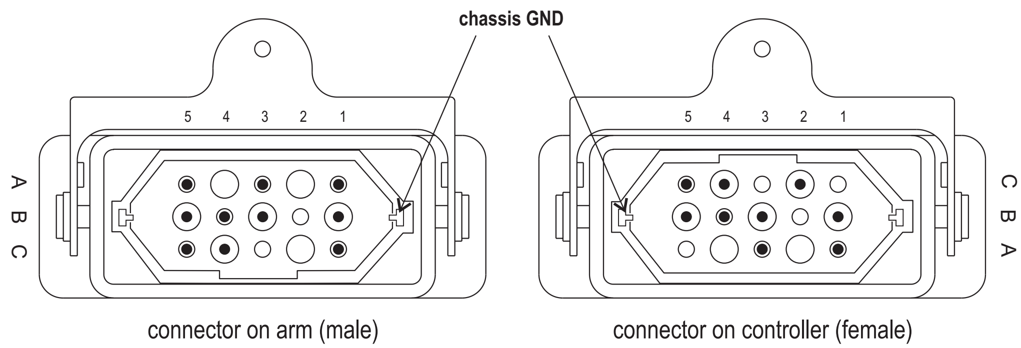


Figure 7-9: Pin numbering for the copper umbilical cable (shipped 2000 and later)

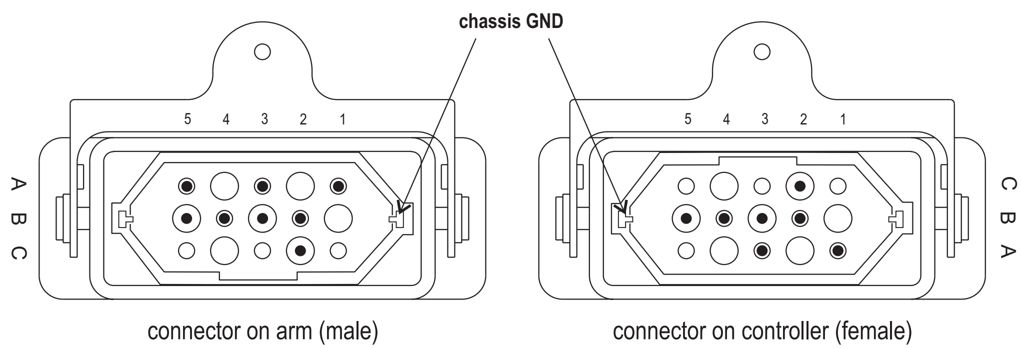


Figure 7-10: Pin numbering for the fiber optic umbilical cable (older F3 models)

Note: The arm connects to the controller chassis ground via two T-shaped pins on the edges of the umbilical connector.

Table 7-8: Pinouts for the copper umbilical connector

Pin	Signal Name	Signature	Description
A1	Return GND	10A	Signal and power ground return
A2	--	--	--
A3	Motor Power	+77 VDC, 10A	Power supply for amplifiers in the arm
A4	--	--	--
A5	Battery Test	0 to 4.5 VDC	Use to check battery voltage level
B1	TX+ to arm	RS-485 0 to 5 VDC, 50mA	Serial communication to the arm
B2	--	--	--
B3	BRAKE_V	24 VDC, 1A	Power to disengage brakes (only enables when arm power is enabled)
B4	OPT_PWR	+24 VDC, 1A	Power supply for end-of-arm options and brake release
B5	SYS_PWR	+12 VDC, 3A	Power supply for amplifiers and support electronics
C1	TX- to Robot	RS-485 0 to 5 VDC, 50mA	Serial communication to the arm
C2	--	--	--
C3	--	--	--
C4	RX+ from arm	RS-485 0 to 5 VDC, 50mA	Communication line from the arm
C5	RX+ from arm	RS-485 0 to 5 VDC, 50mA	Communication line from the arm

Table 7-9: Pinouts for the fiber optic umbilical connector

Pin	Signal Name	Signature	Description
A1	Return GND	10A	Signal and power ground return
A2	--	--	--
A3	Motor Power	+77 VDC, 10A	Power supply for amplifiers in the arm
A4	--	--	--
A5	Battery Test	0 to 4.5 VDC	Use to check battery voltage level (arm connector only)
B1	--	--	
B2	RX from Robot	Fiber Optic 1.25 Mbit	Communication line to the arm
B3	BRAKE_V	24 VDC, 1A	Power to disengage brakes
B4	OPT_PWR	+24 VDC, 1A	Power supply for end-of-arm options and brake release
B5	SYS_PWR	+12 VDC, 3A	Power supply for amplifiers and support electronics
C1	--	--	--
C2	TX to Robot	Fiber Optic 1.25 Mbit	Communication line to the arm
C3	--	--	--
C4	--	--	--
C5	--	--	--

The Expansion Amplifier Connector (option)

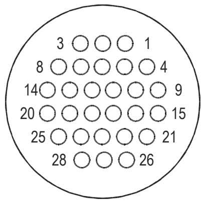


Figure 7-11: Expansion amplifier connector

The optional expansion amplifier connector on the back of the controller lets you synchronize devices with the robot system arm power and brake circuits.

Table 7-10: Pinouts for the expansion amplifier connector

Pin	Signal Name	Signature	Description
8	ArmOn-	Normally open switch contact, 48 V, 100 mA max.	Arm power switch contact
19	ArmOn+	Normally open switch contact, 48 V, 100 mA max.	Arm power switch contact
20	Brake+	Normally open switch contact, 48 V, 100 mA max.	Brake switch contact
25	Brake-	Normally open switch contact, 48 V, 100 mA max.	Brake switch contact

Note: The expansion amplifier option uses a standard CPC-28 connector.

Note: See also the ActiveRobot commands AxisPGain, AxisNegativeLimit, AxisTurnsPerUnit, AxisPulsesPerMotorTurn in the *ActiveRobot User Guide*, or the RAPL-3 commands `gains_set`, `jointlim_set`, `jointlim_get`, `xratio_set`, and `xpulses_set` in the *RAPL-3 Language Reference Guide*.

Connecting to the E-Stop Chain

You can use the ArmOn and Brake switch contacts on the expansion amplifier connector to remove power from external devices when the controller E-Stop is pressed.

To connect an external device to the E-Stop chain

Connect all external devices in series between pins 8 and 19 (ArmOn) or between pins 20 and 25 (Brake) on the expansion amplifier connector, as shown in Table 7-10.

Note: When an E-Stop is pressed, the Brake contacts engage approximately 200 ms after ArmOn. Contacts are open when arm power is off.

Do not use the GND pin for your external device if you are using the Brake contact pair to remove power when an E-Stop is pressed. *When arm power is off, the controller maintains 10 Ω between the Brake+ signal and GND.*

General Purpose Input/Output Port (GPIO)

Connect devices to the GPIO port on the back of the controller to monitor and control external events in your robot application.

The general purpose input/output (GPIO) port provides a total of sixteen inputs and outputs for connecting external hardware devices to the robot system. With the exception of the analog input, GPIO inputs and outputs are electrically isolated from the main controller power and logic circuits.

GPIO outputs include low current optically isolated relay drivers with 50 mA capacity, and 1 A relay contact outputs with normally closed (NC) and normally open (NO) contacts. All relays are connected to a common line, RLYCOM, which is fused on the front panel.

Connect devices to the GPIO port through a standard DD-50 connector. To connect devices more easily, you can extend the port with the optional GPIO termination block (part number SEC-23-501) available from Thermo CRS.

Note: For installation instructions for the GPIO termination block, see Appendix B, GPIO Termination Block Option.

Warning! Do not use the numbers embossed on the plastic inside the connector. *Refer to the pin numbers printed directly on the controller. Incorrectly matched pins in your GPIO connection can severely damage the controller.*

Pinouts for the GPIO Port

The GPIO controller port uses the numbering convention for a ribbon-type connector instead of standard DD-50 numbering.

Note: Refer to the large numbers printed directly on the controller and the numbering scheme shown in Figure 7-12.

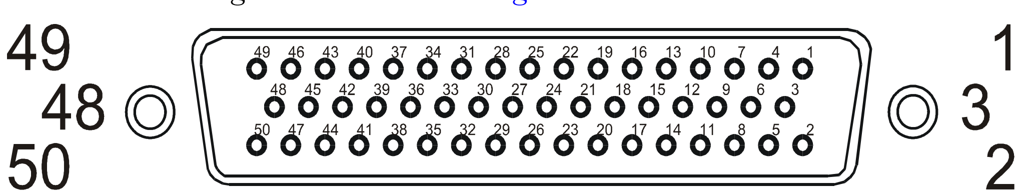


Figure 7-12: Pin numbering scheme used by the GPIO connector

Table 7-11: Pinouts for the GPIO connector

Pin	Function	Signature	Description
1	+24 V	24 VDC internal	Optional Source for 24 V, internal
2	+24 V	24 VDC internal	Optional Source for 24 V, internal
3	IPW	20-28 VDC	Isolated Power, externally supplied
4	IPW	20-28 VDC	Isolated Power, externally supplied
5	GPI0	Opto	General Purpose input #1
6	GPI1	Opto	General Purpose input #2
7	GPI2	Opto	General Purpose input #3
8	GPI3	Opto	General Purpose input #4
9	GPI4	Opto	General Purpose input #5
10	GPI5	Opto	General Purpose input #6
11	GPI6	Opto	General Purpose input #7
12	GPI7	Opto	General Purpose input #8
13	GPI8	Opto	General Purpose input #9
14	GPI9	Opto	General Purpose input #10
15	GPI10	Opto	General Purpose input #11
16	GPI11	Opto	General Purpose input #12
17	GPI12	Opto	General Purpose input #13
18	GPI13	Opto	General Purpose input #14
19	GPI14	Opto	General Purpose input #15
20	GPI15	Opto	General Purpose input #16
21	GPO0	Opto	General Purpose output #1
22	GPO1	Opto	General Purpose output #2
23	GPO2	Opto	General Purpose output #3
24	GPO3	Opto	General Purpose output #4
25	GPO4	Opto	General Purpose output #5
26	GPO5	Opto	General Purpose output #6
27	GPO6	Opto	General Purpose output #7
28	GPO7	Opto	General Purpose output #8
29	GPO8	Opto	General Purpose output #9
30	GPO9	Opto	General Purpose output #10
31	GPO10	Opto	General Purpose output #11
32	GPO11	Opto	General Purpose output #12
33	Shield		
34	N/C		
35	GPO13NC	Relay	General Purpose output #13, Normally closed contact
36	GPO13NO	Relay	General Purpose output #13, Normally open contact
37	GPO14NC	Relay	General Purpose output #14, Normally closed contact
38	GPO14NO	Relay	General Purpose output #14, Normally open contact

Pin	Function	Signature	Description
39	GPO15NC	Relay	General Purpose output #15, Normally closed contact
40	GPO15NO	Relay	General Purpose output #15, Normally open contact
41	GPO16NC	Relay	General Purpose output #16, Normally closed contact
42	GPO16NO	Relay	General Purpose output #16, Normally open contact
43	RLYCOM	Relay common	All relays attached here, and to front panel fuse
44	RLYCOM	Relay common	All relays attached here, and to front panel fuse
45	AnalogIn1	Analog	Provides an analog input to the controller
46	AnalogIn2		Not supported
47	IRT	IsoReturn	Return for IPW, externally supplied
48	IRT	IsoReturn	Return for IPW, externally supplied
49	Gnd	Digital	Internal ground return for 24 V
50	Gnd	Digital	Internal ground return for 24 V

Note: Opto = optocoupler (optically coupled). N/C = not connected. ISORET= isolated return.

Note: All opto-outputs are NPN, all opto-inputs require NPN devices.

Wiring Schematic For the GPIO Connector

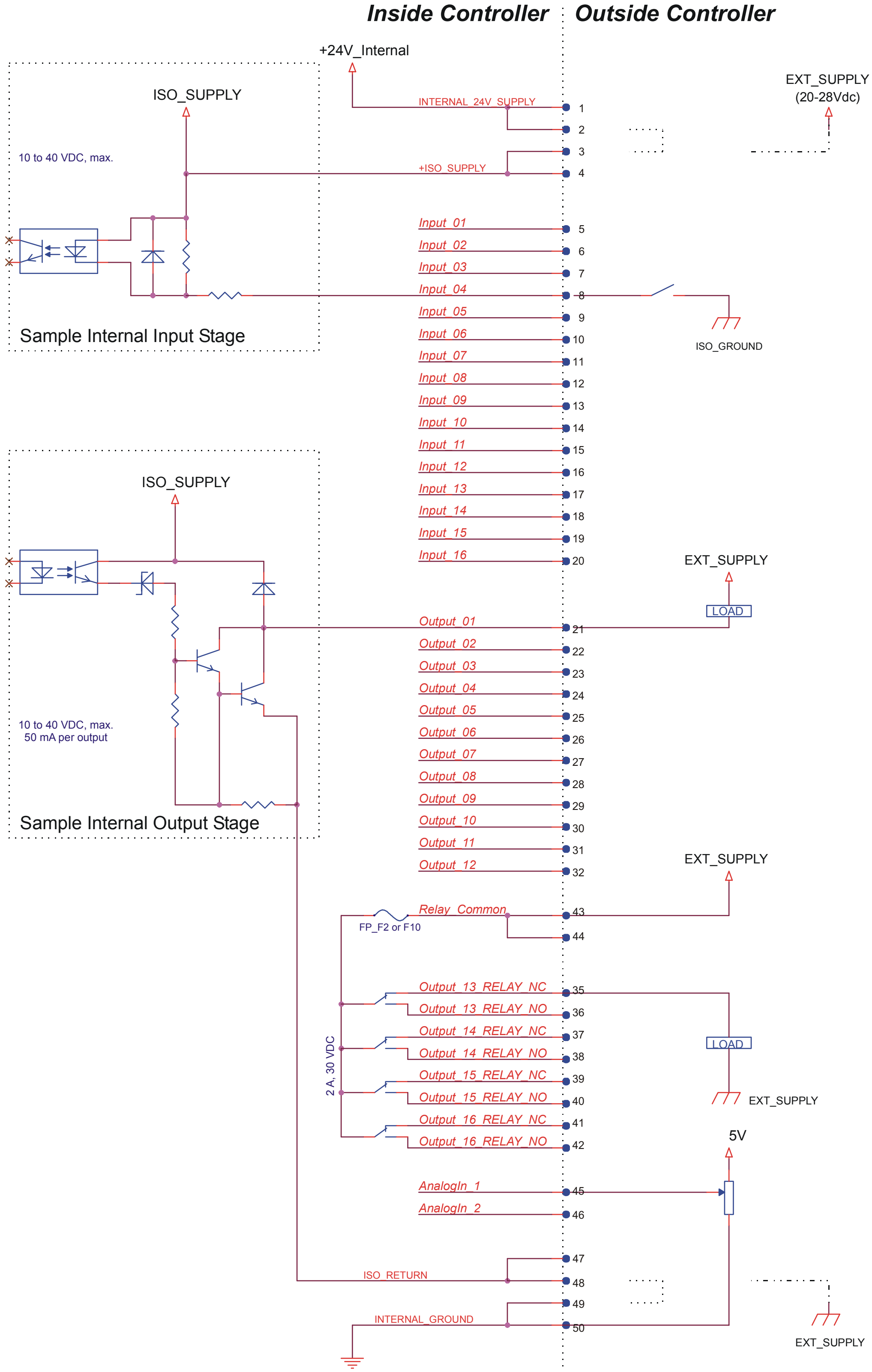


Figure 7-13: Wiring schematic for the GPIO connector

Powering the GPIO Circuit

You must provide power in order to use the isolated inputs and outputs in the GPIO circuit. If you use the internal controller supply, GPIO inputs and outputs will not be isolated from the main controller circuit.

Note: The internal power supply can only provide a maximum of 1 A for all external devices. Take care not to overload the controller.

Connecting External Power

- Use a 20-28 VDC power supply.
- Connect the positive terminal from your external supply to the +ISO_SUPPLY line on pin 4, as shown in Figure 7-13.
- Connect the common ground terminal from your external supply to the ISO_RETURN line on pin 48.

Warning! Do not allow a potential difference of more than 50 V between the controller ground and the reference ground for the optically isolated GPIO circuit. *A large difference in potential between the two circuits could seriously damage the controller.*

Connecting Internal Power

- Do not use the internal supply if you require an isolated circuit for your GPIO devices.
- Using a wire jumper, connect the +ISO_SUPPLY line to the INTERNAL_24V_SUPPLY line by connecting pins 2 and 3, as shown in Figure 7-13.
- Using a wire jumper, connect the ISO_RETURN line to the INTERNAL_GROUND line by connecting pins 48 and 49, as shown in Figure 7-13.

Connecting Inputs and Outputs

Connect inputs and outputs to the GPIO circuit as shown in Figure 7-13.

Note: An open input is off.

- Connect input devices as switches between the desired INPUT line (pins 5 through 20) and the ground from your power supply.

  Note: The internal power supply ground is connected to pin 50.

- Connect output devices between the desired OUTPUT line (pins 21 through 32) and the positive terminal from your external supply. Do not exceed a load of 50 mA per output.

  Note: The positive INTERNAL_24V_SUPPLY line is connected to pin 1.

Using the Relays

Relays behave like switches between the output pairs and the shared Relay_Common line. Each relay output terminal consists of a normally open (NO) and a normally closed (NC) contact pair.

If an external power supply is connected to the relay contacts, take care not to exceed the 2 A, 30 VDC rating for the circuit.

Warning! The relay circuit may be damaged by AC power. *The controller relays are not rated for AC use.*

Note: Relay contacts are fused through the front panel fuse F2.

Using GPIO Devices in Your Application

To integrate GPIO devices into your application with ActiveRobot, refer to the following commands in the *ActiveRobot User Guide*: AnalogInput, CTPath, CTPathGo, Input, Inputs, Motor, Output, Outputs. Or, in RAPL-3, refer to the following commands in the *RAPL-3 Language Reference Guide*: `analogs_get`, `cpath`, `ctpath`, `ctpath_go`, `input`, `inputs`, `motor`, `output`, `outputs`, `output_get`, `output_pulse`.

System Input/Output (SYSIO)

The system input/output (SYSIO) port on the back of the controller provides inputs and outputs to the main controller circuit for connecting safety devices and replicating the front panel input buttons.

Note: The front panel LCD status display cannot be replicated through the SYSIO port.

Designing a Safe Front Panel Device

The SYSIO port allows you to replicate the front panel buttons on a remote device. Because of the dangers inherent in operating a robot system, you must ensure that your remote panel is safe for the operators of your robot system:

- **Provide an E-Stop button within reach of the remote panel.** Ideally, the E-Stop should be located next to the replicated front panel buttons.

- **Do not provide multiple points of control.** If your remote panel allows the operator to enable arm power or enable an application to continue, you must ensure that the Arm Power and Pause/Continue buttons on the controller are inaccessible whenever the remote panel is in use. You can make the front panel inaccessible simply by locking the controller into a secure cabinet.

  Note: The cabinet must also provide sufficient air flow for the controller.

The SYSIO Port

The SYSIO port provides optically isolated inputs intended for 20 to 28 V operation. The outputs from the SYSIO connector are 24 V, 50 mA outputs, capable of supporting a combined load of up to 1 A, suitable for driving low current lamps or indicators. If larger voltages and currents are required, connect an external power supply and use the outputs to drive relays.

Connect devices to the SYSIO port through a standard DB-25 connector.

Warning! Do not use the numbers embossed on the plastic inside the connector. *Refer to the pin numbers printed directly on the controller. Incorrectly matched pins in your SYSIO connection can severely damage the controller.*

Pinouts For the SYSIO Port

Like the GPIO port, the SYSIO controller port uses the numbering convention for a ribbon-type connector instead of standard DB-25 numbering.

Note: Refer to the large numbers printed directly on the controller and the numbering scheme shown in Figure 7-14.

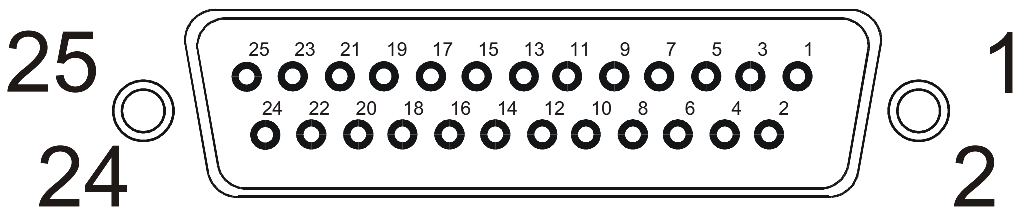


Figure 7-14: Pin numbering scheme used by the SYSIO connector

Table 7-12: Pinouts for the SYSIO connector

Pin	Function	Signature	Description
1	+24 V	Power	Optional Source for external I/O, internal supply
2	+24 V	Power	Optional Source for external I/O, internal supply
3	IPW	20-28 VDC	Isolated input for external power supply
4	IPW	20-28 VDC	Isolated input for external power supply
5	RPS	Opto-input	Pause/Continue
6	ERA	Opto-output	unused
7	HMS	Opto-input	unused
8	R0A	Opto-output	Pause/Continue Ack
9	PRS	Opto-input	F2
10	R1A	Opto-output	unused
11	CSS	Opto-input	F1
12	HMA	Opto-output	Home Ack
13	JigIns	Opto-input	unused
14	PRA	Opto-output	F2 button Ack
15	APA	Opto-output	Arm Power Ack
16	CSA	Opto-output	F1 button Ack

Pin	Function	Signature	Description
17	REMONSW+	Contact-input	
18	REMONSW-	Contact-input	
19	REMESTOP+	Contact-input	remote E-Stop
20	REMESTOP-	Contact-input	remote E-Stop
21	N/C		unused
22	Shield		Ground shield
23	IRT	IsoRet	Isolated return for external power supply
24	IRT	IsoRet	Isolated return for external power supply
25	Gnd	Digital	Internal return for 24 V

Note: Opto = optocoupler (optically coupled). N/C = not connected, ISORET= isolated return, Ack = acknowledged.

Note: All opto-outputs are NPN, all opto-inputs require NPN devices.

Wiring Schematic for the SYSIO Connector

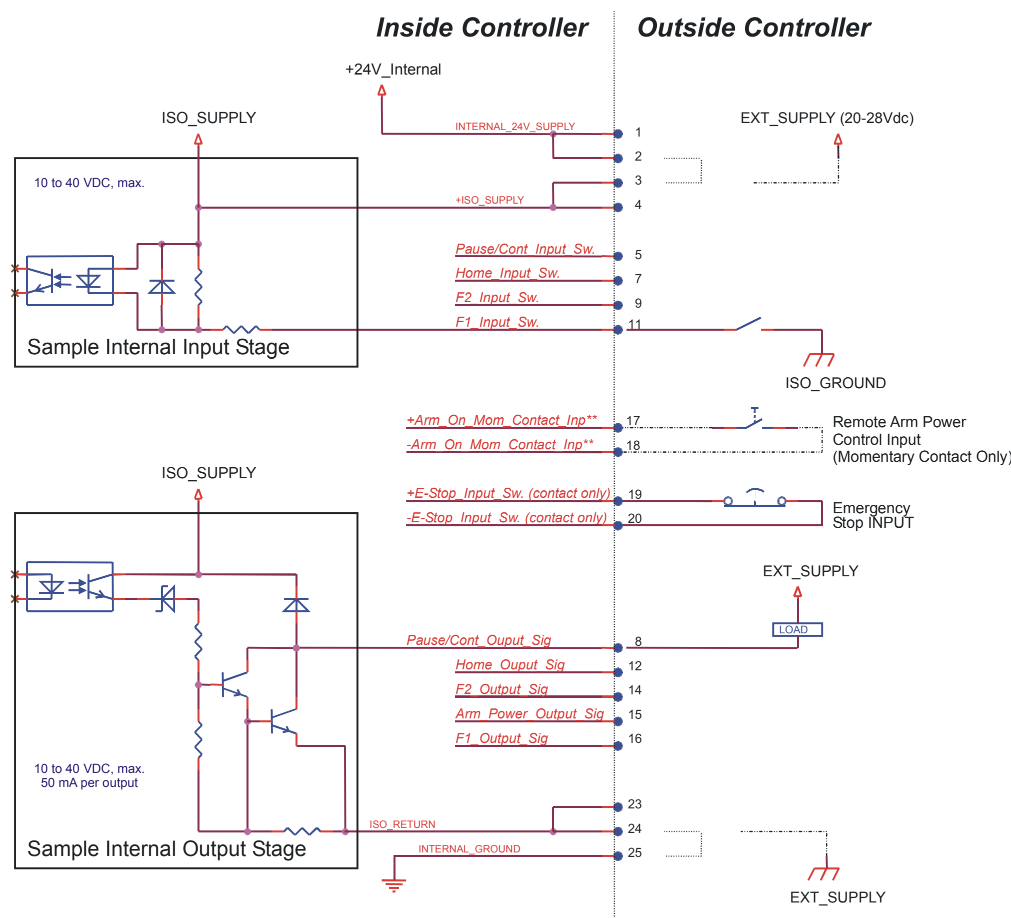


Figure 7-15: Wiring schematic for the SYSIO connector

Installing a Workcell Beacon

To increase safety in the workcell, you can install a workcell beacon to warn operators when arm power is on. The 24 V arm power output on the SYSIO port is sufficient to power a small 24 V, 25 mA lamp.

To connect a workcell beacon light

- Connect a 24 V, 25 mA lamp between pins 15 and 23 on the SYSIO port.
- If you do not have any external E-Stop devices, connect a wire jumper across pins 19 and 20 to close the SYSIO E-Stop circuit.

  Note: Unlike the flashing beacon on the arm, a beacon connected through the SYSIO port is continuously lit when arm power is on.

Thermo CRS recommends the following Beacon Lamp and Tower assembly, available from Patlite Visual Lighting Products:

Catalog Number	Name	Electrical Specifications
LE102P/FBP-A	Amber Flashing Tower Lamp	0.6W, 24 V, 25 mA
SZ-011	Mounting Bracket for Tower	

For ordering information, contact sales@patlite.com or visit their website http://www.patlite.com.

Connecting External E-Stop Devices

You can connect additional E-Stop safety devices through the E-Stop contact terminals on the SYSIO port. For guidelines on E-Stop design, see “Adding E-Stop Devices” on page 4-12.

To connect external devices to the controller E-Stop circuit

Connect all E-Stop devices in series between pins 19 and 20 on the SYSIO port, as shown in Figure 7-15.

Replicating the Arm Power Button

You can replicate the front panel Arm Power button through the Arm_On contact terminals on the SYSIO port.

Warning! Do not provide multiple points of control in your workcell. *The Arm Power button must only be accessible from one location. If you provide an external Arm Power button through the SYSIO port, you must ensure that the Arm Power button on the front panel is safely locked out.*

For guidelines on how to safely replicate the front panel, see “Designing a Safe Front Panel Device” on page 7-17.

To replicate the Arm Power button

- For safety reasons, you must use a momentary contact switch for the Arm Power button. This prevents arm power from being applied automatically when an E-Stop is reset.
- Connect the switch for your external Arm Power button between pins 17 and 18 on the SYSIO port.
- If you do not have any external E-Stop devices, connect a wire jumper across pins 19 and 20 to close the SYSIO E-Stop circuit.
- Lock out the front panel Arm Power button.

Powering Inputs and Outputs in the SYSIO Circuit

You must provide power in order to use the isolated inputs and outputs in the SYSIO circuit. If you use the internal controller supply, SYSIO inputs and outputs will not be isolated from the main controller circuit.

Note: The internal power supply can only provide a maximum of 1 A for all external devices. Take care not to overload the controller.

Connecting External Power

- Use a 20-28 VDC power supply.
- Connect the positive terminal from your external supply to the +ISO_SUPPLY line on pin 4, as shown in Figure 7-15.
- Connect the common ground terminal from your external supply to the ISO_RETURN line on pin 24.

Warning! Do not allow a potential difference of more than 50 V between the controller ground and the reference ground for the optically isolated SYSIO circuit. *A large difference in potential between the two circuits could seriously damage the controller.*

Connecting Internal Power

- Do not use the internal supply if you require an opto-isolated circuit for your SYSIO devices.
- Using a wire jumper, connect the +ISO_SUPPLY line to the INTERNAL_24V_SUPPLY line by connecting pins 2 and 3, as shown in Figure 7-15.
- Using a wire jumper, connect the ISO_RETURN line to the INTERNAL_GROUND line by connecting pins 24 and 25, as shown in Figure 7-15.

Creating a Remote Front Panel

You can connect a remote front panel using the optically isolated SYSIO input and output terminals provided by the SYSIO port.

Note: An open input is off.

Warning! Do not provide multiple points of control in your workcell. *The Pause/Continue button must only be accessible from one location. If you provide an external Pause/Continue button through the SYSIO port, you must ensure that the Pause/Continue button on the front panel is safely locked out.*

For guidelines on how to safely replicate the front panel, see "Designing a Safe Front Panel Device" on page 7-17.

- Connect input devices as switches between the desired INPUT line (pins 5, 7, 9, and 11) and the ground from your power supply.

  Note: The internal power supply ground is connected to pin 25.

- Connect output lamps between the desired OUTPUT line (pins 8, 12, 14, 15, and 16) and the positive terminal from your external supply. Do not exceed a load of 50 mA per output.

  Note: The positive INTERNAL_24V_SUPPLY line is connected to pin 1.

- If you do not have any external E-Stop devices, connect a wire jumper across pins 19 and 20 to close the SYSIO E-Stop circuit.

Using SYSIO Devices in Your Application

To integrate SYSIO devices into your application with ActiveRobot, refer to the following commands in the *ActiveRobot User Guide*: AllowArmPower, IsPowered, PanelButton, PanelButtons, PanelLight, WaitForButton. Or, in RAPL-3, refer to the following commands in the *RAPL-3 Language Reference Guide:* `armpower`, `onbutton`, `panel_button`, `panel_button_wait`, `panel_buttons`, `panel_light_get`, `panel_light_set`, `panel_lights_get`, `panel_lights_set`, `panel_status`, `robotispowered`.

Serial Ports

The C500C controller provides four ports for serial communication:

- The **Teach Pendant** port on the front of the controller uses a non-standard connector and is reserved for the teach pendant.
- The **SIO0** and **SIO1** ports at the back of the controller use standard DB-9 connectors and are available for general use.

  Note: The **SIO0** and **SIO1** ports are configured as standard DTE ports. To connect a computer to one of these ports, you must use a null modem serial cable.

- The **Console** port on the front of the controller uses a standard DB-9 connector and is used to connect a development computer to the controller.

  Note: The **Console** port is configured as a standard DCE port.

Changing Serial Port Baud Rates

The serial ports can be configured to communicate at 300, 600, 1200, 2400, 4800, 9600, 19200, 38400, 57600, or 115200 baud. You can temporarily change the baud rate with the system command `siocfg`, or permanently set the baud rate via the controller's diagnostic mode. Default communication speeds for the C500C controller are provided in Table 7-13.

Warning! Do not change the baud rate for the teach pendant. *The Pendant port must be set to 19200 baud in order to use the teach pendant.*

Warning! Not all baud rates are supported by Robcomm3. *Robcomm3 supports communication at 57600, 38400, 19200, 9600 or 2400 baud. If you set the* ***Console*** *port to communicate at an unsupported rate, you will have to use a third party terminal emulator to re-establish communication with the controller.*

Table 7-13: Default serial port baud rates

Port name	ID Number	Default baud rate
SIO0	0	57600
SIO1	1	57600
Teach Pendant	2	19200
Console	3	57600

Note: The port ID is used to identify the port with the `siocfg -c` option.

To change the baud rate temporarily

- From the system prompt, use the command `siocfg`. For example, to set the console port to its default settings, enter:

  ```
  $ siocfg -c 3 -b 57600 -d 8 -p 0 -s 1
  ```

  Note: The default settings for the Console port are 57600 baud, 8 data bits, no parity, 1 stop bit. For more information on `siocfg`, see the *CROS and System Shell Guide* on your documentation CD.

- All parameters set with `siocfg` are lost when the controller is shut down.

To permanently change the baud rate in diagnostic mode

1 Shut down and turn off the controller.

2 Connect your computer to the Console port on the front of the controller.

3 Using Robcomm3 or another terminal emulator, open a terminal window.

Note: Your terminal session must be configured to communicate at the correct baud rate for the controller Console port. If your Console baud rate is unsupported by Robcomm3, you must use a third party terminal emulator.

4 Hold down the F1, F2, and Pause/Continue buttons simultaneously while turning on the controller power. The controller will boot into diagnostic mode and display the message:

```
C500C-B
Diagnostic Mode
```

5 In your terminal window, you should see the diagnostic mode prompt. Enter the following command:

```
: set
```

The current settings for your controller are displayed.

6 To reset the Console port to its factory default settings, enter the following commands:

```
: set cport 3
: set cspeed 57600
: set tport 3
: set tspeed 57600
: boot
```

Note: File transfer and communication should generally use the same baud rate. `cport` and `cspeed` set the serial port and baud rate for communications, `tport` and `tspeed` set the serial port and communication rate for file transfer over a given port.

Note: To communicate with Robcomm3, `cspeed` and `tspeed` can only be set to 9600, 19200, 38400, or 57600 bps.

When the controller finishes booting, you should be able to connect at the new baud rate.

The MCE port

The MCE port on the back of the controller is a serial port connected directly to the motion control engine on the controller. This port is reserved for force control input and output from the optional Force Sensor Kit.

For more information on connecting to the MCE port, see the user guide for the Force Sensor option.

CHAPTER 8

Maintenance Procedures

In order to prolong the life of your robot system, inspect the components of your robot and schedule routine maintenance as described in this chapter.

Cleaning

Warning! Electric Shock Hazard. *Do not immerse any part of the robot system in liquid.*

Exterior surfaces on the arm and controller should be cleaned using mild cleaning products only. Some solvents and degreasers may damage printed surfaces.

When cleaning the arm, take care not to allow liquids to seep inside the controller or enter the arm casing through any of the seams. Be particularly careful to avoid amplifiers and connectors when cleaning the wrist and the waist area on the arm.

Routine Inspection

To ensure that your robot system continues to function safely and efficiently, inspect the robot exterior and functional specifications at regular intervals.

Monthly Inspection

- Inspect seams and other arm seals for lubricant leakage. A small amount of leakage is normal. Wipe any excess lubricant from the arm surface.
- Inspect the air filter at the back of the controller and clean it if necessary. The filter can be removed from the controller and rinsed under water.
- If the arm is dirty, wipe the exterior clean with a damp cloth.
- Visually inspect the arm and cables for signs of damage or wear. **Do not use the robot with a damaged cable.**
- Inspect all E-Stops and safety devices to ensure that they are functioning normally. See "Checking Devices in the E-Stop Circuit" on page 5-8 for a detailed procedure.

Annual Inspection

- Check the depth of the chain tensioners on joints 2 and 3, and adjust as required. See “Adjusting Chain Tensioners” on page 8-2.
- Replace the encoder battery pack. See “Replacing Encoder Batteries” on page 8-3.
- Verify that the beacon light on the arm is functioning normally.
- Verify that the arm accurately carries out tasks in your robot application.

Adjusting Chain Tensioners

Chain tensioners in the base of the arm ensure that the chain inside the arm is under tension at all times. Tensioner cups on joints 2 and 3 ensure that the chain inside the arm is under tension at all times. You may need to adjust the tensioners occasionally as the chain relaxes under use.

Note: Chain tension adjustments may affect the calibration of the arm, requiring taught locations to be re-entered.

If the distance between the top of the plunger and the lip of the tensioner cup is more or less than 2 mm [0.08 in.], you should adjust the chain tensioner.

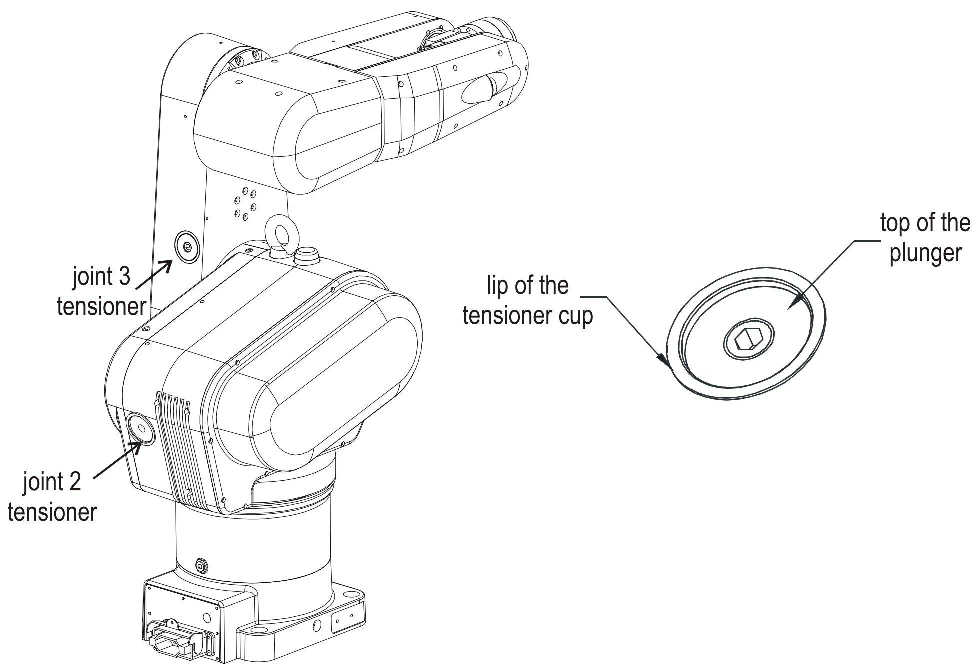


Figure 8-1: The distance between the top of the plunger and the lip of the tensioner cup should be about 2 mm [0.08 in.].

To adjust the chain tensioners

Using a 4 mm hex key, tighten or loosen the bolt until the distance between the top of the plunger and the lip of the tensioner cup is approximately 2 mm [0.08 in.].

Warning! Do not overtighten or completely unscrew chain tensioners. *Excess strain can cause chain fatigue. If the tensioner is unscrewed too far, the bolt may fall out, releasing the chain.*

Replacing Encoder Batteries

To avoid losing encoder data due to battery failure when the robot system is powered off, replace all encoder batteries on a yearly basis. You may also need to replace the batteries in the event of an encoder failure.

Caution! Do not mix old and new batteries in the battery pack. Replacing batteries individually could result in battery failure and loss of encoder data. *Always order batteries in sets of three and replace all the batteries in the encoder battery pack at the same time.*

Replacement batteries can be ordered directly from CRS (part number R-BAT-NiMH1.2), or from a local supplier. Always order replacement batteries in sets of three.

Note: The encoder battery pack requires three VARTA-VA1200-AA batteries. These are continuous-charge, 1.2 V NiMH batteries. Do not use NiCd batteries.

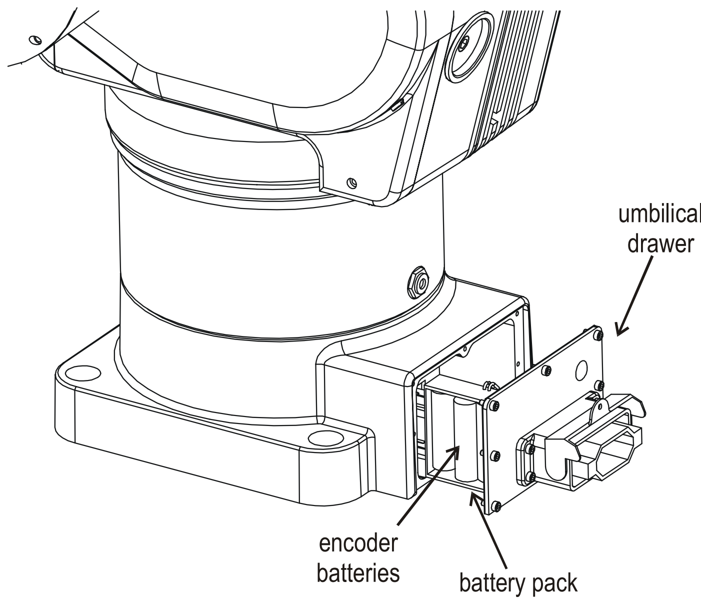


Figure 8-2: Pull out the umbilical drawer to access the encoder battery pack.

Note: The F3 shown here has an air intake fitting on joint 1. If the air intake fitting for your F3 arm is located on the back of the umbilical drawer, you must disconnect the air fitting to pull the drawer out.

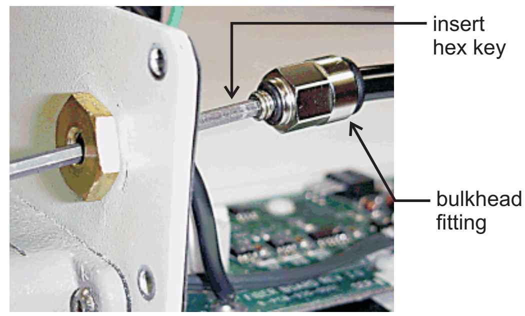
To replace the encoder batteries

Caution! Without battery support, the encoders begin to lose power immediately. *If all three batteries are not changed within 10 minutes, you may need to re-home the arm.*

1 With the controller shut down and powered off, remove the umbilical cable from the connector at the back of the arm.

2 Using a 2.5 mm hex key, unscrew and remove the seven socket head cap screws from the umbilical drawer at the base of the F3.

3 If the air intake fitting for your arm is located on the back of the umbilical drawer, perform these additional steps:



   a Disconnect the air line from the base of the arm, if applicable.

   b Insert a 2.5 mm hex key into the socket of the bulkhead fitting and turn clockwise to release the bulkhead connector from the brass fitting on the back of the drawer.

4 Carefully pull the umbilical drawer out just enough to access the battery pack on the left-hand side.

Warning! Do not pull the drawer out farther than necessary to reach the batteries. *Forcing the drawer or pulling too sharply can damage or disconnect connections inside the arm.*

5 Remove all three batteries from the battery pack.

6 Taking care to correctly align the batteries with the polarity shown on the battery pack, insert three new batteries into the battery pack.

Note: If the arm is mounted on a track, tape the batteries to the battery pack to ensure that they do not slip out when the robot system is in use.

7 If the air intake fitting for your arm is located on the back of the umbilical drawer, re-connect the air fitting as follows:

   a Slide the drawer part of the way in, until you can pull the bulkhead fitting back into the brass fitting on the back of the drawer. **Take care not to crimp or kink the air line.**

   b Using the 2.5 mm hex key, turn the socket on the bulkhead fitting counter-clockwise to lock the fitting back into place.

   c Re-connect the air line to the air intake fitting, if applicable.

8 Taking care not to trap any wires, carefully slide the umbilical drawer back into the base of the arm.

9 Fasten the drawer back into place with the seven socket head cap screws.

Scheduled Maintenance

To keep the arm in good working order, schedule the following maintenance procedures according to the duty cycle for your application.

Duty Cycle	Chain Re-lubrication	Factory Servicing
Heavy	every 10,000 hours	every 20,000 hours
Normal	every 20,000 hours	every 40,000 hours
Light	every 30,000 hours	every 60,000 hours

When assessing the duty cycle for your application, consider factors such as the environment in which the robot is used, typical payloads, cycle times, accelerations, distance traveled, and how often the arm is in motion.

Example of Duty Cycle Determination

A robot system is used in a laboratory application to move a light payload. The environment is controlled, the payload is less than rated, and default accelerations are used. In addition, the arm is only in motion 50% of the time during a pick-and-place operation.

Based on this information, the robot in this example has a light duty cycle.

Re-lubricating the Chain

To keep the arm in good working order, you should re-apply lubricant to the drive chains inside joints 2 and 3 after every 10,000 to 30,000 hours of use, as determined by your duty cycle.

Use only LPS ChainMate Chain & Wire Rope Lubricant to lubricate Thermo CRS robot systems. For ordering information, contact LPS laboratories directly or visit their website http://www.lpslabs.com.

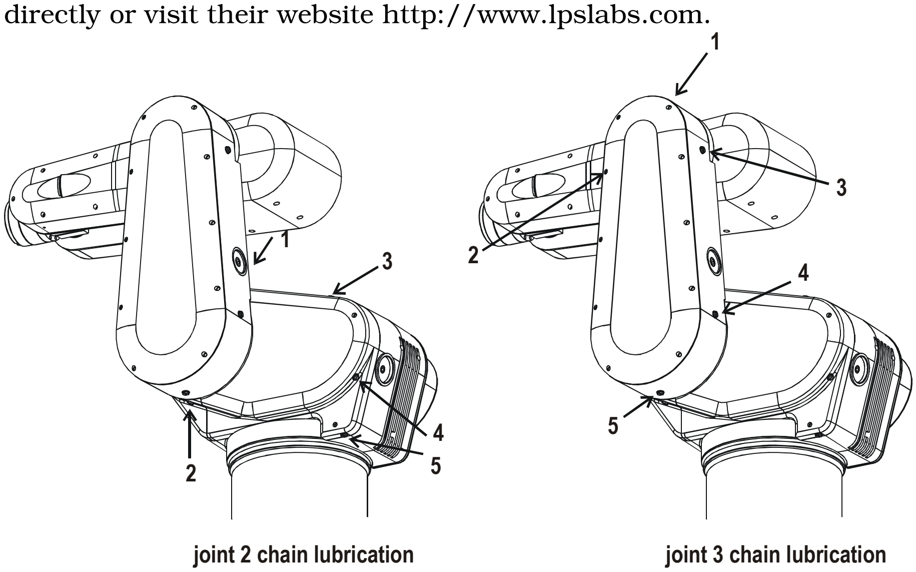


Figure 8-3: Lubrication points are indicated by arrows. Apply lubricant in the order shown.

Note: If the arm is mounted inverted, reverse the order shown in Figure 8-3.

To re-apply lubricant

1. Place the arm in the ready position.
2. Shut down and turn off the controller.
3. For joints 2 and 3, apply lubricant to each of the five access holes in the order shown in Figure 8-3:

   Warning! Do not apply excessive amounts of lubricant. *A single spray of lubricant in each hole is generally sufficient. Apply lubricant to the lowest access hole last to allow excess lubricant to drain out of the joint.*

   a. Using a flat head screwdriver, remove the slotted machine screw from the hole. Take care not to lose the washer.
   b. Holding down the aerosol dispenser for approximately a 2 second burst, spray LPS ChainMate lubricant into the hole.
   c. Using the washer, replace the machine screw in the access hole.
4. Allow any excess lubricant to drain out of the lowest access hole.
5. Tighten the machine screws onto the washers to ensure that the joint is sealed and wipe any excess lubricant from the outside of the robot.
6. Turn the robot system back on and slowly move joints 2 and 3 through the full range of motion in order to distribute lubricant over the chain.

Returning the Arm For Factory Maintenance

To prolong the life of your robot system, the following maintenance procedures are recommended after every 20,000 to 60,000 hours of use, as determined by your duty cycle:

- Joint 5 belt inspection
- Harmonic drive re-greasing
- Bearing re-lubrication
- Seal inspection
- Chain replacement
- Harness replacement

These factory maintenance procedures require specialized tools and equipment and should only be performed by CRS Robotics. To arrange for factory maintenance, contact the Customer Support Group for return authorization and instructions.

Checking the Encoder Batteries

When the controller is powered off or unplugged from the arm, batteries in the base of the arm supply power to maintain encoder memory. If you are planning to shut down the system for longer than a few days, verify that the batteries are sufficiently charged.

About the Encoder Batteries

The encoders require a minimum of 3.0 VDC from the batteries in order to maintain encoder memory when the controller is powered off.

The batteries are continuously charged whenever the controller is powered on and connected, and reach maximum capacity after 72 hours of continuous power. Once fully charged, they can maintain the encoders without external power for six weeks or more.

Note: Below 3.0 VDC, the encoders lose positional information and enter a reset state. Once the encoders reset, the arm loses its positional information and must be re-homed. See “About Calibration and Re-homing” on page 9-9.

Checking the Encoder Battery Voltage

The umbilical cable connector on the arm provides a test pin to for checking the battery voltage.

To check the battery voltage

1. With the controller shut down and powered off, remove the umbilical cable from the connector at the back of the arm.
2. Immediately connect a voltmeter across pins A1 and A5 on the umbilical connector at the base of the arm and measure the voltage. The battery charging voltage is around 4.2 V.
3. Continue checking the battery voltage over the next 4 hours while the batteries drop from the charging voltage to the resting voltage of 3.6 V.

   Warning! Do not allow the voltage to drop below 3.4 V. *If the battery voltage begins to drop below 3.6 V, immediately re-connect the umbilical cable and turn on the controller to prevent losing positional information.*

4. If the battery voltage stabilizes around 3.6 V, the batteries are functioning normally. If the battery voltage drops significantly below 3.6 V at any time during the test, connect the arm to a powered controller. Keep the controller powered on and replace the batteries as soon as possible.

Checking Front Panel Fuses

Fuses located inside the access panel on the front of the controller protect the controller circuits from overload.

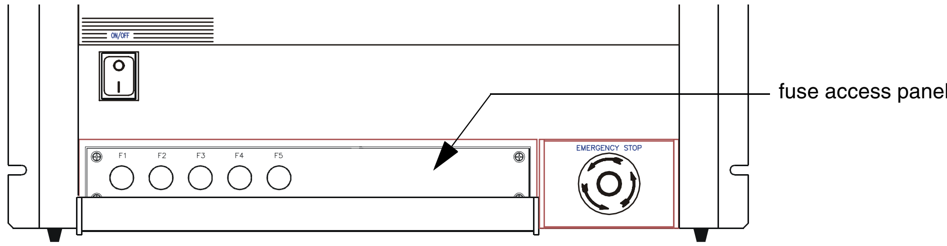


Figure 8-4: The fuses are located behind the fuse access panel.

Under normal operating conditions, the front panel fuses should not need to be replaced. A blown fuse may indicate a more serious problem with your robot system. If you replace fuses often within a short period of time and cannot identify the cause of the failure, contact the Technical Services Group for assistance.

Table 8-1: Front panel fuses

Fuse	Signal Name	Fuse Rating	Function
F1	24V-CB	250 V, 1A, slow blow	• internal 24 V power supply • main controller board circuits
F2	RLYCOM	250 V, 1A, slow blow	• GPIO relay common
F3	12VSPLY	250 V, 3A, slow blow	• arm circuits • arm power relays
F4	24VSPLY	250 V, 2A, slow blow	• internal 24 V power supply • main controller board circuits • brake power • servo gripper
F5	77VSPLY	250 V, 10A, slow blow	• arm power

Note: All fuses are standard 1/4 in. x 1 1/4 in.

To inspect and replace a controller fuse

1. With the controller shut down and powered off, open the fuse panel on the front panel of the C500C controller.
2. Unscrew the fuse clip and remove the affected fuse.
3. Measure the resistance across the fuse. If the resistance is larger than 2 Ω, the fuse has blown and must be replaced.

   Note: Test fuses with an Ohm-meter. Visual inspection can be deceptive.
4. Insert a new fuse **of the same rating** in the fuse clip. Ratings for the controller front panel fuses are given in Table 8-1.
5. Close the fuse panel.

Inspecting AC Fuses

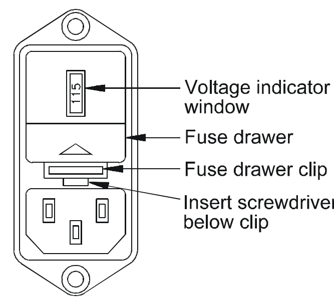
The AC fuses for your robot system are located inside the fuse drawer at the back of the controller.

Warning! High Voltage. *Always shut down and unplug the controller before inspecting the AC fuses.*

Table 8-2: AC fuses required for the F3 Robot System

Mains Voltage	Required Fuses
100 VAC	10 A, 250 V, 6.3 mm x 32 mm [¼ in. x 1¼ in.], slow blow
115 VAC	10 A, 250 V, 6.3 mm x 32 mm [¼ in. x 1¼ in.], slow blow
230 VAC	5 A, 250 V, 6.3 mm x 32 mm [¼ in. x 1¼ in.], slow blow

To inspect the AC Fuses



1. Shut down and turn off the controller.
2. Unplug the power cord from the power connector at the back of the controller.
3. Insert a screwdriver below the clip to release the fuse drawer.
4. Make sure that the voltage is properly selected for your local mains power. If it is not correctly set, see “Installing the Controller Fuse Drawer” on page 4-5.
5. Remove the two AC fuses from the fuse drawer and measure the resistance across each fuse. If the resistance is larger than 2 Ω, the fuse has blown and must be replaced.

   Note: Test fuses with an Ohm-meter. Visual inspection can be deceptive.

6. If necessary, replace blown fuses with the appropriate fuses for your local mains power. Determine the required fuse rating from Table 8-2.
7. Replace the fuse drawer into the power module and push until you hear the drawer click into place.

Preparing the Robot System For Shipping

If you need to ship the robot system, follow these guidelines to ensure that the arm and controller are packaged safely:

- To place the arm in its packing position, enter the command `/diag/f3pack` from the ash prompt. The arm will move to the position it was in when it was shipped from the factory.
- Use the file transfer utility to make a backup copy of all files in the /app and /conf directories on the controller.
- Use the original packing materials.
  - Fasten the arm to the bottom of the crate with the shipping bolts.
  - Secure the controller in the pre-shaped foam box fill.
- Fill any remaining space inside the controller and arm shipping crates with foam.

CHAPTER 9

Troubleshooting

This chapter contains diagnostic procedures to help you correct problems with your robot system. If a problem cannot be resolved easily, see "Contacting the Technical Services Group" on page 9-11.

Warning! *Do not open the controller case or remove arm covers unless instructed by Thermo CRS-authorized personnel. Service procedures should only be carried out by qualified service technicians.*

Troubleshooting Common Problems

The following are commonly seen problems that can be resolved without opening the controller or the arm covers.

The Controller LCD Display Remains Blank

If the controller display remains blank after the system is powered on, there may be a problem with the power supply. **Switch the controller off** and try the following troubleshooting steps:

- Make sure that the controller is plugged into a live power outlet.
- Verify that the power plug is securely connected in the power connector at the back of the controller.
- Verify that the voltage indicator is correctly selected for your local power. See "Installing the Controller Fuse Drawer" on page 4-5.
- Unplug the controller and check the AC fuses. See "Inspecting AC Fuses" on page 8-9.

Joint *N* Is Limp

If you cannot move the arm because a joint is limp, you need to unlimp the affected joint.

- Unlimp all joints by entering the command `nolimp` at the ash prompt.

Home Light Does Not Come On

If the Home light does not come on when you boot the controller, the robot system cannot find the calibration file.

To restore the calibration file

1. Connect your development computer to the Console port.
2. Using the file transfer utility, transfer the file `robot.cal` from the calibration disk to the /conf directory on the controller.

   Note: The calibration disk is a 3.5 inch floppy disk shipped with your robot system. If you have lost the calibration disk, contact the Technical Services Group for assistance.

3. Shut Down and reboot the controller.

Arm Power Is Intermittent

If arm power is intermittent, there may be a connection problem with the umbilical cable.

Warning! High Voltage Risk. Do not use a damaged *umbilical* ***cable.*** *The umbilical cable carries high voltages. A damaged cable presents a serious risk of electric shock.*

To inspect the umbilical cable

1. Shut down and turn off the controller.
2. Visually inspect the cable for damage. **Do not use a damaged cable.**

   Note: Replacement cables are available from Thermo CRS.

3. Disconnect the cable and inspect the connectors to ensure that they are clean and free of corrosion.
4. If the cable and connectors are in good condition, plug the cable back in. See “Connecting the Umbilical Cable” on page 4-8.
5. Ensure that the latch is properly closed over the connector at both ends of the cable. Connectors must be securely latched to function normally.

Arm Power Cannot Be Turned On

If arm power does not come on when the Arm Power button is pressed, try the following troubleshooting steps:

- Make sure that the E-Stop circuit is closed.
  - Verify that all E-Stop buttons and devices have been reset. You cannot turn on arm power while an E-Stop is triggered.
  - Verify that the teach pendant or its dummy plug is plugged into the *Pendant* port on the front of the controller.
  - Verify that the SYSIO port at the back of the controller is terminated with a dummy plug or a correctly wired SYSIO device.
- Check the fuses.
- Clear any persistent motion errors (see the procedure below).
- Re-enable the Arm Power button (see the procedure below).
- Shut down and reboot the controller.

Clearing Persistent Motion Errors

In case of a critical failure caused by robot runaway, collisions, overspeeds, or encoder faults, arm power is automatically removed and cannot be restored until motion errors are cleared from the amplifier.

To clear motion errors

1. With the robot system turned on, open a terminal window on the development computer.
2. At the ash prompt, enter the command:

   ```
   test> clrerror
   ```

   Persistent error bits are cleared from the amplifier. You should see:

   ```
   Error state has been cleared.
   ```

   Note: You can verify that errors are cleared with the command `ampstat`.

3. Press the Arm Power button on the controller. You should be able to power the arm.

   Note: A few errors, such as `overcurrent`, are only cleared by a reboot.

Re-Enabling the Arm Power Button

The ash command `armpower` can be used to disable or enable the Arm Power button. If the button has been disabled, you cannot apply arm power until it is re-enabled.

To allow arm power

At the ash prompt, enter the command:

```
test> armpower on
```

The Arm Power button on the controller is enabled and can be used to power the arm.

Note: Shutting down and rebooting the controller also re-enables the Arm Power button.

Pneumatic Tool Malfunction

If your pneumatic tool is not functioning normally, check the following:

- Verify that the air line on the wrist is properly connected. See "Using the Pneumatic Connector" on page 7-5.
- Verify that the pneumatic port is activated. See "Enabling Pneumatic Control" on page 7-5.
- Ensure that the air intake line is properly connected at the base of the arm. See "Connecting a Pneumatic Tool" on page 7-6.
- Check the air supply lines for leaks or pinching.

Encoder Fault Message

An encoder fault message occurs when the encoder batteries drop below the voltage required to maintain positional information. To ensure safety, the controller removes armpower as soon as positional information is lost.

You must recharge or replace the batteries and re-home the arm before you can continue running your robot application.

To recover from an encoder error, perform the following steps:

1. Re-home the arm. See "Re-Homing the Arm" on page 9-10.
2. With the arm connected to the controller, leave the robot system powered for a full 72 hours to re-charge the batteries.
3. Check the encoder battery voltage, as described in "Checking the Encoder Batteries" on page 8-7.
4. If the voltage is still low after 72 hours of charging, replace the batteries and re-home the arm. See "Replacing Encoder Batteries" on page 8-3.

Controller Always Boots in Diagnostic Mode

If the controller always boots in diagnostic mode after a shutdown, try the following:

1 In diagnostic mode, enter the command:

```
: set boot /kernel
```

2 Initiate the boot sequence by entering the command:

```
: boot
```

The controller will begin cycling through the normal bootup sequence.

3 Shut down and reboot the controller. The controller should resume booting normally.

4 If the controller still does not boot normally, rebuild the filesystem and reinstall firmware on the controller, as described in “Installing New Firmware” on page A-1.

Caution! *Rebuilding the filesystem will erase all application and data files on the controller.*

Caution! *When reinstalling the CROS firmware, make sure that you install the correct version on the controller. Although versions are generally backwards compatible, review the release notes thoroughly before changing versions of CROS. A few early RAPL-3 commands are not supported in all versions.*

Terminal Window Locks Up

If you have opened a terminal window on the development computer but cannot issue any robot system commands, try the following steps:

- Make sure that the development computer is functioning normally:
    - Try moving the terminal window around the screen. If you cannot move the window, shut down and restart the terminal program.
    - Try pressing the Num Lock key on your keyboard. The Num Lock light on the keyboard should turn on and off. If the Num Lock light does not respond, reboot the computer.
- If you are using a teach pendant, check to see whether the Teach Pendant has point of control. If the pendant has control, transfer point of control back to the development computer. See “Transferring Control To or From the Teach Pendant” on page 6-3.
- A background process on the controller may have point of control. To return point of control to the Console port, press **Ctrl+E**.
- Verify that the development computer is securely connected to the Console port via a straight-through RS-232 cable.
- Make sure that you have correctly configured the serial port connection. See “Connecting the Development Computer” on page 4-10.
- With the terminal window open, try shutting down and rebooting the controller.

Terminal Communication Error

If you see the message "Communication error" in the terminal window, or garbage text appears on screen, you may have the baud rate set incorrectly for the Console port. Make sure that you have correctly configured the serial port connection, as described in "Connecting the Development Computer" on page 4-10.

Robcomm3 Terminal Communication Error

If you see the message "Communication error" in the Robcomm3 terminal window, or garbage text appears on screen, you may have the baud rate set incorrectly for the Console port. Robcomm3 can only communicate at certain baud rates. Try the following procedure.

1. Verify that the development computer is connected to the Console port on the front of the controller.
2. Change the baud rate setting in Robcomm3:
   a. Select **COM Settings** in the **C500** menu.
   b. In the **Communications Setup** window, change the baud rate. The factory default for the C500C controller is 57600 Baud.
   c. Click **OK** to apply the change.
   d. Open a terminal window to the controller.
3. If the problem persists, repeat Step 2 until you have tried all possible baud rates.

If none of the baud rates available in Robcomm3 resolve the problem, the baud rate for the controller may be set to a baud rate that Robcomm3 does not support. In this case, you must take the following steps:

1. Use a third party terminal emulator to establish communication with the controller. Configure the terminal as follows:
   - 8 Data Bits
   - No Parity
   - 1 Stop Bit
   - No Flow Control
   - TTY or ANSI emulation
   - 115200 baud
2. If you cannot communicate at 115200 baud, configure the terminal for 300, 600, 1200, or 4800 baud.
3. Once you have established communication with the controller, use your terminal connection to change the baud rate back to a rate that is supported by Robcomm3. See "Changing Serial Port Baud Rates" on page 7-23.

Diagnostic Commands

If you have a development computer connected to your robot system, you can use diagnostic commands to help troubleshoot problems.

Testing Amplifier Status

The ash command `ampstat` returns the status of all amplifiers in the arm. From an ash prompt, enter:

```
test> ampstat
```

The status of the amplifiers is displayed in the terminal window. If the amplifiers are responding normally, you should see the following:

```
Amplifier Status
1......OK
2......OK
3......OK
4......OK
5......OK
6......OK
```

If you encounter a communication error message, verify that the umbilical cable is securely fastened and try again. Communication error messages may indicate a communication failure between the controller and the arm.

If you encounter an encoder fault message, see "Encoder Fault Message" on page 9-4.

Verifying Encoder Feedback

You can also test feedback from the encoders to ensure that the arm position is being relayed properly.

To test encoder feedback

1. Remove arm power by pressing an E-Stop button. The LED on the Arm Power button should now be off.
2. From ash, enter the command `w1` to display the position of each encoder. If your arm is in the ready position, the motor pulse count display will look something like this:

   ```
   -1  +0   +51200   +1    +0    +1
   ```

   Note: A variation of a few motor pulses is normal.

   Note: To return to the ash prompt, press **Ctrl+E**.

3. Starting with joint 1, manually push against each joint and observe the display in the terminal window. The number of counts should change in response to the movement.

   Note: Although brakes prevent joints 1,2, and 3 from moving, the encoders will register a small movement when the joint is pushed.

Determining System Uptime

You can find out how long the system has been in use with the `odometer` command.

To determine uptime

At the ash prompt, enter the command:

```
test> odometer
```

The total number of hours in use since the controller firmware was installed is displayed in the terminal window.

Note: The odometer resets to zero when you re-install firmware.

Determining Version Numbers For Your System

When troubleshooting, you may need to determine the version of CROS and the motion control engine used by your robot system.

To obtain the kinematics version

- At the ash prompt, enter the command `robotver` to return the version of the kinematics engine used by your system.

To obtain the CROS version

- At the ash prompt, enter the command `crosver` to return the version of CROS used by your system.

These version numbers can sometimes help the Technical Services Group to identify the cause of a problem with your robot system.

About Calibration and Re-homing

Absolute encoders mounted on the motor shaft in each joint provide positional feedback to the controller.

Each absolute encoder has a zero position, which does not necessarily correspond to the zero position for the joint. The arm's calibration identifies the offsets between the encoder's zero position and the joint's zero position.

When your robot system is calibrated at the factory prior to shipping, the joints are precisely aligned in the zero position. The offset between the encoder zero position and the joint zero position is then saved in the robot.cal file, and alignment markers are placed on the arm to identify the zero position of each joint.

As a joint moves, each motor shaft rotates through many revolutions. The encoder in each joint keeps track of how many times the motor shaft has rotated and stores this information, called multiturn data, in battery-maintained memory. The controller combines the motor shaft position and the multiturn data returned by the encoder with the offset value in the robot.cal file to determine the joint's position in the world coordinate system.

Re-homing

Because the absolute encoders in the F3 arm are battery-maintained, the F3 arm does not need to be re-homed after a controller shutdown. However, during an extended period without power (typically longer than six weeks), or due to battery failure or a service intervention, the multiturn data may be lost. If this happens, the encoders lose track of the arm's position and the arm must be re-homed.

When you re-home the arm, you manually place the arm into its calibration position using the alignment markers on each joint. By lining up the markers, you return each motor shaft (and hence, each encoder) to a position less than one motor rotation from the joint's zero position. You then clear the multiturn data from each encoder's memory, restoring the arm to its original precise calibration.

Re-calibration

Re-calibration is generally only performed after a service intervention or a severe collision. During re-calibration, a new robot.cal file is created with exact zero position offsets for each encoder. Under normal use, the offsets for the encoders do not change, and re-calibration is not required.

To ensure accuracy, re-calibration requires specialized tools and should only be performed by qualified service personnel. For more information on re-calibrating your robot system, contact the Customer Support Group.

Re-Homing the Arm

You must connect a development computer to the robot system in order to re-home the arm.

To re-home the arm

1 Verify that the calibration file robot.cal is located in the /conf directory on the controller. Without this file, the arm cannot be re-homed.

Note: To restore the calibration file, see "Loading the Robot Calibration File" on page 5-5.

2 Remove arm power by pushing an E-Stop button.

3 Halt any processes running on the controller by pressing **Ctrl+E**.

4 Manually back-drive each joint until the alignment markers are aligned.

5 When the markers for all joints have been aligned, reset the encoder multiturn data by entering the command:

```
$ /diag/encres
```

You will be prompted to enter a module address. Select 'wrist' or enter module address `8` to reset the encoders in joints 4, 5, and 6.

6 Repeat the `/diag/encres` command for all encoders used by your robot system. If you receive an error message when resetting the encoders, re-align the markers for those encoders and try again.

- Select 'waist' or enter module address `16` to reset the encoders in joints 1, 2, and 3.
- Select 'track' or enter module address `80` to reset the encoder for a track.

7 When all encoders have been reset, shut down the controller by entering the command:

```
$ shutdown now
```

8 Switch off the controller when the shutdown cycle is complete.

9 Wait 10 seconds.

10 Turn the controller on.

11 Reset the triggered E-Stop and apply arm power.

12 At the ash prompt, enter the command:

```
test> calrdy
```

The arm moves to the calrdy position.

13 Inspect the calrdy position. All links should be extended vertically, as shown in the illustration at right. If any joints are misaligned, repeat the re-homing procedure for those joints.

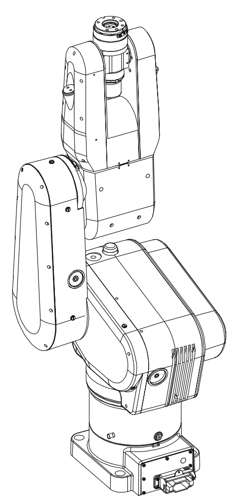


Figure 9-1: The calrdy position

Contacting the Technical Services Group

Before contacting Thermo CRS, make sure that you can provide a clear description of the problem. The following information will help the Technical Services Group to diagnose and resolve the problem efficiently:

- Serial numbers for the arm and controller (located on the back panel of the controller and at the base of the arm).
- Whether the arm is part of a POLARA laboratory system.
- A brief description of the operating environment, the type of robot application and the duty cycle involved.
- Any errors or warning messages observed.
- A description of the bootup screen information.
- CROS and Kinematics version numbers for the controller and the development computer:
    - For controller version numbers, see "Determining Version Numbers For Your System" on page 9-8.
    - The CROS version of the development computer is only needed if you are using RAPL-3. Open Robcomm3 and select **Version** under **C500** on the main menu to view the CROS version number.
- If you are using ActiveRobot, the ActiveRobot.dll version number, shown on the **General** tab in the ActiveRobot Configuration utility.
- Steps necessary to reproduce the problem and the circumstances surrounding the failure.

Once you have gathered all of the relevant information, contact the Technical Services Group by telephone, fax, or e-mail.

Telephone

1-905-332-2000 (voice)
1-800-365-7587 (voice: toll free in Canada and United States)

Fax

1-905-332-1114 (facsimile)

E-Mail

Technical Services: support@crsrobotics.com

APPENDIX A

Installing New Firmware

Under certain circumstances, you may need to re-install CROS or install a new version of CROS on the controller. This document contains instructions for backing up controller files and installing new firmware with the CROS Firmware Download Utility.

Caution! Files on the controller may be destroyed by the firmware installation process. *Always back up controller files before updating firmware.*

Backing up Controller Files

When new firmware is installed, all files on the controller are erased. Before proceeding, make sure that your application and configuration files are backed up to a safe location on the development computer.

To back up application and configuration files

1 Connect a development computer to your robot system.

2 Using the file transfer utility, transfer all files in the /app and /conf directories from the controller to the development computer.

Using the Firmware Download Utility

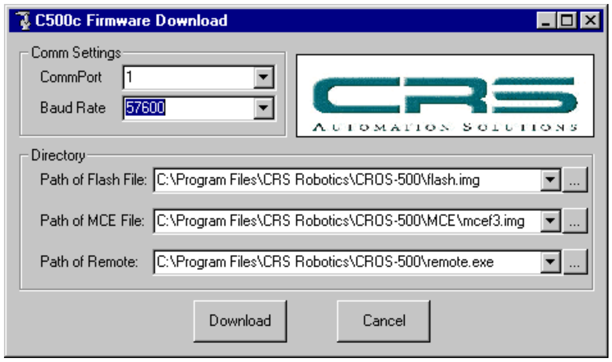
The Firmware Download Utility is automatically installed when you install CROS on the development computer.

To download CROS onto the controller

1 On the development computer, start the CROS-500C Firmware Download Utility. The download utility is located in the CRS Robotics folder under Program Files on your Windows Start Menu.

Note: If you don't see the download utility on your Start Menu, you can click Find and select Files or Folders to search for “download.exe”. Double-click the file to start the download utility.

The download utility opens the following configuration screen:



2 Verify that the settings are correct for your robot system.

Setting	Required Value
CommPort	The number of the development computer COM port that is connected to the robot system.
Baud Rate	The baud rate of the controller *Console* port. The factory default setting for the *Console* port on a C500C is 57600 bps.
Path of Flash File	The name and location of the file flash.img on the development computer. You can press the "..." button to search for the file yourself.
Path of MCE File	The name and location of the file mcef3.img on the development computer. You can press the "..." button to search for the file yourself.
Path of Remote	The name and location of the file remote.exe on the development computer. You can press the "..." button to search for the file yourself.

When the settings are correct, click **Download** in the Firmware Download window. The download utility then prompts you to restart the controller in Diagnostic mode.

3 Restart the controller in Diagnostic mode:

a Shut down the controller by entering the command `shutdown now`.

b Switch off controller power.

c While holding down the F1, F2, and Pause/Continue buttons, switch on controller power. Continue holding the buttons for 10 seconds.

d The controller boots into Diagnostic Mode. Verify that the message

```
Diagnostic Mode
```

is displayed on the controller LCD screen.

4 On the development computer, click **OK** to start the download.

Rebuilding the File System on the Controller

For most versions of CROS, you need to completely rebuild the file system once the download is complete.

Note: See the release notes for your version of CROS to determine whether this step is required.

To rebuild the file system

1. Switch off controller power.
2. While holding down the F2 and Home buttons, switch on controller power.
3. The controller LCD displays the message `Loading new MFS from Flash` while the file system is being rebuilt. When the process is complete, the controller continues with its normal bootup sequence.
4. Using the Robcomm3 file transfer utility, transfer your backup copies of the files from the /app directory and the files /conf/robot.cal, /conf/robot.cfg, /conf/rc, /conf/simsockd.cfg, and /conf/startup.sh (if applicable) back onto the controller.
5. Shut down and reboot the controller.
6. Re-compile and test all application files on the controller.

APPENDIX B

GPIO Termination Block Option

A GPIO termination block is available as an optional component for Thermo CRS robot systems. It provides easier access to GPIO connections by extending the pins in the GPIO port to external screw terminals.

The mounting rail bracket on the underside of the GPIO block fits all standard DIN EN rails.

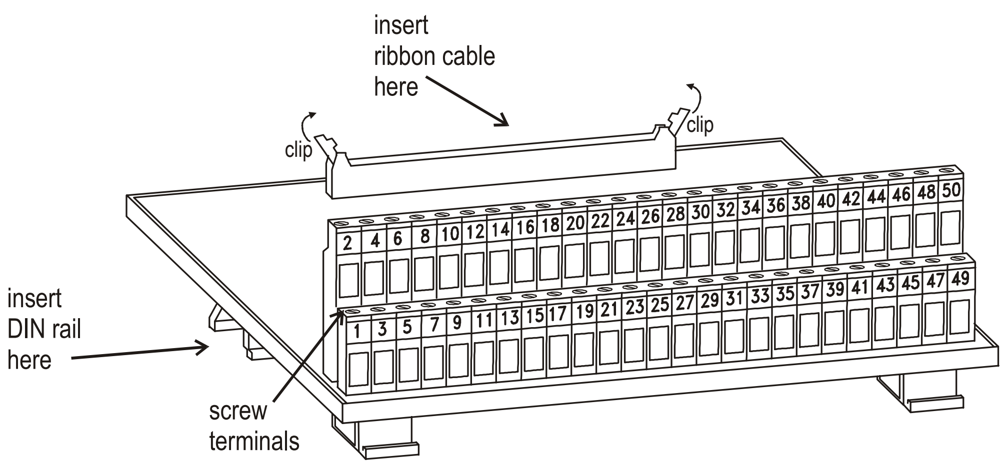


Figure B-2: The GPIO termination block

Installing the GPIO block

1 Mount a DIN rail outside the arm's work space, near the back of the controller.

Note: The ribbon cable is 152 cm [5 ft.] in length. Mount the rail close enough to the controller to ensure that the cable is strain-relieved.

2 Snap the GPIO termination block onto the rail.

3 With the controller shut down and powered off, connect the ribbon cable between the controller and the GPIO block:

a Connect the male DD-50 ribbon connector to the GPIO port at the back of the controller.

b Connect the box header end of the ribbon cable to the connector on the GPIO termination block.

4 Provide power for the GPIO circuit, as described in "Powering the GPIO Circuit" on page 7-16.

5 Referring to "Pinouts for the GPIO Port" on page 7-12, and "Wiring Schematic For the GPIO Connector" on page 7-15, connect your devices to the GPIO block terminals.

Note: The screw terminal numbers printed on the GPIO terminal block correspond to the GPIO pin numbers printed on the back of the controller. **Do not use the pin numbering embossed on the plastic inside the GPIO connector on the controller.**

Glossary

absolute encoder
Precision device for converting the rotation of a motor shaft into a digital signal. Absolute encoders (used in the F3 arm) record the exact position of the motor shaft as well as the number of turns.

See: incremental encoder.

ActiveRobot
The ActiveX component for creating robot applications under Microsoft Windows.

See: *ActiveRobot User Guide* on the documentation CD.

application shell (ash)
Command-line application development environment under CROS. The application shell provides an integrated environment for developing, compiling, and running robot applications on the controller

See: *Application Shell Guide* on the documentation CD.

arm
An articulated, mechanical manipulator.

articulated robot
Robotic arm consisting of rigid links connected by rotary joints. This type of robot most closely resembles a human arm.

ash
See: application shell.

autohoming
Procedure which returns the arm to a homed state using positional data stored in a calibration file (poweroff.cal) on the controller. Autohoming is completely automated and generally much faster than manually homing the arm.

See: homing

awareness barrier
Device that warns a person of a hazard by physical and visual means.

awareness signal
Device that warns a person of a hazard by audible or visible means.

axis
1. Reference line of a coordinate system.

2. A line which passes through any of an arm's joints about which a link or similar section rotates.

beacon
Awareness signal that indicates a condition or hazard. The beacon on the arm flashes amber when the arm is powered.

collision
Unscheduled physical contact between the arm and an object.

controller
Device that controls and powers the arm.

country kit
Kit used to customize the C500C controller for local AC power. It consists of a power cord, voltage module, and fuses.

CRS Robotics Robot Operating System (CROS)
Operating system on the C500C controller.

See: *CROS and System Shell Guide* on the documentation CD.

development computer
Personal computer used to create robot applications and execute controller commands in terminal mode. The development computer is connected to the Console port on the controller,

diagnostic mode
Controller mode for low-level diagnostic operations.

emergency stop (E-Stop)
Switch connected to the controller E-Stop circuit that removes arm power and halts robot motion when triggered. Once triggered, it must be manually reset.

end effector, end-of-arm tool
Work-performing device attached to the tool flange, such as a gripper, dispenser, buffing wheel, or spray head.

firmware
Programming stored in non-volatile memory on the controller, consisting of the diagnostic monitor and the operating system (CROS).

force sensor kit
Optional end-of-arm device that enables the robot system to sense forces and torques.

See: *Force Sensor Guide* on the documentation CD.

General Purpose Input Output (GPIO)
The GPIO port on the back of the controller provides inputs and outputs for connecting external hardware devices to the robot system.

gripper
End effector designed to grasp or hold objects.

hardstop
Hardware safety device fastened at a fixed position that determines the absolute ends of movement of a joint or track. A hardstop restricts the workspace and provides some safety in the case of robot runaway.

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

homing
Procedure by which the motion control engine exactly locates the position of each of the arm's axes.

I/O
Input/output.

incremental encoder
Precision device for converting the rotation of a motor shaft into a digital signal. Relative encoders (used in the CataLyst, A255 and A465 arms) record the relative angular displacement of the motor shaft.

See: absolute encoder.

interlock
In robot systems, a device that automatically prevents robot use under dangerous conditions. For example, a door contact switch can be interlocked with the arm power cicuit to prevent robot use when the door is open.

joint
Location where two links join, usually consisting of a motor and drive.

See: link.

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
Rigid part of a robot arm between two neighboring joints.

live-man switch
3-position enabling switch on the teach pendant, used to ensure safety while moving the arm in teach mode.

maximum space
See: work space.

motion control engine (MCE)
Controller processor responsible for calculating robot trajectories.

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.

operator
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.

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

pneumatic tool
Tool actuated by the flow of pressurized air.

range of motion
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.

RAPL-3
Robot Automation Programming Language. A high-level, block-structured, compiled language, similar to C, introduced in 1997. RAPL-3, and its predecessor, RAPL-II, are proprietary languages used to program Thermo CRS robots.

See: *RAPL-3 Language Reference Guide* on the documentation CD.

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

reach
Maximum distance to which the arm can extend the tool flange or gripper plus the length of the workpiece. Reach defines the work space of the arm.

repeatability
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 repeated cycles). Also, the cycle-to-cycle error of the robot system when trying to perform a specific task.

resolution
Smallest increment of motion or angular displacement that can be detected or controlled.

Robcomm3
Proprietary application development environment that runs under Microsoft Windows. Robcomm3 is used for editing and compiling RAPL-3 programs, transferring files between the computer and the controller, and communicating with the controller in terminal mode.

See: *Robcomm3 Guide* on the documentation CD.

robot calibration file (robot.cal)
File that contains calibration information for your robot system. The robot.cal file must be present in the /conf directory on the controller in order to use the robot system.

robot configuration file (robot.cfg)
File which contains the configuration information for your robot system.

The following parameters are stored in /conf/robot.cfg: whether or not the system has a track, positive and negative track travel limits, units of measurement (metric or English), the number of axes for the robot system, the tool transform, base offset, and gripper type, and the force enable password for the force sensor.

robot system
System comprised of an arm, a controller, and an end effector. The robot system may also include the teach pendant and other connected devices in the workcell.

robot
Controlled, reprogrammable, multi-purpose, manipulative machine with several degrees of freedom, which may be either fixed in place or mobile for use in automatic applications.

safeguard
Barrier, device, or procedure designed to protect persons from a hazardous point or area.

servo control
Control exercised over the position of a motor shaft via electronic feedback.

servo-actuated device
Device controlled by applying or removing power based on electronic feedback.

System Input/Output (SYSIO)
The SYSIO port on the back of the controller provides inputs and outputs for connecting safety devices and creating a remote front panel.

system integrator
Person or company who designs, constructs, and installs a robot system.

teach pendant
Hand-held control unit connected to the controller. The teach pendant is used to move the robot, teach locations, and run robot programs.

tensioner
Device used to maintain a constant tension for the drive chains.

tool center point (TCP)
The centre of the tool coordinate system. If no tool transform is set, the tool center point corresponds to the center of the tool flange.

tool transform
Offset value applied to the tool frame of reference. By default, the origin of the tool frame of reference is located at the centre of the surface of the tool flange. By applying a tool transform, you center the tool frame of reference at another point such as the tip of an end-of-arm tool.

track
Linear axis along which the entire arm can be moved under program control.

umbilical cable
Cable that connects the controller and the arm.

work space
Volume of space that can be swept by all robot parts plus the space that can be swept by the end effector and the workpiece.

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

workpiece
Object held by an end-effector.

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