Brooks

PreciseFlex™ 400 Robots

User Manual

Part Number 615287, Revision B

Brooks Automation

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Revision History

Revision	ECO	Date	Action	Author
A	EC149518	March 7, 2024	Released manual at Rev. A to follow standard Brooks technical publication styles.	M. Ashenfelder
B	EC154084	April 19, 2024	Divided the document into two manuals: a user manual and a service manual.	M. Ashenfelder

Table of Contents

1. Safety

Safety Setup

Brooks uses caution, warning, and danger labels to convey critical information required for the safe and proper operation of the hardware and software. Read and comply with all labels to prevent personal injury and damage to the equipment.

⚠️ **DANGER**	
Read the Safety Chapter	
Failure to review the *Safety* chapter and follow the safety warnings can result in serious injury or death. - All personnel involved with the operation or maintenance of this product must read and understand the information in this safety chapter. - Follow all applicable safety codes of the facility as well as national and international safety codes. - Know the facility safety procedures, safety equipment, and contact information. - Read and understand each procedure before performing it.	

Explanation of Hazards and Alerts

This manual and this product use industry standard hazard alerts to notify the user of personal or equipment safety hazards. Hazard alerts contain safety text, icons, signal words, and colors.

Safety Text

Hazard alert text follows a standard, fixed-order, three-part format.

- Identify the hazard
- State the consequences if the hazard is not avoided

- State how to avoid the hazard.

Safety Icons

- Hazard alerts contain safety icons that graphically identify the hazard.

- The safety icons in this manual conform to ISO 3864-1:2011 *Graphical symbols — Safety colours and safety signs* and ANSI Z535 standards.

Safety Icon Examples	
	Warning
	Two-Person Lift
	Electric Shock

Signal Words and Colors

Signal words and colors inform of the level of hazard.

	Danger indicates a hazardous situation which, if not avoided, **will result in serious injury or death**. The Danger signal word is white on a red background with an exclamation point inside a yellow triangle with black border.

⚠ **WARNING**	Warning indicates a hazardous situation which, if not avoided, **could result in serious injury or death**. The Warning signal word is black on an orange background with an exclamation point inside a yellow triangle with black border.
⚠ **CAUTION**	Caution indicates a hazardous situation or unsafe practice which, if not avoided, **may result in minor or moderate personal injury**. The Caution signal word is black on a yellow background with an exclamation point inside a yellow triangle with black border.
NOTICE	Notice indicates a situation or unsafe practice which, if not avoided, **may result in equipment damage**. The Notice signal word is white on blue background with no icon.

Alert Example

The following is an example of a Warning hazard alert.
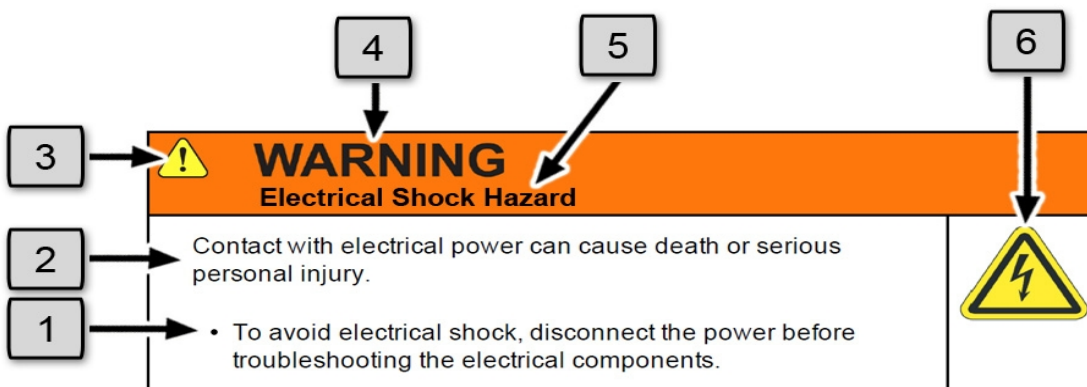
Number	Description
1.	How to Avoid the Hazard
2.	Source of Hazard and Severity
3.	General Alert Icon

Number	Description
4.	Signal Word
5.	Type of Hazard
6.	Hazard Symbol(s)

General Safety Considerations

⚠ WARNING	
Software	
Software is not safety rated. Unplanned motion can occur as long as power is supplied to the motors. Maximum torque could be momentarily applied that may cause equipment damage or personal injury. • Only operate the robot with its covers installed. • Guarantee that safety controller features are in place (for example, an emergency stop button and protective stop). • Regularly test safety components to prove that they function correctly.	

⚠ WARNING	
Robot Mounting	
Before applying power, the robot must be mounted on a rigid test stand, secure surface, or system application. Improperly mounted robots can cause excessive vibration and uncontrolled movement that may cause equipment damage or personal injury. • Always mount the robot on a secure test stand, surface, or system before applying power.	

⚠ WARNING	
Do Not Use Unauthorized Parts	
Using parts with different inertial properties with the same robot application can cause the robot's performance to decrease and potentially cause unplanned robot motion that could result in serious personal injury. • Do not use unauthorized parts. • Confirm that the correct robot application is being used.	

⚠ WARNING	
Magnetic Field Hazard	
This product contains magnetic motors that can be hazardous to implanted medical devices, such as pacemakers, and cause personal harm, severe injury, or death. • Maintain a safe working distance of 30 cm from the motor when with an energized robot if you use a cardiac rhythm management device.	

⚠ CAUTION	
Unauthorized Service	
Personal injury or damage to equipment may result if this product is operated or serviced by untrained or unauthorized personnel. • Only qualified personnel who have received certified training and have the proper job qualifications are allowed to transport, assemble, operate, or maintain the product.	
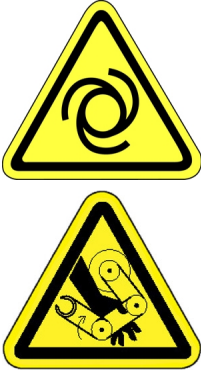
⚠ **CAUTION**

Damaged Components

| The use of this product when components or cables appear to be damaged may cause equipment malfunction or personal injury.

• Do not use this product if components or cables appear to be damaged.

• Place the product in a location where it will not get damaged.

• Route cables and tubing so that they do not become damaged and do not present a personal safety hazard. | ⚠ |

⚠ **CAUTION**

Inappropriate Use

| Use of this product in a manner or for purposes other than for what it is intended may cause equipment damage or personal injury.

• Only use the product for its intended application.

• Do not modify this product beyond its original design.

• Always operate this product with the covers in place. | ⚠ |

⚠ **CAUTION**

Seismic Restraint

| The use of this product in an earthquake-prone environment may cause equipment damage or personal injury.

• The user is responsible for determining whether the product is used in an earthquake prone environment and installing the appropriate seismic restraints in accordance with local regulations. | ⚠ |

Mechanical Hazards

⚠ CAUTION	
Pinch Point	
Moving parts of the product may cause squeezing or compression of fingers or hands resulting in personal injury. • Do not operate the product without the protective covers in place.	

⚠ WARNING	
Automatic Movement	
Whenever power is applied to the product, there is the potential for automatic or unplanned movement of the product or its components, which could result in personal injury. • Follow safe practices for working with energized products per the facility requirements. • Do not rely on the system software or process technology to prevent unexpected product motion. • Do not operate the product without its protective covers in place. • While the collaborative robotics system is designed to be safe around personnel, gravity and other factors may present hazards and should be considered.	

⚠ CAUTION	
Vibration Hazard	
As with any servo-based device, the robot can enter a vibratory state resulting in mechanical and audible hazards. Vibration indicates a serious problem. Immediately remove power. • Before energizing, ensure the robot is bolted to a rigid metal chamber or stand.	

Electrical Hazards

Refer to the specifications of the *Guidance Controller Quick Start Guide* for the electrical power.

⚠️ **DANGER**	
Electrical Shock Hazard	
Contact with electrical power can cause personal harm and serious injury. • To avoid electrical shock, disconnect the power before troubleshooting the electrical components. • Check the unit's specifications for the actual system power requirements and use appropriate precautions. • Never operate this product without its protection covers on.	⚡

⚠️ **WARNING**	
Electrical Burn	
Improper electrical connection or connection to an improper electrical supply can result in electrical burns resulting in equipment damage, serious injury, or death. • Always provide the robot with the proper power supply connectors and ground that are compliant with appropriate electrical codes.	⚡

⚠️ **WARNING**	
Electrical Fire Hazard	
All energized electrical equipment poses the risk of fire, which may result in severe injury or death. Fires in wiring, fuse boxes, energized electrical equipment, computers, and other electrical sources require a Class C extinguisher. • Use a fire extinguisher designed for electrical fires (Class C in the US and Class E in Asia). • It is the facility's responsibility to determine if any other fire extinguishers are needed for the system that the robot is in.	⚡

NOTICE

Improper handling of the power source or connecting devices may cause component damage or equipment fire.

- Connect the system to an appropriate electrical supply.
- Turn off the power before servicing the unit.
- Turn off the power before disconnecting the cables.

Ergonomic Hazards

⚠ **CAUTION**

Heavy Lift Hazard

Failure to take the proper precautions before moving the robot could result in back injury and muscle strain.

- Use a lifting device and cart rated for the weight of the drive or arm.
- Only persons certified in operating the lifting device should be moving the product.

⚠ **CAUTION**

Tipover Hazard

This product has a high center of gravity which may cause the product to tip over and cause serious injury.

- Always properly restrain the product when moving it.
- Never operate the robot unless it is rigidly mounted.

⚠ CAUTION	
Trip Hazard	
Cables for power and communication and facilities create trip hazards which may cause serious injury. • Always route the cables where they are not in the way of traffic.	

Emergency Stop Circuit (E-Stop)

The integrator of the robot must provide an external emergency stop switch.

⚠ WARNING	
Emergency Stop Circuit	
Using this product without an emergency stop circuit may cause personal injury. • Customer is responsible for integrating an emergency stop circuit into their system. • Do not override or bypass the emergency stop circuit.	

Recycling and Hazardous Materials

Brooks Automation complies with the EU Directive 2002/96/EU Waste Electrical and Electronic Equipment (WEEE).

The end user must responsibly dispose of the product and its components when disposal is required. The initial cost of the equipment does not include cost for disposal. For further information and assistance in disposal, email Brooks Automation Technical Support at support preciseflex@brooksautomation.com.

2. Introduction to the Hardware

Explanation of the Product Label

The Product Label is on the robot interface panel at the base of the robot. Use the following sections to decode the Part Number and Serial Numbers .
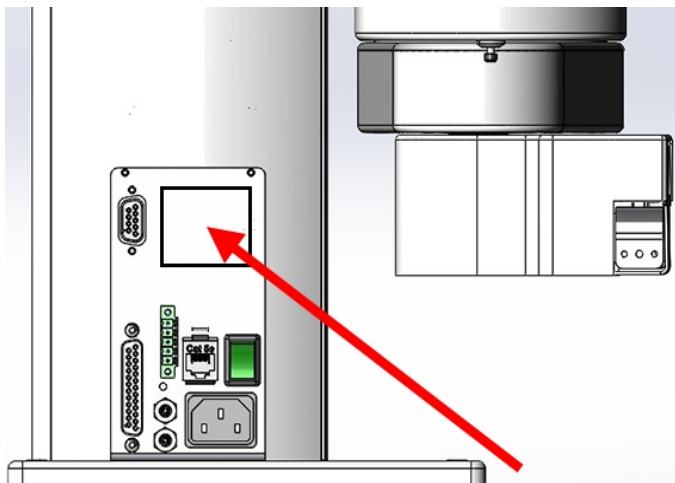
Product Label at the Base of the Robot

P/N:PF0S – MA – 0040X – 7

S/N:FOC – 2312 – 9L – 04318

C CSA® US

Contract #: 263533

100 – 240 VAC +/ – 10 %

50/60 Hz

400 W MAX

CE
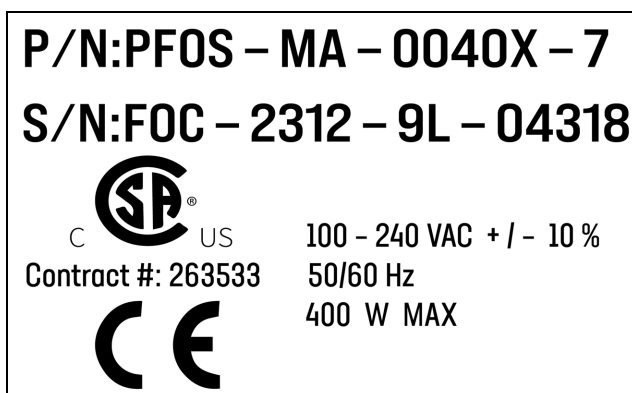
Sample Robot Product Label

Example Sections from the Product Label

$$\boxed{\text{P/N:PF0O} - \text{MA} - \text{00030} - \text{07}}$$

In the example above, the first line of the label -- Product Number (P/N) -- describes these properties of its product.

- PF0S = PreciseFlex F400 (with Servo Gripper)
- MA = Machine Assembly
- 0040 = PreciseFlex 400
- X = Extended reach
- 7 = 750 mm Z Stroke
- <None> = Not Low Voltage

Refer to the P/N - Part Number table for detailed information about the Product Number naming scheme.

$$\boxed{\text{S/N:P0O} - \text{2312} - \text{9L} - \text{04318}}$$

In the example above, the second line of the label -- Serial Number (S/N) -- describes these properties of its product:

- F0C = PreciseFlex 400
- 23 = Two-Digit Year Code
- 12 = Two-Digit Month Code
- 9L = Revision
- 04318 = Robot Unit Build Number

Refer to the Explanation of the Product Label table for detailed information about the Serial Number naming scheme.

$$\boxed{\text{Contract \#: 263533}}$$

Brooks Automation's Contract ID within the CSA Group
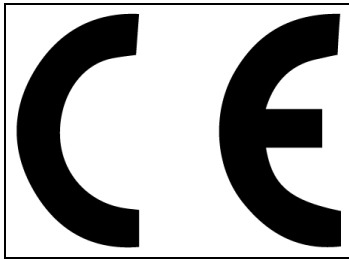
The CE Marking affirms compliance with relevant EU legislation. See Standards Compliance and Agency Certifications for more information.

Robot Power Requirements

Letter	Description
A	Robot power voltage requirements.
B	Robot power frequency requirements
C	Robot power maximum draw

P/N - Part Number

The robot part number follows the scheme: AAAA-BB-CCCCD-EFF. Refer to the table below to decode this scheme.

AAAA	
CODE	**PRODUCT**
PP00	PrecisePlace 100

PP0S	PrecisePlace 100 (w/ Servo Gripper)
PF0S	PreciseFlex 400
PF30	PreciseFlex 3400
PFD0	Direct Drive Robot
PFC0	C-Series
PF0X	Linear Rail
BB	

CODE	TYPE
MA	Machine Assembly
CCCC	

CODE	TYPE
PF0S	0040 = PreciseFlex 400
PF30	0040 = PreciseFlex 3400
PFD0	0040 = Direct Drive 4 0060 = Direct Drive 6
D	

CODE	ARM LENGTH
0 / S	Standard
X / L	Extended / Long
E	

NUMBER	AXIS SIZE
4	400 mm Z Stroke
7	750 mm Z Stroke
12	1160 mm Z Stroke
10	1.0 m rail
15	1.5 m rail
20	2.0 m rail
FF (Optional)	

CODE	Description
LV	Low Voltage

Serial Number (SN)

The robot serial number follows the scheme: AAA - BBCC - EF-GGGG. Refer to the table below to decode this scheme.

AAA	
CODE	**MODEL**
P00	PrecisePlace 100
P0S	PrecisePlace 100 (w/ Servo Gripper)
F0C/F0X	PreciseFlex 400
F3C	PreciseFlex 3400
FC0	C-Series
FXB	Linear Rail
BBCC	
CODE	**MFG DATE CODE (START DATE)**
BB	Two-Digit Year Code
CC	Two-Digit Month Code
EF	
Code	**Rev Code**
E	Major Rev Code
F	Minor Rev Code Valid for Rev Code 9J and up
GGGGG	
G	Sequential Production Number

Facilities Panel

The Facilities Panel (Figure 2-1 and Table 2-1) is located at the base of the robot.
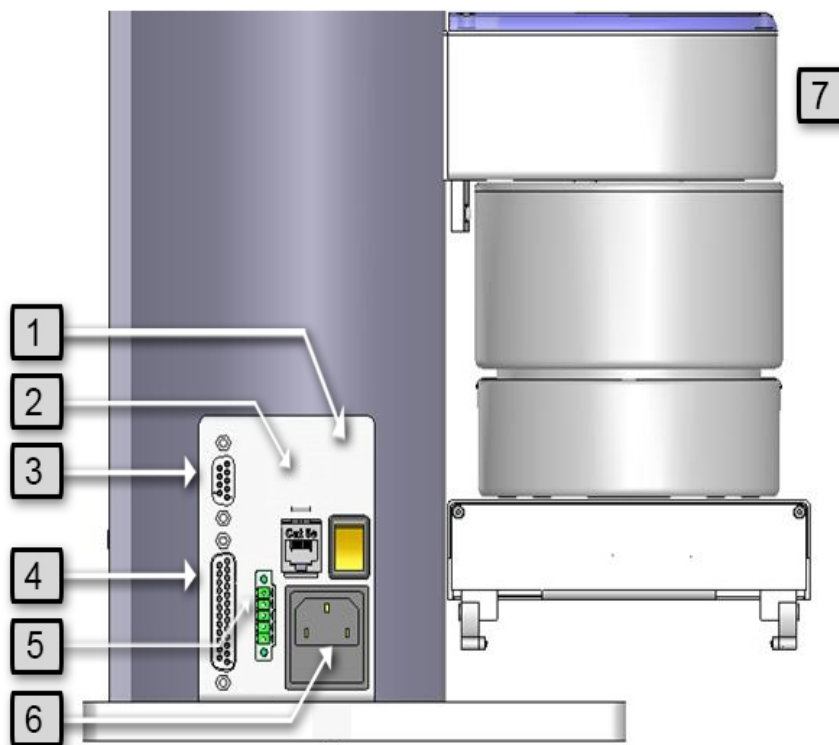
Figure 2-1: Facilities Panel

Table 2-1: Facilities Panel key

Annotation	Name	Description
1	Power Switch	Lighted power switch
2	Ethernet Connector	For Ethernet to computer cable
3	9 Pin2D Sub Connector	Contains RS-232 Serial Port, 24 VDC, Ground can be used for optional teach pendant
4	25 Pin D Sub Connector	For optional DIO module, 12 inputs, 8 outputs
5	E-Stop Connector	E-Stop and Cell Interlock Signals
6	Power Entry Module	For IEC plug. Contains dual fuse drawer.
7	Power Status Light	Blinks to indicate the power status.

To simplify interfacing, most of the electrical interfaces provided by the robot's embedded Guidance Controller are available on the Facilities Panel. These include:

- Digital input signals
- Digital output signals
- Ethernet port
- Remote Front Panel / MCP / E-Stop
- RS-232 serial interface

Each of these interfaces is described in detail in the following sections. In addition, the robot's controller, which is mounted in the inner link of the robot, may contain additional interfaces (e.g. inputs or outputs). Refer to the *Guidance 1000A/B Controllers, Hardware Introduction and Reference Manual* for additional information.

⚠ **DANGER**

High Voltage

| The Guidance 1400B controller, and the 24 VDC and 48 VDC power supplies are all open frame electrical devices that contain unshielded high voltage pins, components and surfaces. The main AC power should always be disconnected before the Facilities Panel is removed. | ⚠ |

If the pneumatic gripper option is ordered, one air line is routed through the interior of the robot. At the Facilities Panel, this air line is presented in a fitting on a sub plate mounted to the facilities panel. The other end of this line exits at the Outer Link. When using this line, clean, dry external air should be provided.

⚠ **CAUTION**

High Pressure Air

| The maximum air pressure that can be conveyed by the air lines through the robot is 75 PSI. Applying a pressure exceeding this level may disconnect interior connections or damage fittings or hoses. If a higher pressure is required, an external air line should be utilized. | ⚠ |

System Description and Overview

NOTE: See [Robot Anatomy](#) for detailed illustrations.

The PreciseFlex 400 Robot is a 4-axis robot that includes an embedded Guidance 1400B 4-axis motion controller, a 48 VDC motor power supply, and a 24 VDC logic power supply located inside the base of the robot. In addition, it may optionally include an electric gripper and electric gripper controller.

The Z-axis of this robot is available with a standard travel of 400 mm and an optional travel of 750 mm. The robot is designed as tabletop unit and can carry a payload of up to 500 grams in the standard version with a servo gripper and 1.2 kg in the standard version without a gripper. These robots are low cost, extremely quiet and smooth, very reliable, and have excellent positioning repeatability. To achieve these results, the axes are powered by brushless DC motors with absolute encoders. With these characteristics, these robots are ideal for automating applications in the Life Sciences, Medical Products, Semiconductor, and Electronics industries.

A number of communications and hardware interfaces are provided with the basic robot. These include an RS-232 serial interface, an RS-485 serial interface, an Ethernet interface, and a number of digital input and output lines. In addition, the robot can be purchased with several types of optional PreciseFlex peripherals. These include digital cameras, remote I/O, and a hardware manual control pendant.

The controller is programmed by means of a PC connected through Ethernet. There are three programming modes: a Digital IO (PLC) mode, an Embedded Language mode, and a PC Control mode. When programmed in the PLC or Embedded Language mode, the PC can be removed after programming is completed and the controller will operate standalone. The PC is required for operation in the PC Control mode.

In all modes of operation, the controller includes a web based operator interface. This interface is used for configuring the system, starting and stopping execution, and monitoring its operation. The web interface can be accessed locally using a browser or remotely via the Internet. This remote interface is of great benefit in system maintenance and debugging.

The optional machine vision system, PreciseVision, can execute in a PC connected through Ethernet. PreciseVision requires cameras connected via Ethernet or USB, allowing any processor on the network to obtain and process information from any camera on the network, and provide the results to any networked motion controller.

Release History

The PF400 was released in 2011. Since the initial release, designated by SN F0X-wwww-xy-zzzzz, two significant upgrades have been released.

Revision B, designated by Serial Numbers F0B-wwww-xy-zzzzz, was released in 2014, and improved the high-speed, continuous duty performance of the robot. The main changes in this revision were a wider timing belt in J2 (12mm replaced 9mm), changing to all steel drive pulleys from aluminum to improve the bond strength of the drive pulleys to the motor shaft, and changing the slip ring in the wrist for improved reliability.

Revision C, designated by Serial Numbers F0C-wwww-xy-zzzzz, was released in the fall of 2016, and improved the resistance of the robot to high-speed crashes by adding clamp rings and beveled retaining rings to the J2, J3, and J4 bearings, so that these bearings cannot come loose in a high-speed crash. In addition, improved support for pneumatic grippers and control of solenoid valves in the outer link is provided, and some longer life cam followers for the J2 timing belt are installed. In January 2017, a longer life Ethernet cable is expected to be released which should last for the life of the robot running continuous duty for at least 3 years.

System Diagram and Coordinate System

The robot has two important coordinate systems, World and Tool.

The World system is the base coordinate system that everything else is based off of and the tool coordinate system is a transform from the World coordinate system to the robots tool center point. See the graphics below.

World Coordinate System

The center of the World coordinate system is call the World Origin. It is commonly referred to as World (0,0,0,0,0,0) location. The location can be found where the centerline of the robots first rotary joint, intersects the plane of the robots tool flange when the Z carriage is at it's lowest point against the hard stop. This location is different for each and every robot model.
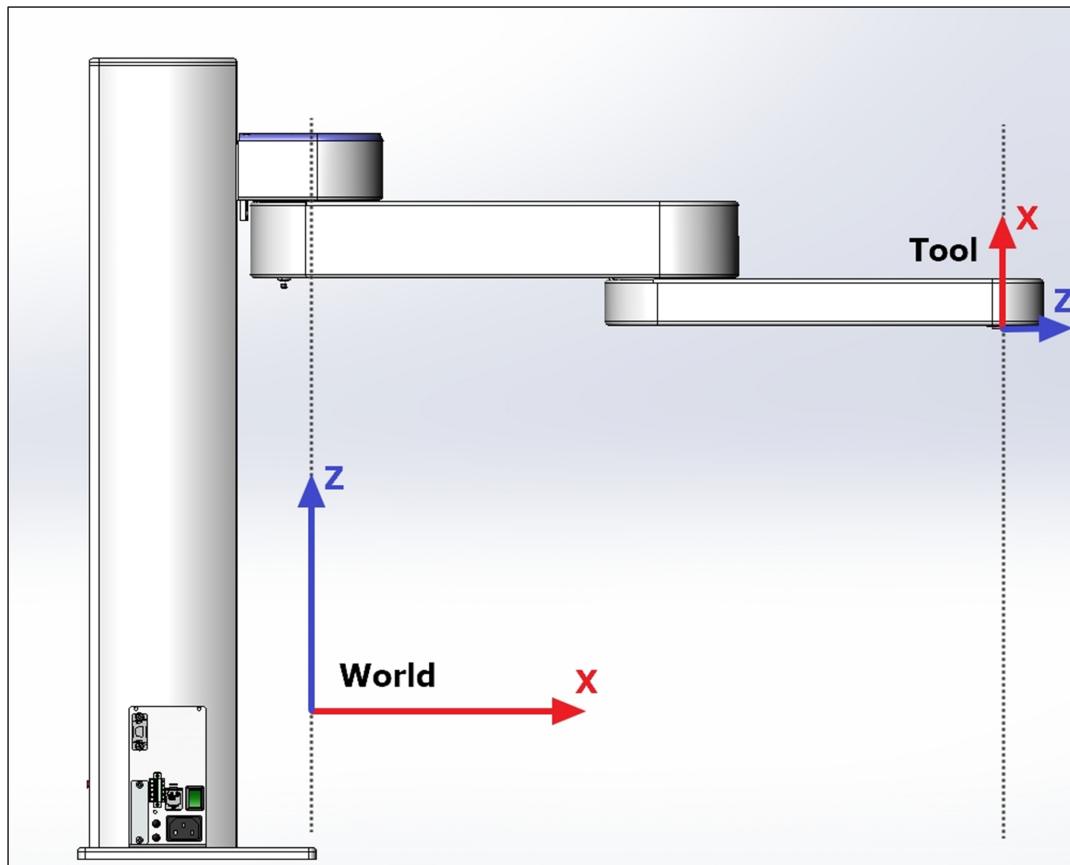
Robot Coordinate Systems - World
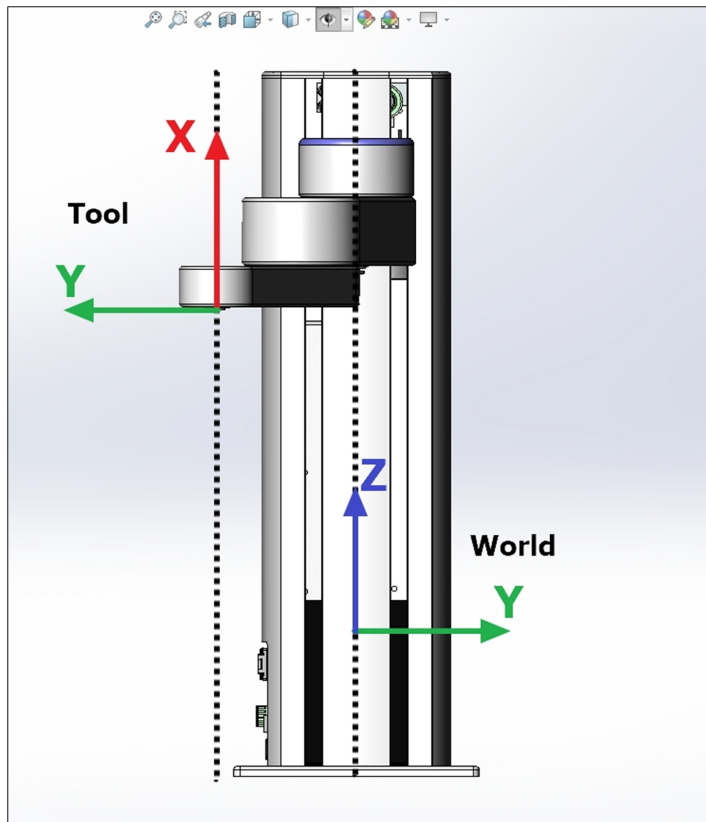
Robot Coordinate Systems - World

Tool Coordinate System

The center of the Tool coordinate system is call the Tool Origin. The tool origin, commonly referred to as Tool (0, 0, 0, 0, 0, 0) location, can be found where the center of the wrist rotary axis, intersects the robot tool flange, and moves with robot. The Z axis points towards the alignment dowel pin, while the X axis Point up the rotary axis.
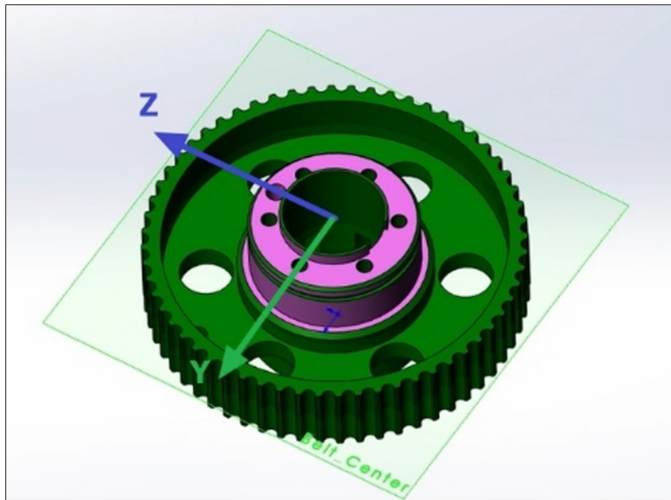
The Tool Origin with Respect to the Final Drive Pully

Robot Joint Motion
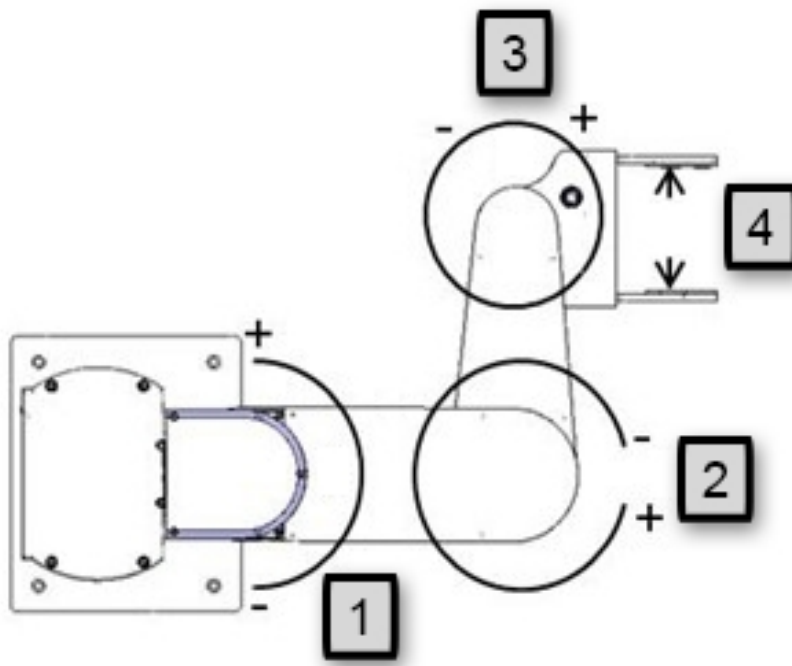
Number	Axis	Description of Motion
J1	Shoulder	Rotates 180°
J2	Elbow	Rotates 334°

Number	Axis	Description of Motion
J3	Wrist	Rotates +/- 970°
J4	Gripper	Positive (+) opens, and negative (-) closes.

J1 and the Z-Axis Column

The first axis of the robot, J1, moves the robot arm up along the Z-axis column. When inner link is closest to the bottom, the Z axis is at its 0 position in the *Joint Coordinate* system and Z=30 mm in the *World Coordinate* system. As the robot arm moves upwards, both its joint position and the World Z Coordinate increase in value.

The Z column also contains the 24 VDC and 48 VDC power supplies and the connector panel. The Guidance controller is located inside the inner link of the robot, and the gripper controller is located inside the outer link.

J2

When the Inner Link is centered on its range of motion, the J2 axis is at its 0 joint angle. A positive change in the axis angle results in a positive rotation about the World Z-axis.

J3

The J3 rotary axis (elbow) rotates the outer link about the world Z-axis. A positive change in the axis angle results in a positive rotation about the World Z-axis. When the link is centered, it is at its 0 joint angle, however there is a hard stop at 10 degrees, so the link cannot reach the center position. The outer link can rotate underneath the inner link, allowing the robot to change configuration from a "left hand" robot to a "right hand" robot without swinging the J3 axis (elbow) through the zero position. This allows the robot to work in very compact workcells.

J4

The J4 rotary axis (wrist) rotates the gripper about the World Z-axis. A positive change in the axis angle results in a positive rotation about the World Z-axis.

The outer link may include a gripper controller that provides control of the optional electric gripper. It is also possible to order the robot with a pneumatic gripper, in which case the outer link will house a solenoid to control air to the pneumatic gripper. A light bar is mounted at the top of the shoulder cover (or column for some robots) and blinks at a rate of once per second to indicate that the controller is operational and at a rate of 4 times per second when power is being supplied to the motors.

The Z-axis includes a fail-safe brake. This brake must be released to move the Z-axis up and down manually. There is a manual brake release button on the bottom of the inner link near the Z-axis. Depressing this button when 24 VDC power is on will release the Z-axis brake while the button is depressed. It is not necessary for the control system to be operating for the brake release to function; the only requirement is providing 24 VDC to the controller. Care should be taken to support the Z-axis when the brake release button is pushed, as the axis will fall due to gravity.

System Components

PreciseFlex 400 Robot

NOTE: See Robot Anatomy for detailed illustrations.

The PreciseFlex 400 Robot (pictured in Figure 2-2 and defined in Table 2-2) is a 4-axis robot that may optionally include an electric or pneumatic gripper.
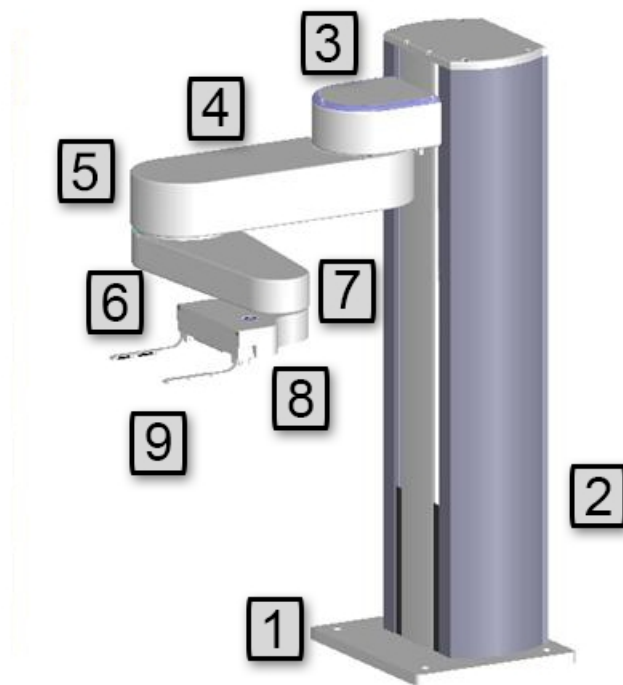
Figure 2-2: PreciseFlex 400 Robot

Table 2-2: PreciseFlex 400 Robot Details

Annotation	Name	Description
1	Base Plate	Plate to attach robot to table
2	Z Column	Vertical column
3	Shoulder	Moves up and down column, rotates Inner Link

Annotation	Name	Description
4	Inner Link	Inner Link
5	Elbow	Joint between Inner and Outer Links
6	Outer Link	Outer Link
7	Wrist	Joint between Outer Link and Gripper
8	Gripper	Gripper mechanism
9	Fingers	Fingers for grasping Titer Plates

Optional Linear Axis Module

The PreciseFlex 400 may be attached to an optional Linear Axis Module. The Linear Axis Module may be ordered in 1000 mm, 1500 mm and 2000 mm travel distances. The module length is about 380 mm longer than the travel distance. All cables and controls are contained inside the Linear Axis Module, which is equipped with drip proof covers and tape seals. Power entry, a power switch, Pendant, and I/O connectors are extended from the base of the robot to the end cap of the Linear Axis Module. The Linear Axis Module is driven by a servo amplifier located in the carriage. This servo amp gets both power and commands from the controls in the robot, so the Linear Axis Module must be slaved to a robot in order to work, and cannot be purchased as a standalone module at this time.

The image below shows a 750 mm vertical travel PreciseFlex 400 on a 1000 mm Linear Axis Module. The robot is positioned in the middle of travel, which is defined as the zero position in the linear axis. The robot may be mounted in this orientation, in which case the linear axis moves along the Y-axis in the robot's coordinate system with the linear axis extending the robot's Y-axis by plus or minus 500 mm. The robot may also be rotated 90 degrees so that it faces the connector end cap of the Linear Axis. In this case the Linear Axis extends the robot's X-axis travel, if the appropriate SW parameter is changed. See Software Reference for more information.

Mounting of Robot and Linear Axis Module

The Robot Base Plate contains a mounting hole pattern for (4) M6 screws along with reference surfaces for locating the robot on a table or work cell surface. The Linear Axis Module contains mounting patterns for both M6 and ¼-20 screws. See Installation Information for details.

Guidance 1400B Controller

The Guidance 1400B Controller is a 4-axis general purpose motion controller that contains four motor drives and four encoder inputs. It must be attached to a heat sink. The heat sink is provided by the inner link housing. The controller includes local digital IO. It also supports RS-232 and RS-485 serial communication and an optional PreciseFlexRemote IO module. It contains two Ethernet ports. The controller and power supplies are shown in the system diagram in Figure 2-3.
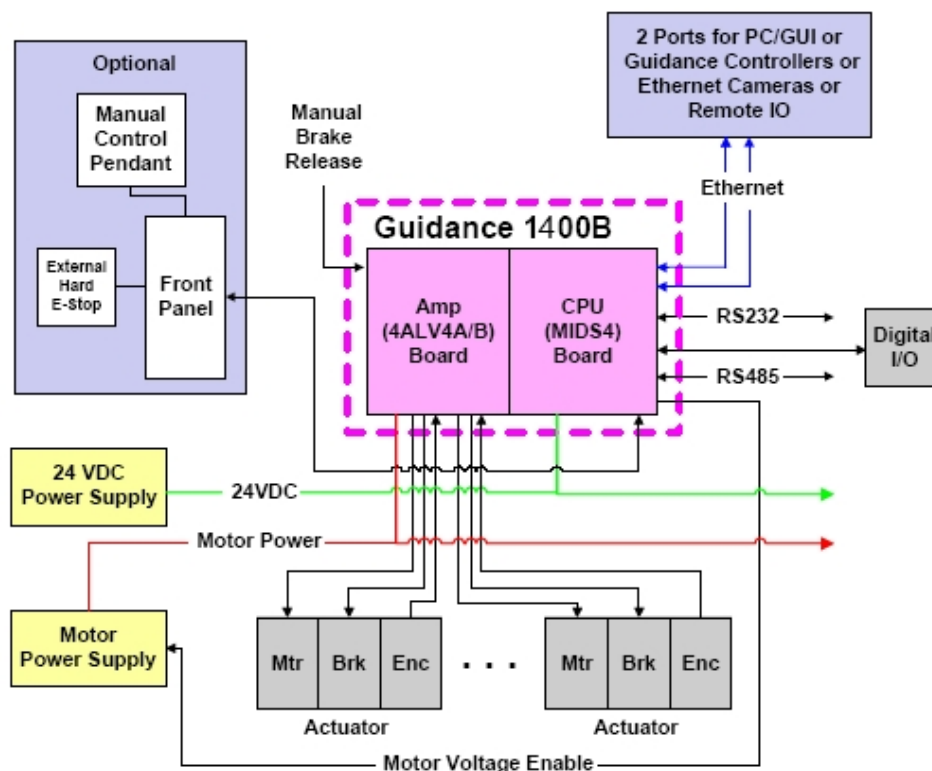
Figure 2-3: Guidance 1400B Controller System Diagram

For detailed information on the controller including interfacing information, see the *Guidance 1000A/B Controllers Manual* (G1X0-DI-A0010).

Low-Voltage Power Supplies

The PreciseFlex 400 Robot has an integrated 125-Watt, 24 VDC Power Supply that accepts a range of AC input from single-phase 90 V to 264 V and an integrated 400 W, 48 VDC Power Supply for the motors.

⚠️ **DANGER**	
High Voltage	
In addition to exposed high voltage pins and components, the heat sinks on the Power Supplies are not grounded and expose high voltage levels. AC power to the robot must be disconnected prior to accessing these units.	⚠️

Energy Dump Circuit

The 48 VDC supply has a regulated output and an overvoltage protection circuit that is triggered if the voltage reaches 60 Volts. Rapid deceleration of the robot motors can generate a Back EMF voltage that can pump up the motor voltage bus. In order to avoid bus pump up, an Energy Dump Circuit is connected to the 48 VDC bus. See Figure 2-4.
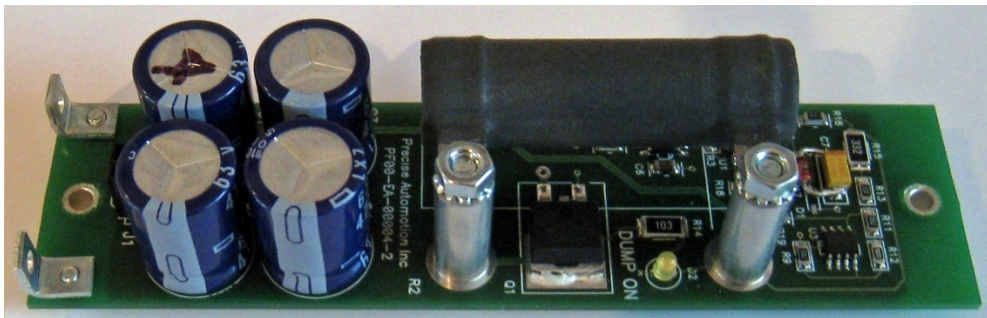
Figure 2-4: 48 VDC Supply

Remote Front Panel, E-Stop Box, and Manual Control Pendant

PreciseFlex offers an E-stop Box or a portable Hardware Manual Control Pendant that includes an E-stop button. The E-stop box can be plugged into the green Phoenix connector in the connector in the Facilities Panel at the base of the robot. The E-stop box completes a circuit from the top pin, Pin 1 (24 VDC) to Pin 2 (E-stop) in this connector. If this circuit is not completed it is not possible to enable motor power to the robot.

The Manual Control Pendants (product number PP10-EP-00013) can be plugged directly into the 9-pin Dsub connector mounted on the robot's Facilities Panel in the base of the robot. If no E-stop box or Manual Control Pendant is connected, a jumper must be connected between these two pins to enable robot motor power.

For those applications where an operator must be inside the working volume of the robot while teaching, a second teach pendant with a 3-position run hold switch is available. The E-stop connections are also present on the 9-pin Dsub connector and each of these units provides the hardware signals to permit power to be enabled and disabled.

E-Stop Box   **Manual Control Pendant**

Optional RS-485 IO Module (GIO)

For users who want to have IO available at the base of the robot, an optional IO module (Figure 2-5) may be added. This module provides 12 digital inputs and 8 digital outputs in a 25-pin Dsub connector at the robot connector panel and is connected via RS-485 to the robot controller.
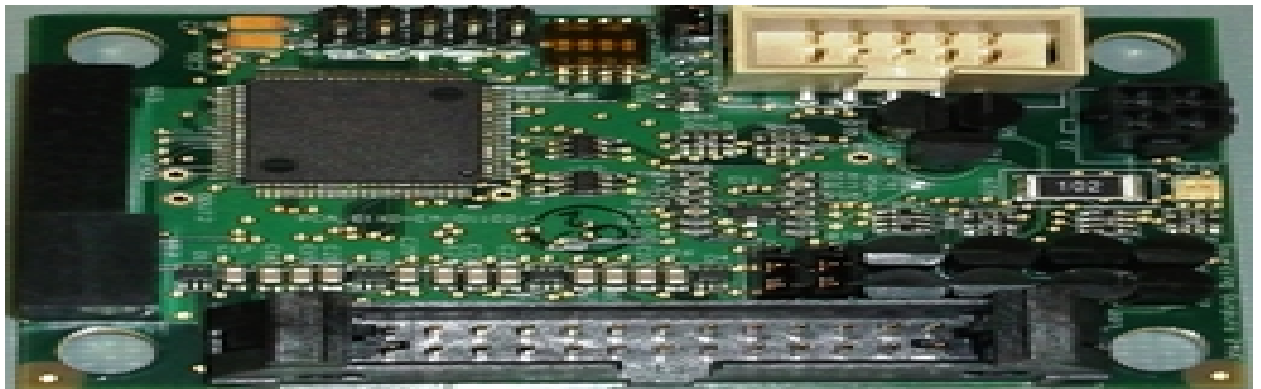
Figure 2-5: Optional Digital IO Module (GIO)

Remote IO Module (Ethernet Version)

For applications that require a large number of Inputs and Outputs, a PreciseFlex Remote IO (RIO) module (Figure 2-6) may be purchased. The RIO interfaces to any PreciseFlex robot and its

embedded Guidance Controller via 10/100 Mb Ethernet and requires 24 VDC power. Up to 4 RIOs can be connected to a controller.

The basic RIO includes: 32 isolated digital input signals, 32 isolated digital output signals and one RS-232 serial line. An enhanced version of the RIO adds 4 analog input signals, a second RS-232 port and one RS-422/485 serial port. The Enhanced RIO module is pictured in Figure 2-6.

⚠️ **WARNING**	
Electrical Shock	
The RIO contains unshielded 24 VDC signals and pins. This product is intended to be mounted in a cabinet or machine chassis that is not accessible when power is turned on.	⚠️

Figure 2-6: Enhanced RIO Module

Machine Vision Software and Cameras

The Guidance 1400 Series controllers support the PreciseVision machine vision system. This is a vision software package than can run on a user-provided PC.

Cameras must be connected via Ethernet or USB. Vendors as DALSA already offer a variety of Ethernet machine vision cameras. In addition, other vendors offer USB cameras that are supported in PreciseVision.

PreciseFlex offers an Arm-Mounted Camera Option for certain robots. Contact sales_ preciseflex@brooksautomation.com for details.

Machine Safety

Safety and Agency Certifications

PreciseFlex systems can include computer-controlled mechanisms that are capable of moving at high speeds and exerting considerable force. Like all robot and motion systems, and most industrial equipment, they must be treated with respect by the user and the operator.

This manual should be read by all personnel who operate or maintain PreciseFlex systems, or who work within or near the work cell.

Read ISO 10218-1:2011 and 10218-2:2011 *Robots for Industrial Environments, Safety Requirements*, ISO/TS 15066 *Robots and Robotic Devices – Collaborative Robots*, and ISO 13849-1:2006 *Safety of machinery — Safety-related parts of control systems*.

Standards Compliance and Agency Certifications

The PreciseFlex robots are intended for use with other equipment and are considered a subassembly rather than a complete piece of equipment on their own. They meet the requirements of these standards:

- EN ISO 10218-1-2011 Robots for Industrial Environments, Safety Requirements
- EN 60204-1 Safety of Machinery, Electrical Equipment of Machines
- EN 61000-6-2 EMC Directive (Immunity)
- EN 61000-6-4 EMC Directive (Emissions)
- EN 61326-1:2013
- CAN/CSA-C22.2 No. 61010-1-12 UPD1:2015, UPD2:2016, AMD1:2018
- CSA-C22.2 No. 61010-2-081:19
- UL 61010-1 (3rd Ed.), AMD1(2018)
- UL 61010-2-081 (3rd Ed.)

To maintain compliance with the above standards the controller must be installed and used in accordance with the regulations of the standards, and in accordance with the instructions in this user's guide.

In addition to the above standards, the PF400 robots have been designed to comply with the following agency certification requirements and carry the CE and CSA marks.

- CE
- CSA
- FCC Class A
  ANSI/RIA R15.06 Safety Standard

Moving Machine Safety

The PreciseFlex robots can operate in Manual Control Mode, in which an operator directly controls the motion of the robot, or Computer Control Mode in which the robot operation is automatic. Manual Control Mode is often used to teach locations in the robot workspace. The robot's speed is limited in Manual Control Mode to a maximum of 250 mm per second for safety. While the PreciseFlex 400 is a light-duty robot that can only apply approximately 20-60 Newtons of force, it is very important for operators to keep their hands, arms and especially their head out of the robot's operating volume. It is important that operators wear safety glasses when inside the robot's operating volume.

In Computer Mode, the robot can move quickly. The PF400 robots have been designed to be "hand-safe" even in computer mode, and in some cases a risk assessment of the application may indicate that it can be used without operator safety screens. However, safety glasses should be worn at all times when an operator is within the robots working volume. Refer to the EN ISO 10218-2-2011 *Robots for Industrial Environments, Safety Requirements* for information on recommended safe operating practices and enclosure design for robots of various sizes and payloads.

Voltage and Power Considerations

The Guidance 1400B controller requires two DC power supplies, a 24 VDC power supply for the processor and user IO and a separate 48 VDC motor power supply.

⚠️ **DANGER**	
Electrical Shock	
The Guidance 1400, the 48 VDC, and the 24 VDC power supplies are all open frame electrical devices that contain unshielded high voltage pins, components and surfaces. These products are intended to be mounted in a cabinet or machine chassis that is not accessible when AC line power is turned on.	⚠️

The PreciseFlex 400 power supplies have an input range of 100 to 240 VAC, +/- 10%, 50/60 Hz. Inrush current can be as high as 100 Amps at 240 VAC for short periods of time. The power supplies are protected against voltage surge to 2000 Volts. Transient over voltage (< 50 μs) may not exceed 2000 V phase to ground, as per EN61800-31996. Revisions A and B of the robot are protected against over current by two 4.0 Amp, 250 V slow blow fuses, for example Littlefuse 0215004.MXP.

The robot consumes less than 200 Watts during normal operation.

The PreciseFlex controller can monitor motor power through its datalogging function. Intermittent power dropouts can be detected by setting a trigger in the data logger which can record and time-stamp power fluctuations.

Mechanical and Software Limit Stops

The Z column, shoulder, and elbow have hard limit stops at the end of travel which are factory installed. The soft-limit stops must be set within the range of these hard stops. The wrist axis has a slip ring when the electric gripper is installed, allowing unlimited rotation. However, software stops limit rotation to plus or minus 970 degrees. Since the robot has absolute encoders with battery backup, even if the robot is turned off, the encoders keep track of joint position. If the wrist axis is rotated manually beyond the 970 degree software limit stops, it will be necessary to rotate it back to within the allowed software limits before the robot will run. The joint position can be viewed either on the optional Manual Control Pendant, or in the Virtual Manual Control Pendant in the Web Based Operator Interface. (See Guidance Controller Setup and Operation Quick Start Guide) For pneumatic configurations a sliding hard stop limits the wrist rotation to 540 degrees.

Stopping Time and Distance

The robot control system responds to two types of E-Stops.

Soft E-Stop

A "Soft E-Stop" initiates a rapid deceleration of all robots currently in motion and generates an error condition for all GPL programs that are attached to a robot. This property can be used to quickly halt all robot motions in a controlled fashion when an error is detected. A soft E-Stop is typically generated by an application program under conditions determined by the programmer.

This function is similar to a "Hard E-Stop" except that soft E-Stop leaves High Power enabled to the amplifiers and is therefore used for less severe error conditions. Leaving power enabled is beneficial in that it prevents the robot axes from sagging and does not require high power to be manually re-enabled before program execution and robot motions are resumed. This function is also similar to a Rapid Deceleration feature except that a Rapid Deceleration only affects a single robot and no program error is generated.

If set, the **SoftE-Stop** property is automatically cleared by the system if High Power is disabled and re-enabled.

Hard E-Stop

A Hard E-Stop is generated by one of several hardware E-Stop inputs and causes motor power to be disabled. However, there is a parameter that determines a delay between the time the hard E-Stop signal is asserted and the time the motor power supply relay is opened. This delay is nominally set at 0.5 seconds. It may be adjusted by an operator with administrator privileges. On the web based operator interface menu, go to Setup/Parameter Database/Controller/Operating Mode/ and set parameter 267 to the desired delay. If this delay is set to 0, the high-power relay will be disabled within 1ms.

For the PreciseFlex 400 robot, the shoulder, elbow, and wrist axes do not have mechanical brakes. Therefore, leaving the motor power enabled for 0.5 sec allows the servos to decelerate the robot.

The servos will typically decelerate the robot at 0.12G, or 1250 mm/sec^2. If the robot is moving at a speed of 500 mm/sec, the distance traveled will be 100 mm to reach a full stop, and the time will be 0.4 sec.

Safety Zones

Safety zones on PreciseFlex robots stop robot motion and disable motor power if the tool center point (TCP) enters or leaves a designated area. When triggered, these zones cause a sudden deceleration, which depends on the setting in "RapidDecel deceleration in %" (Parameter Database ID 2101) and the robot's speed.

Safety zones are not intended to stop the robot during normal operation conditions and will not control the robot's TCP speed.

For configuration details, search for "Safety Zones" in the Online Help section of the Brooks Automation website at https://www2.brooksautomation.com/.

Releasing a Trapped Operator: Brake Release Switch

Should a hard E-Stop be triggered, the Z brake will engage, and motor power will be disconnected from all motors. As the J2, J3, and J4 axes have no brakes, they may be freely pushed by the operator. To release the Z brake, the operator may press the brake release switch, under the inner link, as long as 24 VDC is present. It is not necessary for motor power to be on for the brake release to work.

Brake Release Switch

Appendix A: Installation Information

Setup and Operation

1. Unpack the PreciseFlex robot.
2. Mount the robot.
3. Add or remove a gripper (optional). See the *PreciseFlex Gripper* user manual.
4. Connect the power.
5. Connect the PreciseFlex robot o a PC or tablet, and open the interface.
6. Run the robot. See Accessing the Controller Interface.

Unpacking and Handling Instructions

PreciseFlex robots are shipped in wooden crates with international ratings and foam inserts to protect the robots. As the robots weigh 25 kg or more, two persons should move the robot to the installation location.

Mounting Instructions

PreciseFlex robots must be attached to a rigid surface that can withstand lateral forces of 200 Newtons without moving or vibrating. The robot base has an integrated bolting pattern to accommodate (4) M6 SHCS mounting screws.

Tool Mounting

PreciseFlex robots are typically supplied with an electric gripper. In some cases, a pneumatic gripper may be supplied by PreciseFlex or by the end user. However, the standard robot does not include pneumatic lines, so if pneumatic tooling is needed, the robot must be ordered with pneumatic lines installed. The outer link has a flange for users to attach grippers or tooling.

To facilitate electrical interfacing to user tooling, digital I/O signals are available in the outer link. For robots with an electric gripper, the electric gripper controller in the outer link has two extra inputs and two extra outputs available for users. However, it should be noted that all the wires in the 18 conductor slip ring are consumed by the electric gripper, so any additional IO wiring will have to be routed outside the robot wrist. For robots without the electric gripper, a ribbon cable from the controller is routed to the outer link. This ribbon cable provides four digital inputs and four digital outputs from the controller.

For robots where support for a pneumatic gripper or pneumatic tooling has been ordered, one or two 1/8 in OD air hoses are routed from the connector plate in the base through the robot and out to the outer link. These air hoses can be connected to one or two solenoids mounted in the outer link for tooling control.

ISO Flange for End-of-Arm Tooling

ISO-9409-1-31.5-4-M5
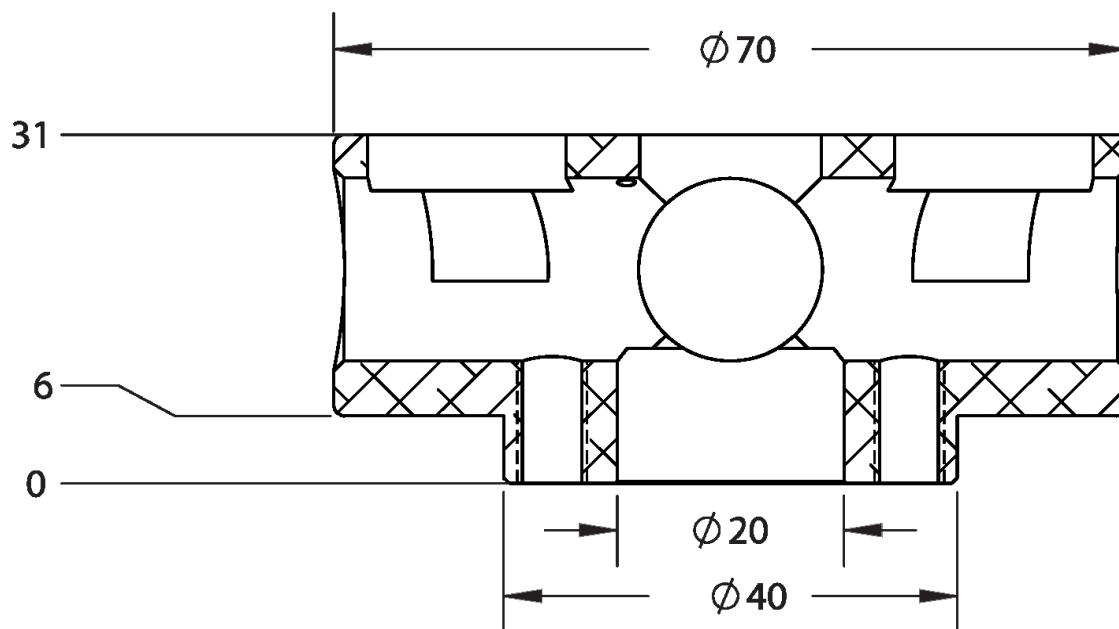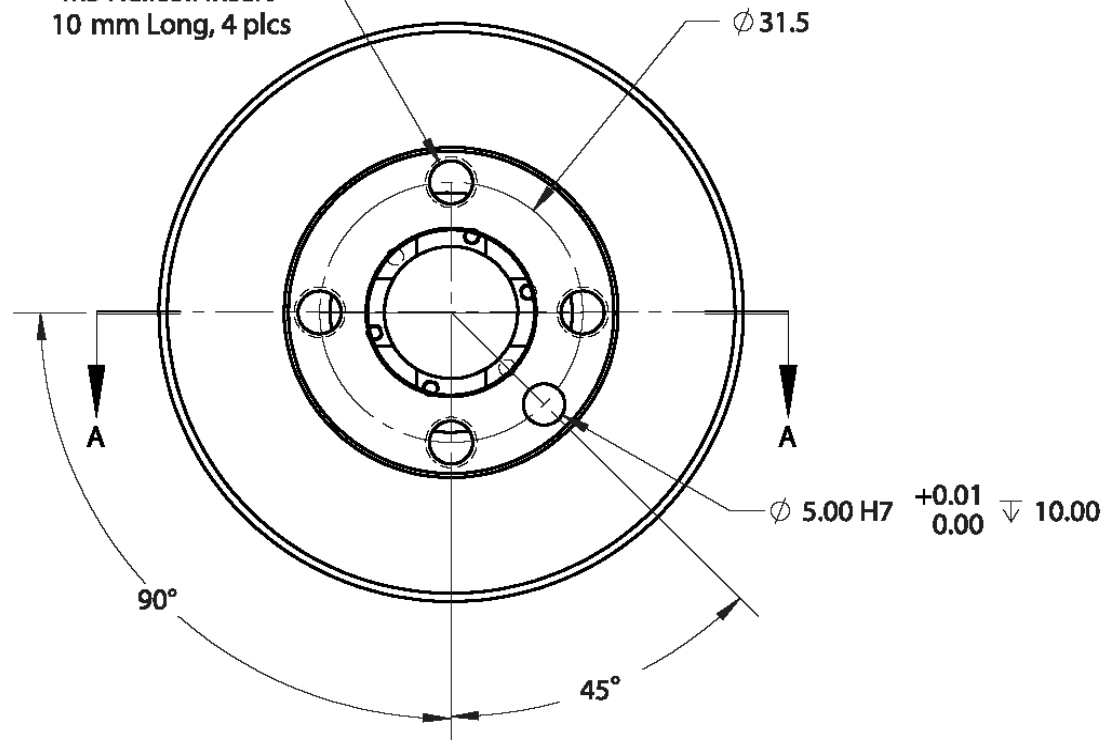
Work Envelope
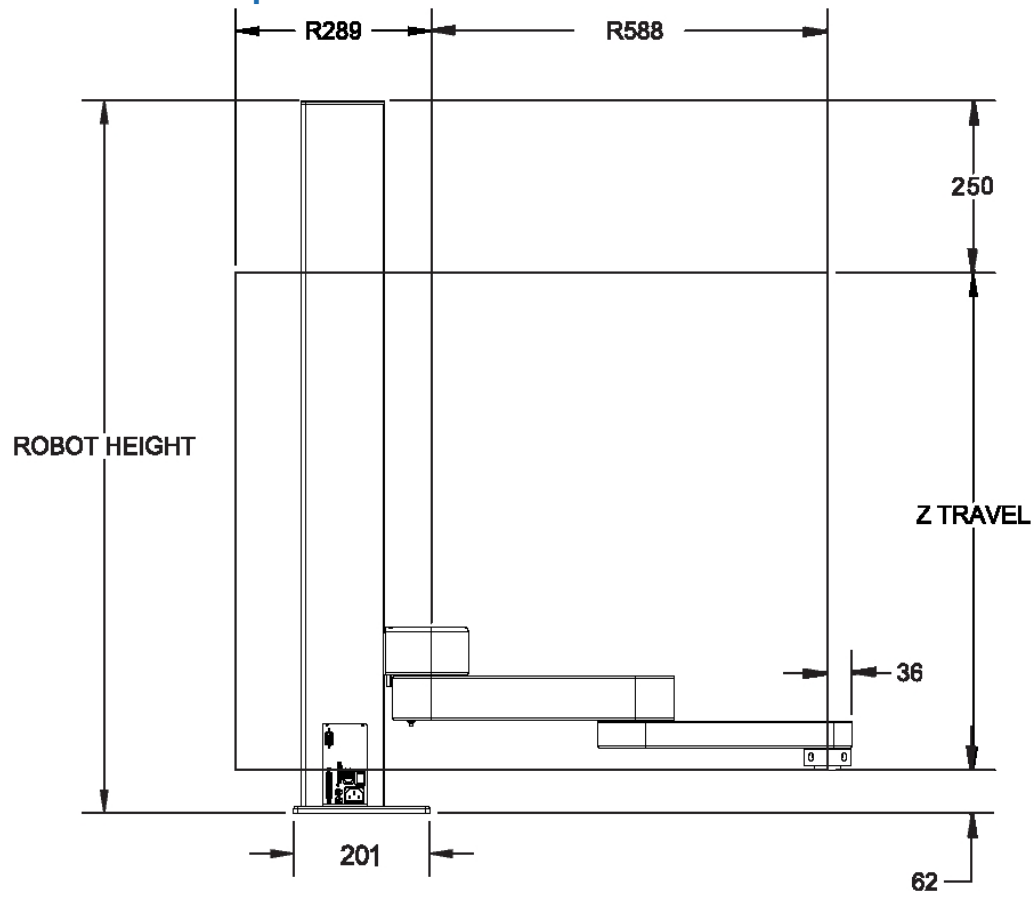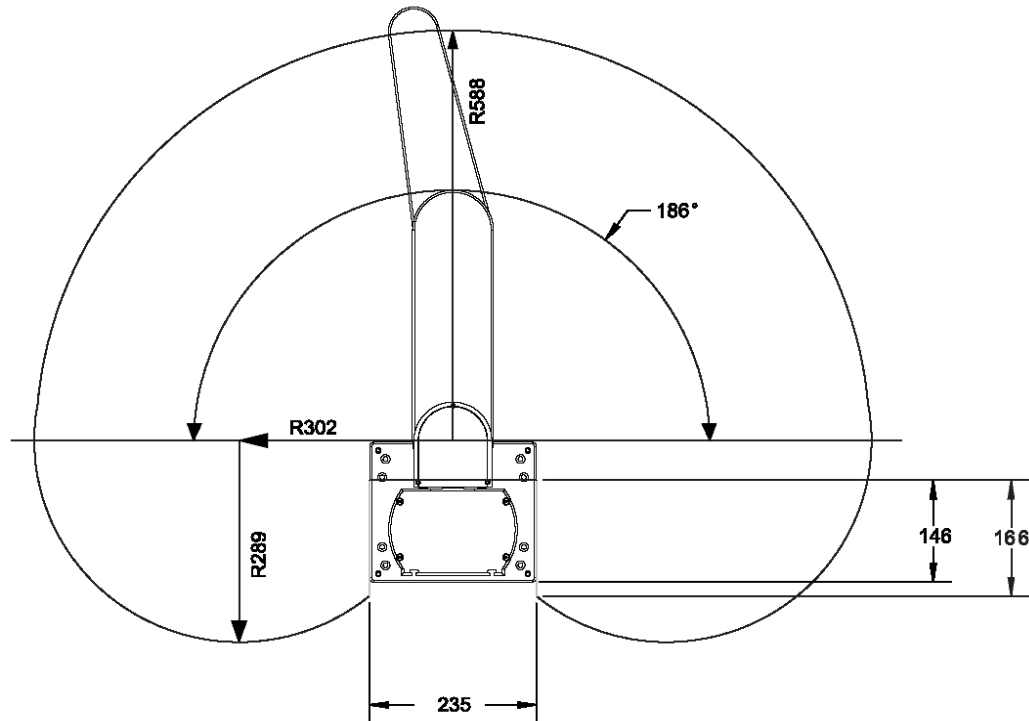
Robot Height	Z Travel
712 mm	400 mm
1062 mm	750 mm
1472 mm	1160 mm

Facilities Connections

The Facilities Panel at the base of the robot (and optional linear axis end cap) includes:

- System AC input power receptacle
- Lighted AC on/off power switch
- Connectors for controller input and output signals
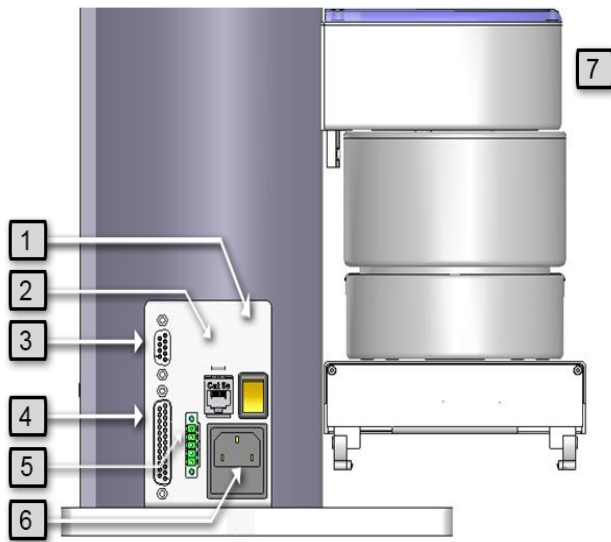
Facilities Panel, Key

Annotation	Name	Description
1	Power Switch	Lighted Power Switch
2	Ethernet Connector	For Ethernet to computer cable
3	9 Pin D Sub Connector	Contains RS-232 Serial Port, 24 VDC, Ground can be used for optional teach pendant.
4	25 Pin D Sub Connector	For optional DIO module, 12 inputs, 8 outputs
5	E-Stop Connector	E-Stop and Cell Interlock Signals
6	Power Entry Module	For IEC plug. Contains dual fuse drawer.
7	Power Status Light	Blinks to indicate power status

System Dimensions

The graphic below shows top and right views. All dimensions are in millimeters.

System Dimensions

Mounting dimensions for Standard Reach are shown below. Increase height by 22 mm for PF3400. For XR robot, R575 increases to R731, and inner link length increases from 225 to 302 mm.

Working Volume
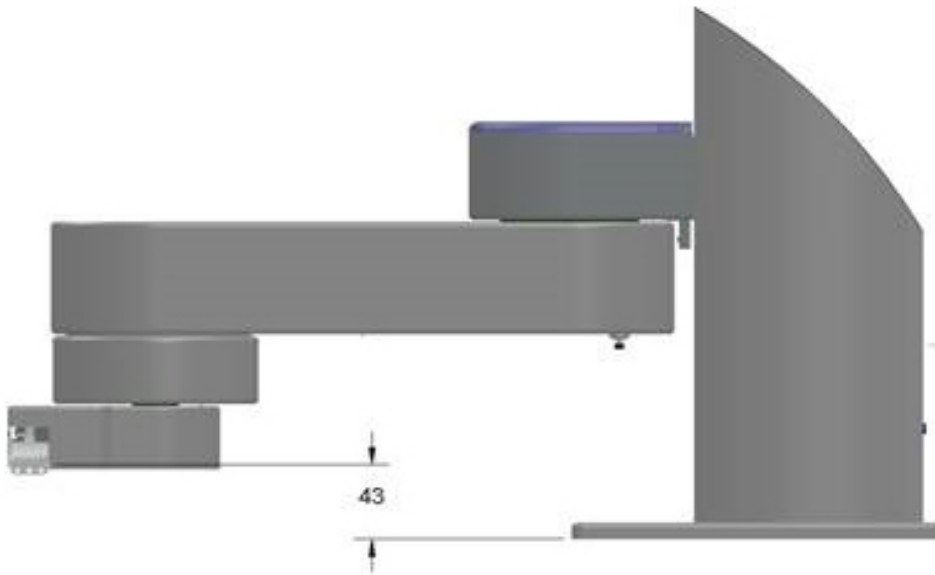
Finger Mount Height from Base PF400
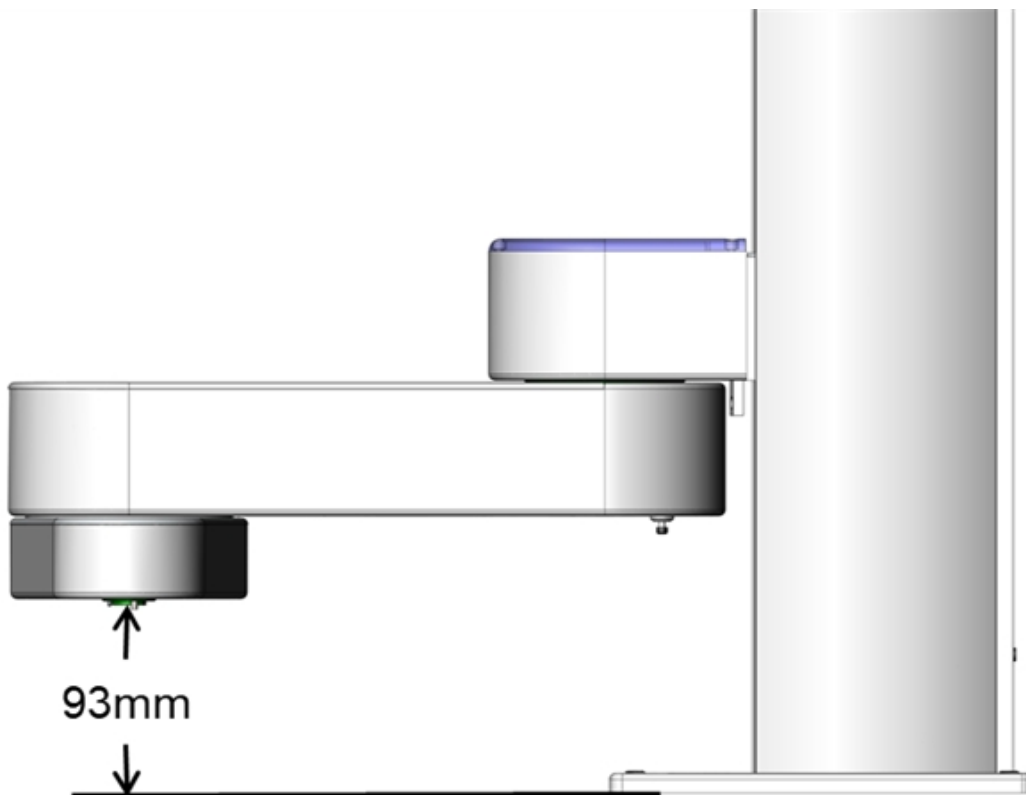
Gripper Flange Mount Height from PF3400
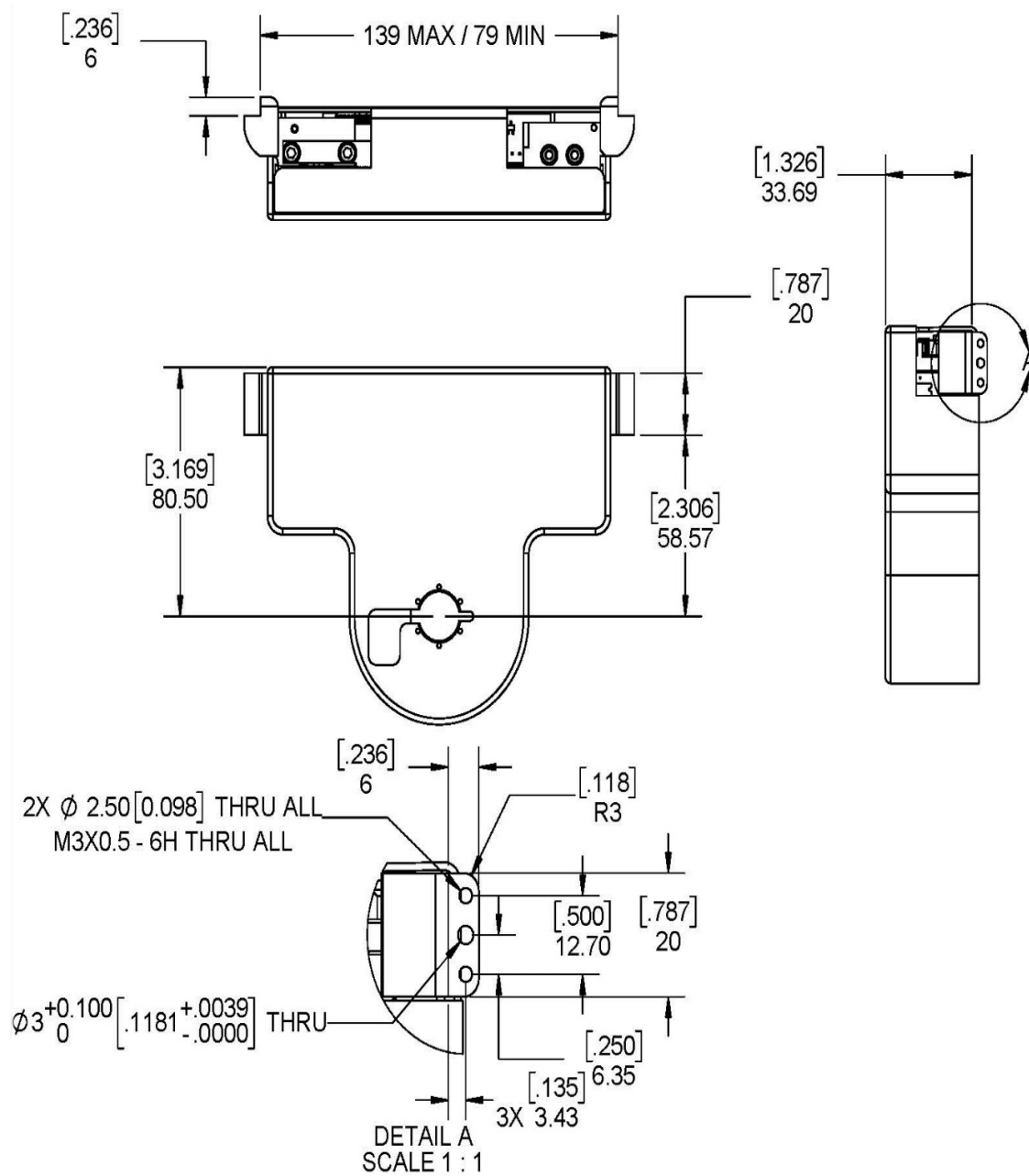
PreciseFlex E-Gripper, Interface Drawing PF400

⌀10.80mm 4Plcs
for wire exit

12.00mm

31.00mm

6.00mm

⌀20.00 H7 ⤵12.00

M5 12mm deep

⌀40.00mm

⌀ 5.00mm H7 $^{+0.01}_{0.00}$ ⤵ 10.00mm

⌀70.00mm

⌀31.50mm BC
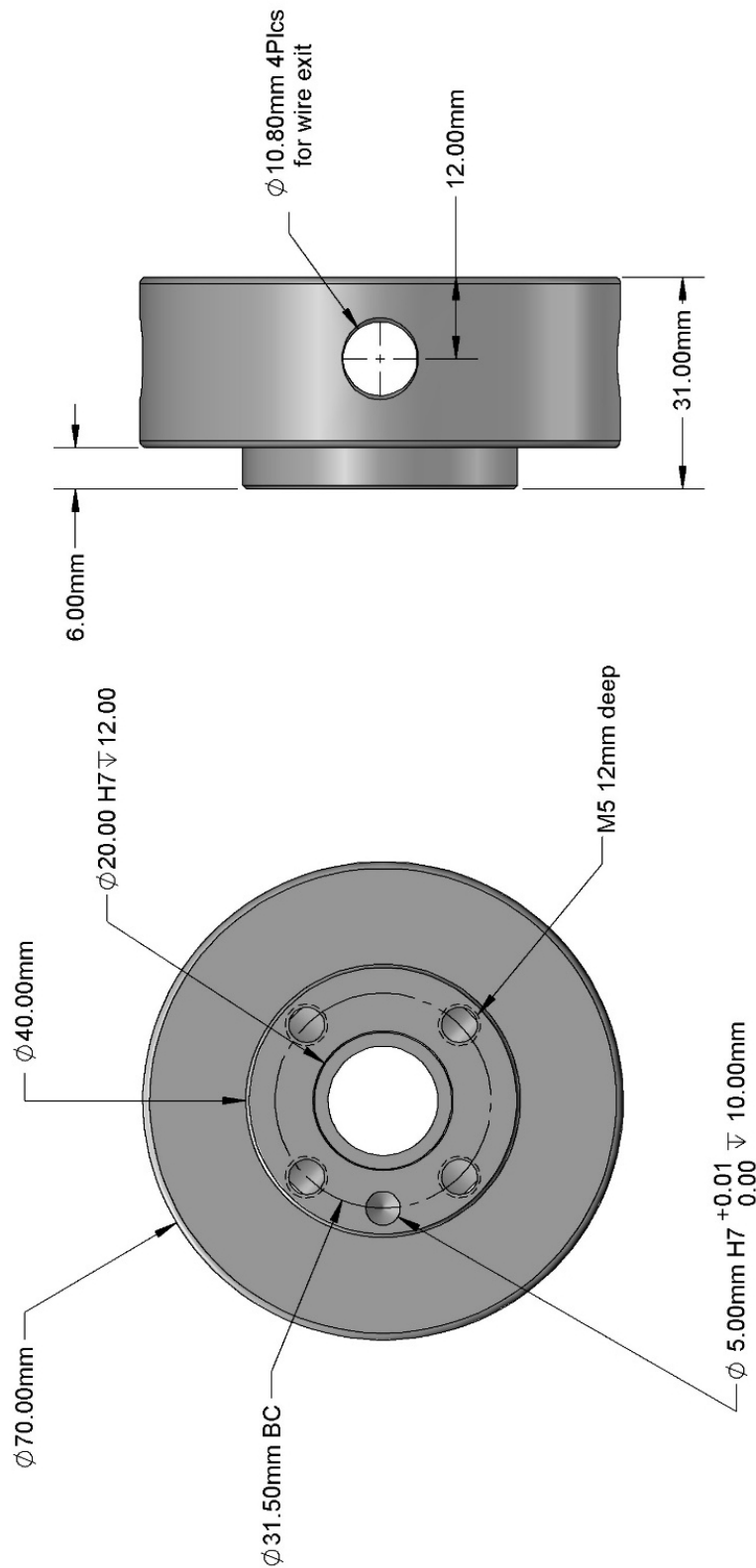
ISO Flange, Installation PF400

DETAIL A
SCALE 1 : 1.5

Opening: 134mm max (shown) to 74mm min

224mm
396mm
40.00mm
29mm
61mm

M3 Dowel
M3 SHCS
3.43mm
12.70mm
20.00mm
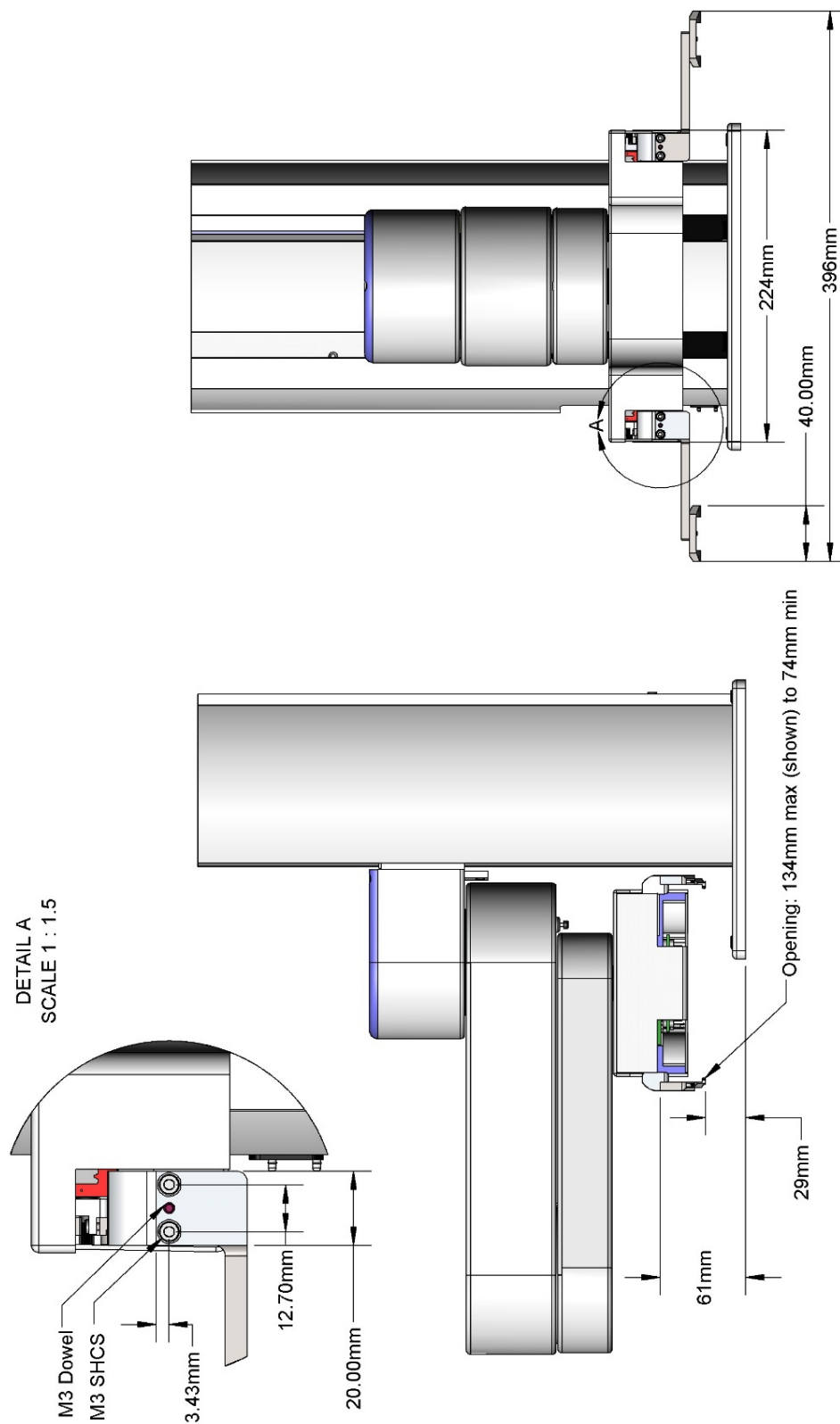
Dual Gripper, PF400 2.5 kg, Standard Reach

Linear Axis Mounting Dimensions

The linear axis has both an M6 and ¼-20 hole pattern inside the extrusion. Loosen the connector end cap slightly and remove the top cover to access these holes patterns. When replacing the top cover, be sure the tape seals are inside the slot in the top cover and not crushed.

Accessing the Robot Controller

Although most of the controller interface signals are exposed on the Facilities Panel at the base, there are times when it may be necessary to access either the robot's controller or its power supplies. To access the robot controller, the cover on the inner link must be removed by removing (4) M3 X 20 SHCS from the bottom of the inner link

See the *Guidance 1000A/B Controller User Manual* for detailed information on hardware configuration and interfacing the controller using the various input and output ports such as those for digital I/O. Also, refer to the *Guidance System Setup and Operation Quick Start Guide* for information on configuring the PC and instructions on operating the robot. Both manuals are available in PDF format and are also contained in the PreciseFlex Library.

Power Requirements

PreciseFlex robots' power supplies have an input range of 100 to 240 VAC, +/- 10%, 50/60 Hz. The robots are equipped with an IEC electrical socket that accepts country specific electrical cords. Power requirements vary with the robot duty cycle, but do not exceed 200 Watts RMS.

Emergency Stop

It is necessary to wire an Emergency Stop Button to the controller. This button may be wired in series with other emergency stop contacts. The E-stop signals are available in the green Phoenix E-stop connector and the Manual Control Pendant 9-pin DSub connector that is mounted on the Facilities Panel. See MCP/E-stop Interface for detailed information on the E-stop signals.

4. Hardware Reference

E-stop Connector

The standard E-stop connector is the green Phoenix connector on the Facilities Panel. Note the E-stop pins on the MCP Interface are in series with the E-stop signals on the Phoenix E-stop connector.

An E-stop box or circuit can be plugged into either one of these two connectors. However in order for the robot to allow motor power to be enabled the E-stop circuit must connect 24 VDC to E-stop1 in both of these two connectors. If no E-stop box or circuit is connected, then the circuit must be completed with a jumper from pin 1 to pin 2 on the Phoenix connector or from pin 1 to pin 6 on the MCP connector. The robot is shipped with a Phoenix jumper plug (PN 1851070) and a jumper plug in the 9-pin Dsub connector that satisfy these requirements. Unlike the Digital IO circuits, the E-stop circuit cannot be configured as "Sourcing" or "Sinking." If a remote signal (for example from a PLC) is used to trigger E-stop, it should be wired to a relay that closes the circuit between pins 1 and 2. When the robot is mounted on a Linear Axis, the MCP Interface is extended to the end cap of the Linear Axis.
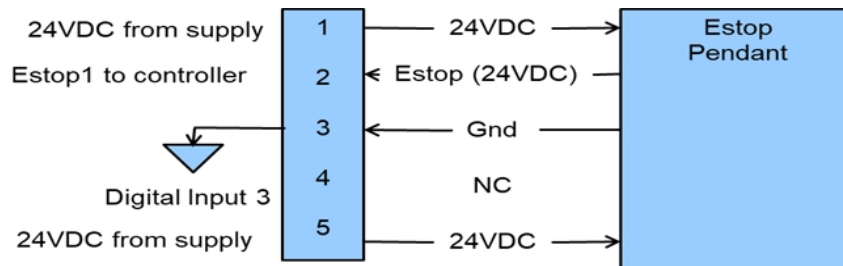
E-Stop Pins on the MCP Interface

MCP / E-stop Interface

The MCP interface includes the signals necessary to connect a Manual Control Pendant, secondary E-stop circuit, or an external RS-485 Remote IO Module. These signals are provided in a DB9

female connector mounted on the robot's[Facilities Panel](#) and on the end cap of the optional Linear Axis.

> ***NOTE:*** The E-stop pins on the MCP Interface are in series with the E-stop signals on the Phoenix E-stop connector.

An E-stop box or circuit can be plugged into either one of these two connectors. However, in order for the robot to allow motor power to be enabled, the E-stop circuit must connect 24 VDC to E-stop1 in one of these two connectors. If no E-stop box or circuit is connected, both circuits must be completed with jumper plugs. (The robot is shipped with a Phoenix jumper plug (PN 1851070) and a Dsub jumper plug that satisfy these requirements.)

If a Manual Control Pendant is not connected to the secondary RS-232 port provided in this connector, this serial interface can be accessed via a GPL procedure as device "/dev/com2" for general communications purposes.

> ***NOTE:*** Unlike the primary serial interface, this secondary serial interface does not support flow control.The RS-485 port is used internally to communicate with the gripper controller and is also be used for the Remote IO option. As such it has a dedicated protocol and is not available for general use. See the table below for more information.

Pins, Connector, and Plug

Pin	Description
1	24 VDC
2	RS-232 TXD
3	RS-232 RXD
4	RS-485-
5	Gnd
6	E-stop1
7	E-stop Daisy Chain
8	48 VDC
9	RS-485+
Interface Panel Connector Part No	DB9 Female Connector AMP 5747150-7
User Plug Part No	DB9 Male Plug Amp 1658655-1 (crimp) Pins 22-26AWG 745254-6

Digital Input and Output Signals

Digital Input Signals

The standard PreciseFlex™ 400 robot provides one general-purpose optically isolated digital input signal at the Facilities Panel (in addition to those signals that are available at the Gripper Control Board). This line is accessed in the Phoenix 5-pin E-Stop connector and is connected to Digital Input 3 in the controller. See Figure 4-1.
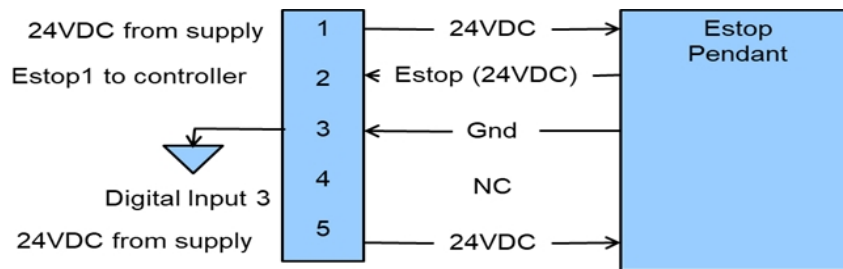
Figure 4-1: E-Stop Pins on the MCP Interface

This input signal can be configured as "sinking" (Figure 4-2) or "sourcing" (Figure 4-3). If an input signal is configured as "sinking," the external equipment must pull its input high to 5 VDC to 24 VDC to indicate a logical high value or must allow it to float to no voltage for a logical low. This input is configured at the factory as "sinking".
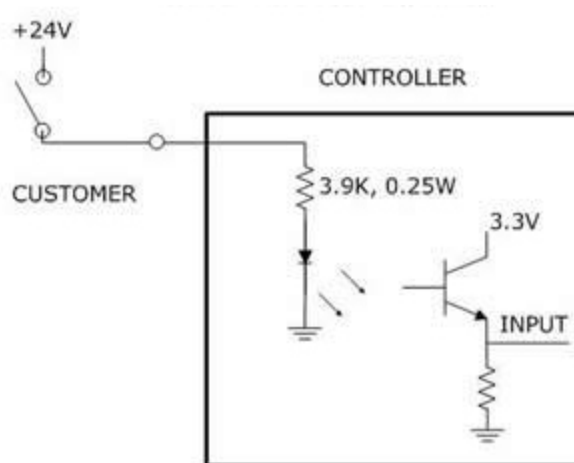
Figure 4-2: Sinking Digital Input
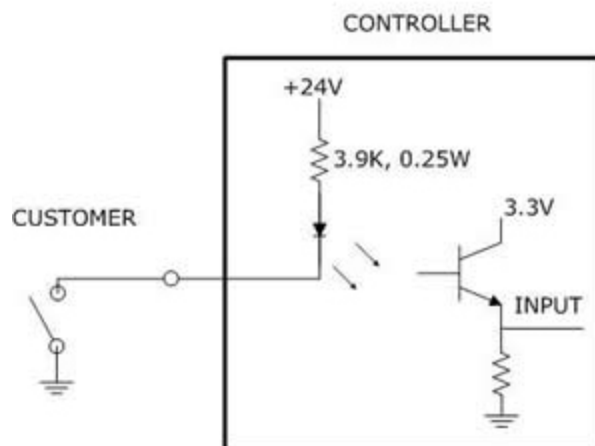
Figure 4-3: Sourcing Digital Input

By setting Jumpers on the CPU (MIDS4) board, the four output signals can be individually configured as "sinking" or "sourcing" and the four digital inputs can be configured as a group to all operate as either sinking or sourcing. For more information on configuring the jumpers, see the *Guidance 1000A/B Controllers, Hardware Introduction and Reference Manual.*

Digital Output Signals

The PreciseFlex robot provides four general-purpose optically isolated digital output signals at the G1400B controller. These output signals can be configured as "sinking" (Figure 4-4) or "sourcing" (Figure 4-5). As shipped from the factory, the output signals are configured as "sinking," i.e. the external equipment must provide a 5 VDC to 24 VDC pull up voltage on an output pin and the controller pulls this pin to ground when the signal is asserted as true.
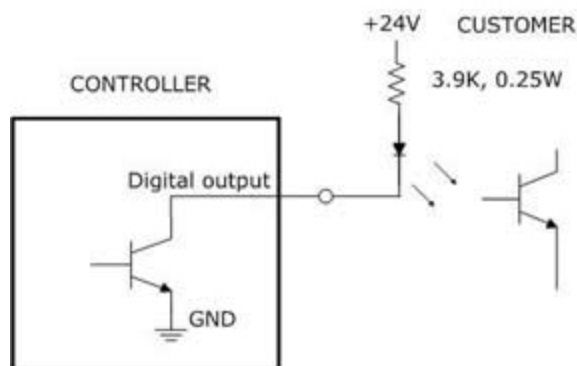
Figure 4-4: Sinking Digital Output

Alternately, the output signals can be configured as "sourcing," i.e. the external equipment must pull down an output pin to ground, and the controller pulls this pin to 24 VDC when the signal is asserted as true.
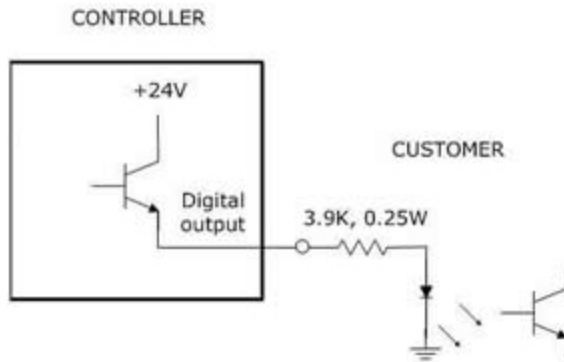
Figure 4-5: Sourcing Digital Output

Outputs can be individually configured as sinking or sourcing signals. For more information on configuring the jumpers, see the *Guidance Controller, Hardware Introduction and Reference Manual.*

The pin out for the G1400B Digital Input and Output Connector and the corresponding GPL signal numbers are described in Table 4-1.

Table 4-1: Pin Out for G1400B Digital Input & Output Connector, GPL Signal Numbers

Pin	GPL Signal Number	Description
1	13	Digital Output 1
2	14	Digital Output 2
3	15	Digital Output 3
4	16	Digital Output 4
5		GND
6		24 VDC output
7	10001	Digital Input 1
8	10002	Digital Input 2
9	10003	Digital Input 3
10	10004	Digital Input 4
User Plug Part No		AMP 1658622-1 or Molex 22-55-2101 or 90142-0010. For the Molex plug, use Molex sockets 16-02-0103 or 90119-2110 and Molex crimp tool 63811-1000.

Gripper Controller Digital Inputs and Outputs

If the robot is equipped with an electric gripper, the gripper controller includes three sinking digital inputs and three sourcing digital outputs. Two inputs and outputs are available in the outer link for application use.

Pin Out & GPL Signal Number

Pin	GPL Signal Number	Description
1	200013	Digital Output 1/LED driver
2	200014	Digital Output 2
3	200015	Digital Output 3
4		24 VDC output
5		GND
6	210001	Digital Input 1
7	210002	Digital Input 2
8	210003	Digital Input 3
User Plug Part No		Amp 794617-8, crimp contacts 1-794611-2

RS-485 Remote IO Module (GIO)

Customers who need additional digital IO may order the RS-485 Remote IO Module. This module installs in the base of the robot and provides 12 Digital Inputs and 8 Digital Outputs in a 25 pin Dsub connector. The RS-485 Remote IO Module (GIO) provides 12 general purpose optically isolated digital input signals and 8 general purpose optically isolated digital output signals. Two inputs, 11 and 12, can be optionally configured as analog inputs by means of jumpers J1 and J2. Connecting J1 to pins 1 and 2 (default) configures these inputs as digital and connecting pins 2 and 3 configures them as analog (if the analog option has been ordered). These input and output signals are intended for interfacing to tooling and sensors or for general application needs. This board is connected to the controller by an RS-485 serial line that allows the controller to scan the GIO I/O with a nominal period of 4 milliseconds.

The DIO signals are accessible via the DB25 female connector that is mounted on the facilities panel when this option is ordered. The DIO signals addresses are determined by a base address set by a DIP switch on the DIO board. For the PF400 robot without the linear axis option the DIO option is located at the robot connector panel and for both this location and also for the location at the end of the optional linear axis, all the address jumpers will NOT be installed, which sets the address of this module to "8." This address avoids conflicts with other RS-485 network controllers for the gripper and optional linear axis. See Installing the Optional GIO Board for details on installing this module.

Ethernet Interface

PreciseFlex robots include an Ethernet switch that implements two 10/100 Mbit Ethernet ports. This capability was designed to permit the controller to be interfaced to multiple Ethernet devices such as other PreciseFlex controllers or robots, remote I/O units and Ethernet cameras. The Ethernet switch automatically detects the sense of each connection, so either straight-through or cross-over cables can be used to connect the controller to any other Ethernet device.

Due to limited space on the Facilities Panel, only one of the two Ethernet ports is available via an external RJ45 connector. This external Ethernet port is typically used to interface the robot to a PC. The second Ethernet port is only available inside the inner link of the robot. In some cases it may be used to connect an Ethernet camera that is mounted on the robot. In this case, a PC that is connected to the Ethernet plug on the Facilities Panel can communicate with the robot's controller as well as receive images from an arm-mounted camera. (For the initial release of this robot, arm mounted cameras are not supported.) If a camera is mounted in the workcell, an external Ethernet switch must be added to connect these cameras and the robot to a PC.

See the *Setup and Operation Quick Start Guide* for instructions on setting the IP address for the controller.

RS-232 Serial Interface

The PreciseFlex robot includes a standard RS-232 serial line equipped with hardware or software flow control. However this port is only available on the G1400B controller in the inner link of the robot and is not brought out to any outside connector on this robot. This port can be used to communicate to the system serial console or can be connected to external equipment for general communication purposes. When used for general communications, this port is referenced as device "/dev/com1" within the Guidance Programming Language (GPL).

The connector for this interface is a standard RJ11 serial interface connector that has pin assignments compatible with standard PC "com" ports. For this robot it is only used for debugging and special service procedures.

Gripper Serial Interface (for Bar Code and other RS-232 devices in Gripper)

It is possible to connect a barcode reader or other RS-232 serial device to the slip ring located in the robot gripper.

NOTE: Effective with Revision 4 of the GSB board in the outer link which controls the gripper, two IO pins have optional assignments based on jumpers.

J4 is connected to pins 2 and 3 to connect Digital Input 1 to pin 6 and is connected to pins 1 and 2 to connect pin 6 to a line that goes back to the controller RS-232 RXD input. J7 is connected to pins 2 and 3 to connect Digital Output 3 to pin 3 and is connected to pins 1 and 2 to connect pin 3 to a line that goes back to the controller RS-232 TXD input. See Figure 4-6.

On the controller CPU board, two more jumpers must be correctly installed to connect RS-232 to the GSB. On the CPU board, shown below, J14 and J15 must be connected to pins 2 and 3 to connect the TXD and RXD inputs from the GSB to the serial inputs in the CPU. The factory configuration for J14 and J15 is connecting pins 1 and 2. This is because prior to Rev 4 of the GSB, the wires connected to these pins in the RS-485 cable were grounded, and if a user plugs in a GSB earlier than Rev 4, they will ground the RS-232 signals unless J14 and J15 are in their factory configuration. See Figure 4-7.
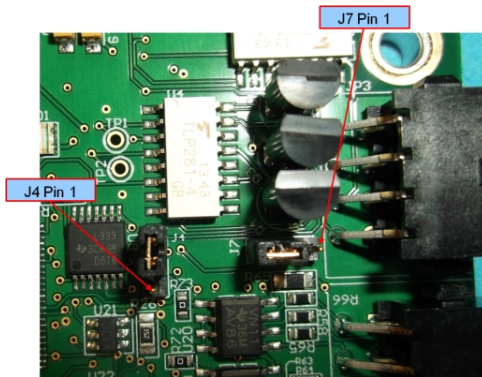
Figure 4-6: J4 & J7 on GSB Board
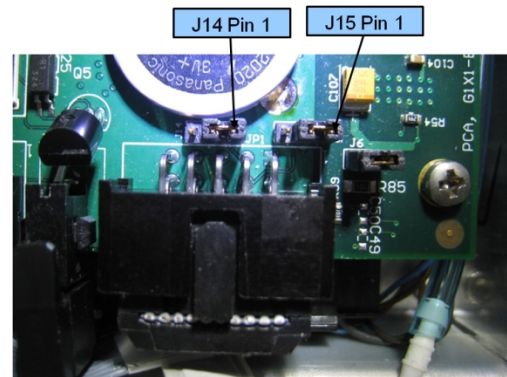
Figure 4-7: J14 & J15 on CPU Board

Refer to drawings "Assembly, Slip Ring, Harness with Sensor, E8" item 8 for the slip ring connector pin assignments inside the gripper for the PF400 robots. The mating connector is TE (Amp) Micro Mate N Lok PN 794617-6 with contacts PN 1-794611-2. It is recommended that 24V bar code readers be used; the 5V supply is limited.

Several barcode readers that have been successfully implemented with the PF400 are the following:
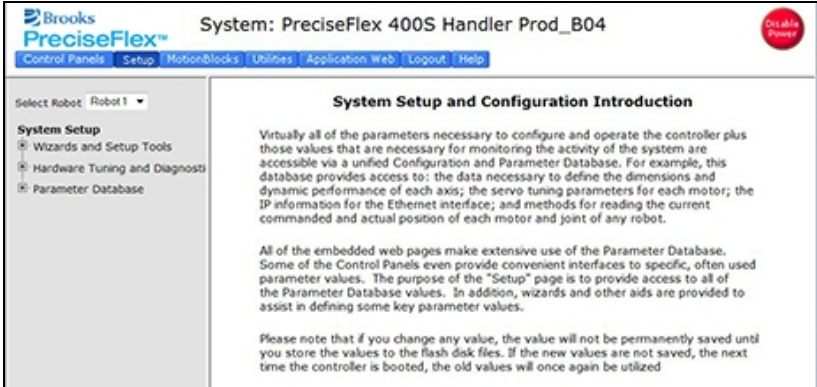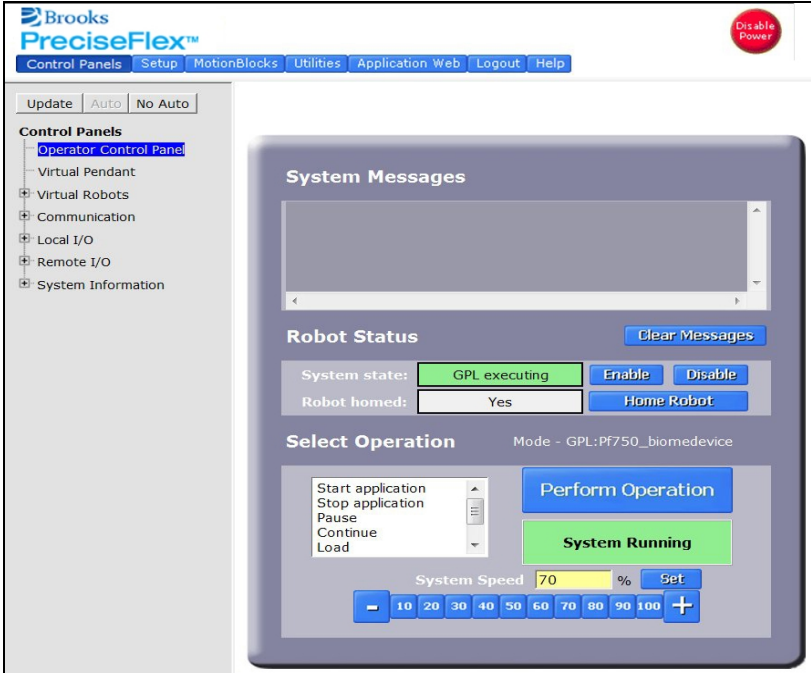
1. Keyence SR750, 1D and 2D, 24 VDC supply, 200 ma, 60 mm distance.
2. Cognex DM50, DM60, DM70, 24 VDC supply, 500 ma, 45 to 110 mm distance.
3. Omron/Microscan MiniHawk, 1D and 2D, 5 VDC supply, need converter from 24 VDC.

5. Software Reference

Accessing the Controller Interface

Many OEM customers run the PreciseFlex 400 using a PC to provide an application-specific operator interface. In order to update software in the controller, and view certain error messages, it is necessary to access the interface embedded in the controller.
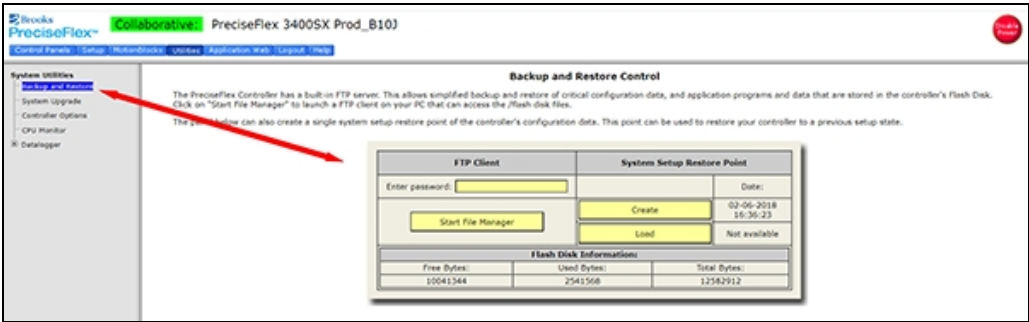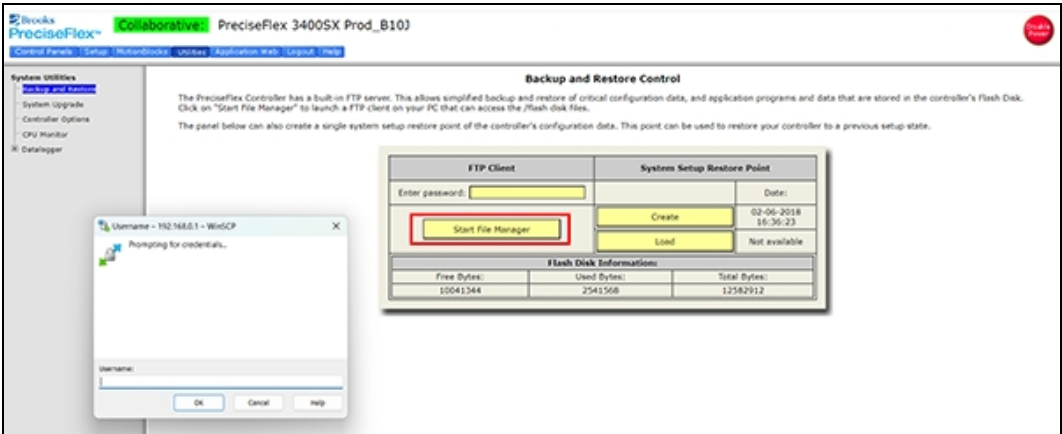
Step	Action
1.	Open a browser in a PC that is connected to the robot via Ethernet. The user must know the IP address of the robot controller. Two common IP addresses are 192.168.0.1 and 192.168.0.10. The PC LAN interface address must be configured correctly (for example 192.168.0.100, with subnet mask 255.255.255.0).
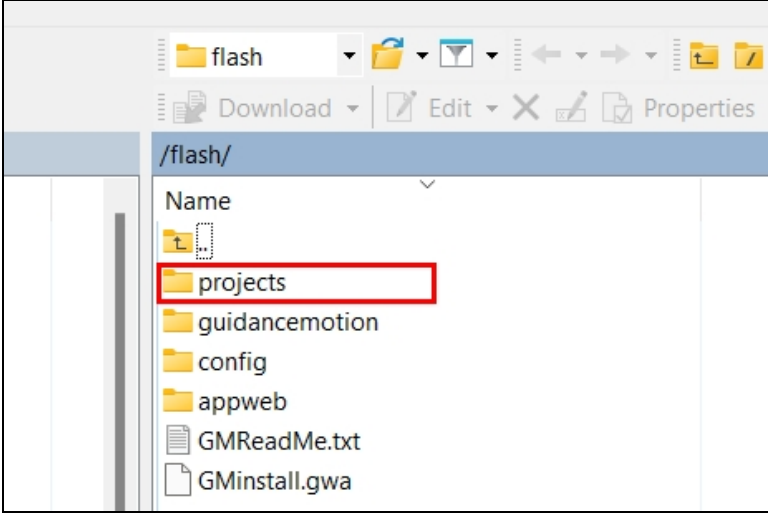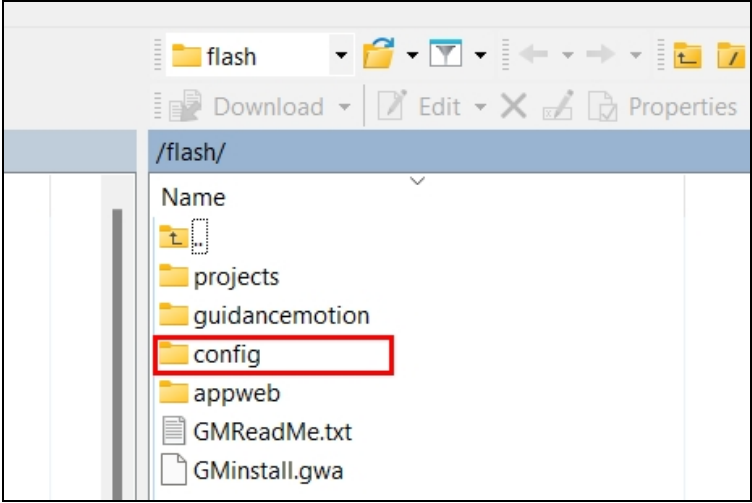
Step	Action
2.	It may be necessary to enter a password if a company has protected access to the web Interface. Once the password has been entered, click **Admin** to access all the features to perform system upgrades.
3.	Click **Control Panels → Operator Control Panel**.
4.	If an application is running, the "System Running" panel will display in green. In order to run diagnostics, stop the application from running. Click **Stop Application** and then **Perform Operation**. This will stop the application from running.

Step	Action
5.	Click **Disable Power** to be sure motor power is off.
6.	To load a new project (for example CAL_PP), click **Unload** and then **Perform Operation** before loading the new project into RAM.

Loading a Project (Program) or Updating PAC Files

If CAL_PP or a different program needs to be loaded into the controller from an external computer, this may be done using the Web Interface.
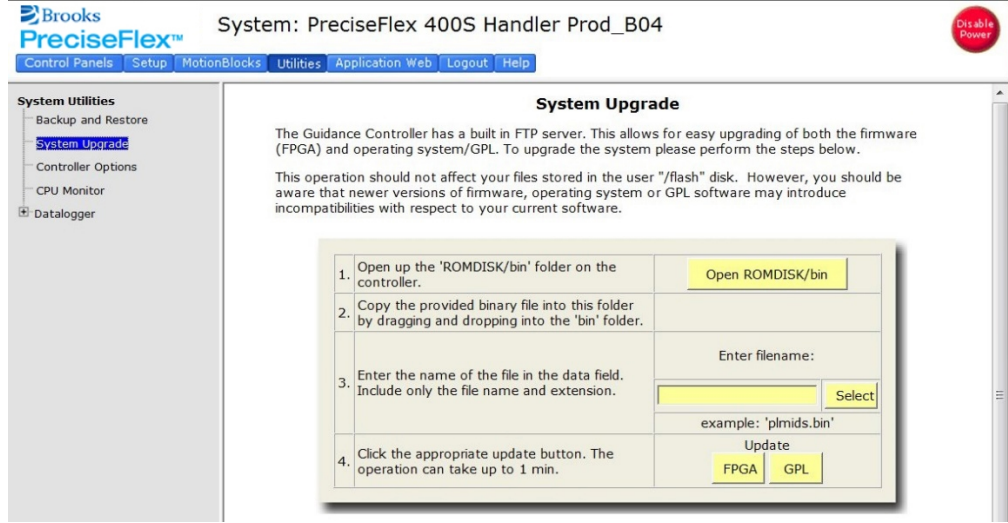
Step	Action
1.	In the Operator Interface, select **Utilities > System Utilities > Backup and Restore**.
2.	Click **Start File Manager** to connect to an FTP utility.

Step	Action
3.	To load a project, open the "Projects" folder and paste the Project folder into this area. There may be several other projects (programs) loaded into this folder, which is stored in flash ram in the controller. A project folder is a software folder than may have several files inside it. Load the entire folder, not just the files inside. flash Download ▾ Edit ▾ ✕ Properties /flash/ Name ↰ [..] 📁 projects 📁 guidancemotion 📁 config 📁 appweb 📄 GMReadMe.txt 📄 GMinstall.gwa
4.	To load or update PAC files, open the "Config" folder and paste a backup copy of the PAC files into the "Config" folder. These files will all have a .pac extension. The robot must be re-booted after new PAC files are installed for them to take effect. flash Download ▾ Edit ▾ ✕ Properties /flash/ Name ↰ [..] 📁 projects 📁 guidancemotion 📁 config 📁 appweb 📄 GMReadMe.txt 📄 GMinstall.gwa
5.	Once the appropriate project (for example CAL_PP) has been loaded into flash memory, it must then be loaded into dynamic memory in order to execute. See "Calibrating the Robot: Setting the Encoder Zero Positions" on page 1 for an example on how to load and execute the CAL_PP program.

Updating GPL (System Software) or FPGA (Firmware)

Both GPL (the system software) and the FPGA firmware may be upgraded in the field.

Step	Action
1.	Get the appropriate upgrade software from Brooks in the form of a .bin file. Email support_preciseflex@brooksautomation.com.
2.	In the operator interface, go to the **Utilities/System Upgrade** menu.
3.	Click **Open ROMDISK/bin**. This will open an FTP window. Select **page** in the browser, scroll to the bottom of the page menu, and click **Open site in Windows Explorer**. This will open a second ftp window in Windows. Paste the appropriate GPL or FPGA .bin file in this window.
4.	Under item 3 in the **System Upgrade** menu, click **Select**. A pick list will open up. Highlight the upgrade code in this pick list and click **Select** again. The name of the file will appear in the filename field.
5.	In the menu, click on either **FPGA** or **GPL** to upgrade the appropriate file. The banner in the Upgrade menu will start flashing for about 10 seconds while the flash RAM is being written with the new file. Wait about 10 additional seconds after this banner stops flashing, then reboot the robot, and the new code will be installed.

Recovering from Corrupted PAC Files
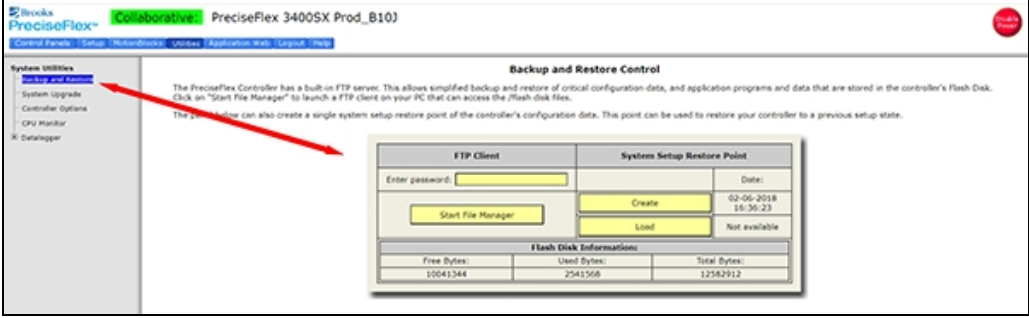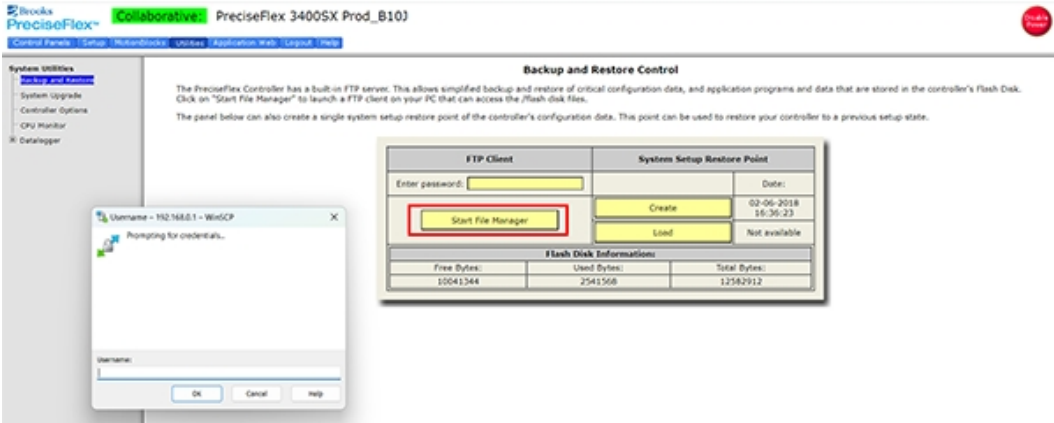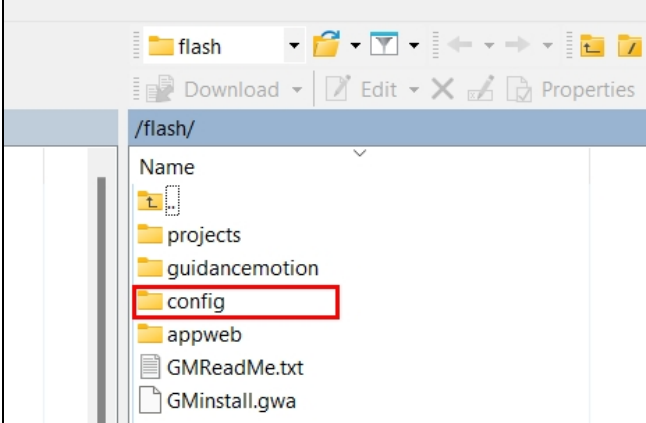
PAC files are configuration files that determine the configuration of the robot for the software, including the robot factory calibration data. These files are stored in Flash RAM. Flash RAM is also used to store robot programs. The Flash RAM requires some time for a complete write cycle. During the write cycle, the console will display a flashing warning not to turn off robot power. If robot power is turned off during the Flash RAM write cycle, the Flash data may be lost or corrupted. If this happens, it is necessary to reload both the robot PAC files and any user programs that were stored in Flash RAM. This problem should typically not be encountered by a user unless the user is changing configuration files in the robot.

Brooks maintains a record of PAC files shipped with each robot Serial Number. If the PAC files have been corrupted, it is possible to get a back up copy from Brooks. The backup copy will contain the factory configuration and calibration data, but will not contain any changes, including any new calibration data, made after the robot has left the factory.

In order to allow the controller to recover from corrupted PAC files, a set of recovery boot up PAC files is loaded in a the system area of the Flash.

The following procedure outlines how to configure the controller to boot up in recovery mode.

Step	Action
1.	Get a set of backup PAC Files from Brooks (support_preciseflex@brooksautomation.com) or local backup.
2.	Remove the Inner Link Cover of the robot.
3.	Move Jumper J8 so it connects the two jumper posts. This will cause the factory default configuration files to be loaded at controller boot up.

Step	Action
4.	Cycle the robot power to reboot the controller.
5.	In the Operator window, click on **Utilities/Backup and Restore** to display the *Backup and Restore Control* window.
6.	Click on **Start File Manager** to connect to an FTP utility.
7.	Open the **Config** folder and drag or copy and paste the backup copy of the PAC files into this folder.

Step	Action
8.	Wait until the console prompt stops flashing, about 10-15 seconds.
9.	Turn off robot power.
10.	Restore Jumper J8 to its previous position.
11.	Reboot the robot. The PAC files should be restored and the robot should run.
12.	If the robot has ever been recalibrated since the back up PAC files were created, it will be necessary to recalibrate the robot, as the calibration files will be out of date.
13.	Replace the Inner Link Cover.

Command Server

Brooks offers a Command Server software package that allows a PC to send high level commands to the PF400 robot. This package is available upon request. Email support preciseflex@brooksautomation.com.

Adding or Removing the Optional Linear Axis

The optional Linear Axis may be added to existing PF400 robots by simply placing the robot on the Linear Axis and plugging in the connectors from the Linear Axis stage. However, the GPL version must be 3.2.H4 or later and the PAC files must be changed to support the robot with Linear Axis. If a robot is installed on, or removed from, a linear axis new PAC files must be obtained from Brooks and installed in the robot controller and the robot must be re-calibrated, using CALPP_Rev21 or later.
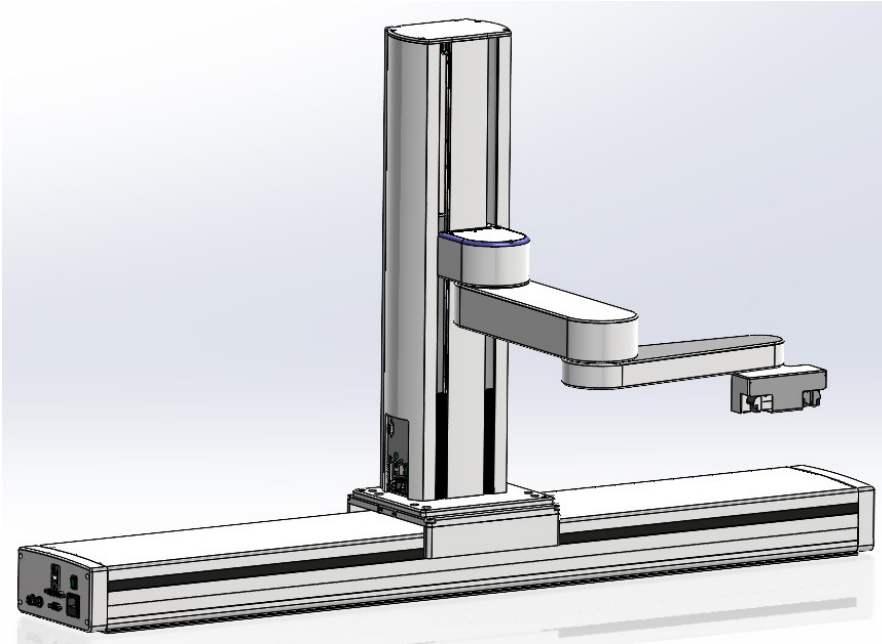
Figure 5-1: PreciseFlex 3400 with 60 N Gripper on 1 m Linear Axis

In addition, when adding a linear axis to a robot with a servo gripper for the first time, the J6 RS-485 termination jumper on the robot controller in the inner link of the robot (see) must be removed, as the RS-485 bus is now extended to the end of the linear rail, where an RS-485 jumper is installed. Failing to remove this jumper can result in RS-485 communication errors as there will be too many loads on the RS-485 bus.

> **NOTE:** For robots with a pneumatic gripper, this jumper should not be removed as the controller will form one end of the RS-485 chain and the GSB controller in the linear rail or the GIO IO board in the end of the linear rail should provide the second termination.
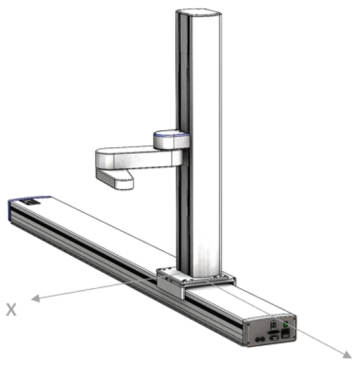
If the GIO is installed, J6 should be installed on the GIO and J6 should be removed from the GSB on the linear rail carriage. (See Replacing the Linear Axis Controller and Installing the Optional GIO Board for pictures.)
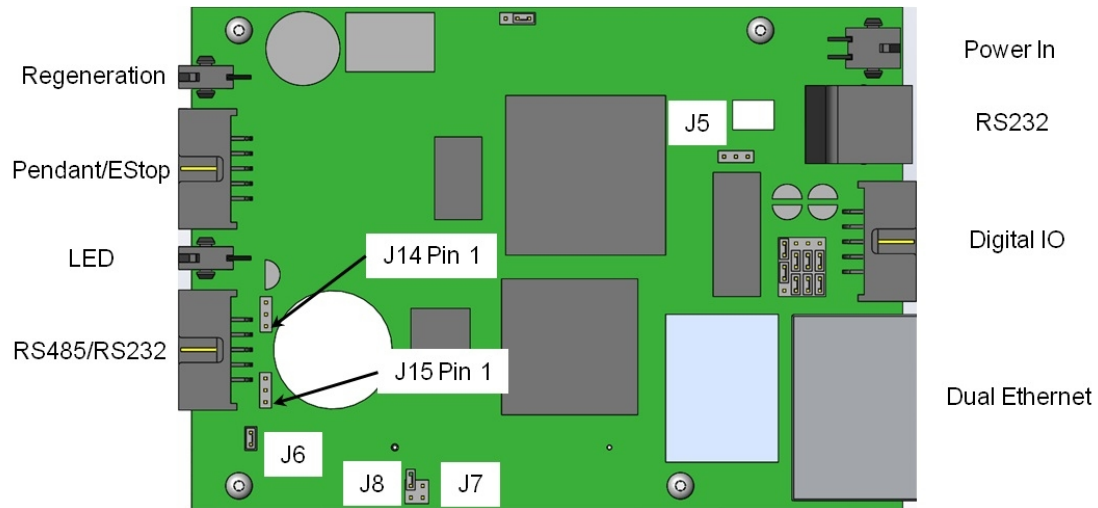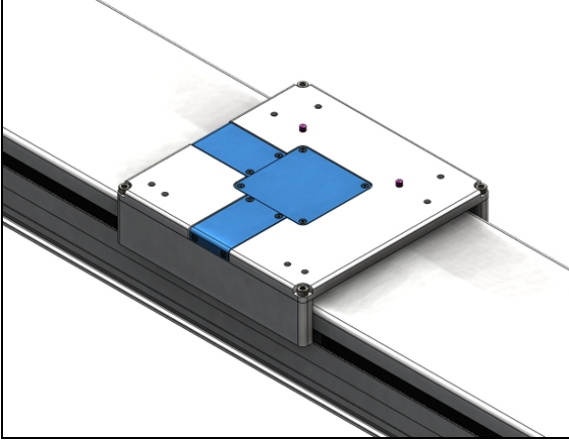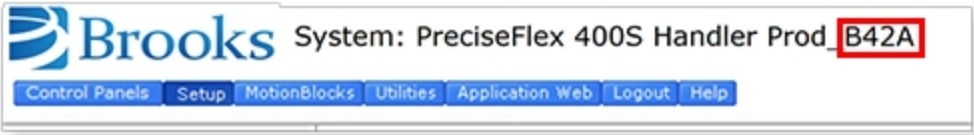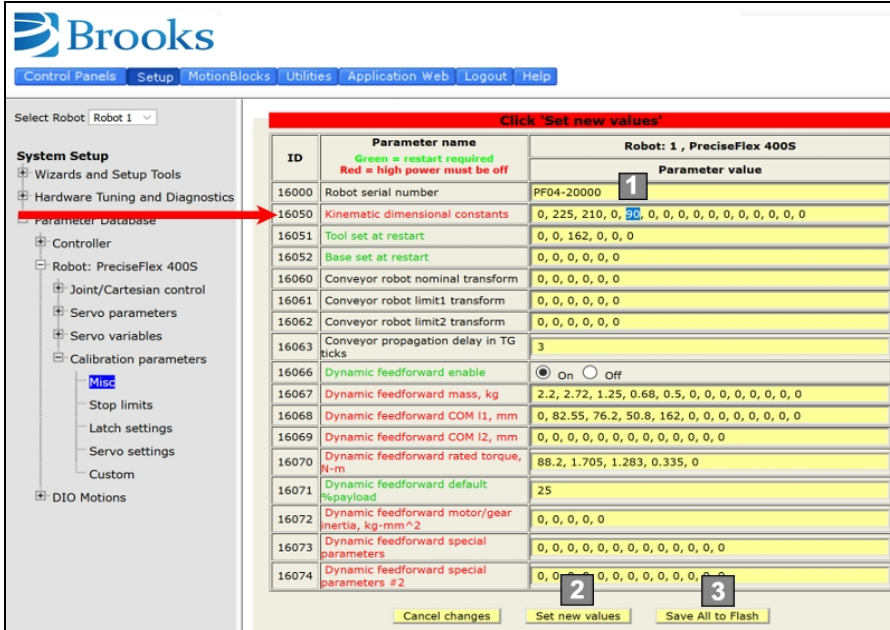
J6 Jumper on Guidance Slave Board (GSB)

There is a configuration parameter in the PAC files which determines whether the Linear Axis is configured to add to the robot's Y Cartesian Axis or X Cartesian Axis. The 5th element of the "Kinematic dimension constants" (16050) will specify the orientation of the rail. A value of 0 has the rail moving along +Y. To have the rail move along +X, the 5th parameter must be set to -90 (degrees).

Follow this procedure to install the Linear Axis.

Step	Action
1.	Choose orientation 0 degrees: Robot y-axis aligns with rail travel (moves "sideways") -90 degrees: Robot x-axis aligns with rail travel (moves "forward and backward")

Step	Action
2.	Route cables. If necessary, remove the covers on the carriage and re-route the cabling so that the connectors can reach the facilities panel.
3.	Attach robot and cables. Mount according to chosen configuration. Attach power, Ethernet, and communication (DB9). 0 degrees -90 degrees
4.	Install new PAC files. Follow standard procedure. Make sure to match the version number of the new files to the files currently installed. Reboot robot after installation. Verify Virtual Pendant now shows new rail axis.

Step	Action
5.	Calibrate the robot. Follow standard procedure. Rail position is described in Cal_pp dialogue.
6.	Set configuration parameter 1. Set the 5th value of parameter 16050 to the chosen orientation (0 or -90) 2. Click "Set new values" 3. Click "Save All to Flash
7.	Wait 10 seconds and reboot the robot. After reboot, the rail is ready to use.

The Linear Axis Option is configured so that the zero position is in the middle of the range of travel. The software is configured so that the Linear Axis position is added to either the Y-axis or X-axis Cartesian position of the gripper. The Linear Axis appears as Joint 6 in Joint Coordinates and in the Virtual Pendant Coordinates. It may be moved by the "Move.OneAxis" command by selecting Joint 6.

The factory test program which is shipped with each robot includes sample code to move the Linear Axis.

Controlling the PreciseFlex Servo Grippers

Overview

The 23 Newton PreciseFlex Servo Gripper with spring return contains a brushless servo motor with an incremental encoder with both counting and motor phase tracks. At power up the encoder provides motor commutation information for a brief period, and then switches the incremental encoder A, B, and Z signals onto the same set of wires. This allows the motor commutation to be initialized at start-up without any motion.

The motor has a 12 tooth pinion gear cut directly on the motor shaft. This pinion drives a pair of opposing racks to open and close a set of finger mounts which are attached to linear ball slides. Various fingers can be attached to the finger mounts.

One finger mount is also attached to a spring return, which applies a continuous closing force to the finger mounts as they are coupled together by the pinion. If power is lost, the gripper will close and maintain a closing force so that it does not drop parts.

In order to avoid the gripper slamming closed from the spring force when motor power is disabled, there is a 500ms delay after an E-Stop or power disable command is sent before the motor power is cut off. During this period, the servo slowly closes the gripper.

In order to support "free" mode, in which the fingers can be moved back and forth freely by hand, in free mode the servo counterbalances the spring by applying an opposing force based on finger position.

Software Revision

The Spring Gripper functionality is fully supported by GPL version 3.1.P11 or later and PAC files PFlex400S_Prod_B03 110913 or later. Some slightly earlier software versions were delivered to beta customers.

Controlling the Gripper

Brooks has created a GPL software routine that controls the spring gripper. This routine includes features for controlling the gripper squeeze force and detecting if a plate is present during a grip. Brooks makes this routine available to customers upon request. This routine is also available in the PreciseFlex Command Server Software for the PF400.

Gripper Squeeze (Simple Method)

The spring applies a closing force of approximately 7 Newtons at a finger opening of 103 mm, which is halfway between a portrait titer plate grip at 83 mm and a landscape titer plate grip at 123 bmm. The force is closer to 6 N in portrait mode and 8N in landscape mode and 9-10N at the full open

homing position. These closing forces appear adequate to prevent dropping titer plates weighing up to 200 gms, and are selected to allow enough motor torque to overcome the spring and still provide reasonable opening force for inside grips.

The motor for the 23 N gripper can apply about 18 N of force at its rated current of 1.26 A. When closing the fingers the motor adds its force to the spring force, so a maximum closing force of about 24-26 N is possible, depending on portrait or landscape gripping. When opening, the motor must oppose the spring force, so a maximum opening force of about 8- 12N is possible, depending on the opening of the fingers.

The motor squeeze force can be limited by modifying the rated current of the motor. This can be done by writing into the 5th field in Parameter Data Base # 10611. The motor current can be set once and saved into flash or modified dynamically by a GPL program using the Controller.PDbNum instruction.

For the PF400 23 N gripper the formula for determining the approximate gripper squeeze is 7 N +(Rated Current/1.26 Amps)X18 N for squeeze and (Rated Current/1.26Amps)X18N –9 N for gripper opening force.

Note that in order to home the gripper must open all the way its maximum hard stop. The spring force at this point is about 10 N. So the motor current should not be set below about 12 N/18 NX1.26 A or 0.8 A for the simple method of controlling gripper squeeze, giving a range of about 18 N minimum to 24 N maximum squeeze for the 23 N gripper.

Gripper Squeeze (Asymmetric Method)

There may be cases where 18 N of squeeze is too much. In this case there is a more sophisticated method to control squeeze.

There are two parameters in the database, 10351 and 10352, that can be used to limit the torque from the PID loop in the positive and negative directions. These parameters were developed to limit the downwards force of a robot running with dynamic feedforward, where the dynamic feedforward compensates for the gravity torque of the robot. The feedforward torque is NOT limited by these parameters, only the PID torque. For a perfectly balanced robot, setting these parameters to a low value for a gravity loaded axis limits the maximum force the axis can apply from any position error. If the axis crashes into a hard stop, the downwards or upwards force can be limited to a small value.

These same parameters can be used to limit the gripper squeeze in an asymmetric manner. Parameter 10352 can be set to a negative value of torque counts (tcnts) to limit the torque from the PID loop in the controller in the negative direction only. Parameter 10351 can similarly be set to limit tcnts from the PID loop in the positive direction. Since the spring compensation in the gripper is treated as a feedforward torque, these parameters do not affect the spring compensation torque.

For this case it is more exact to know the exact number of tcnts to oppose the spring at various openings. For the portrait mode opening of 83 mm it takes 1600 tcnts to oppose the spring. For the landscape mode opening of 123 mm it takes 2200 tcnts to oppose the spring.

If the rated torque of the motor has been set to its maximum value of 1.26 A, the formula for setting parameter 10352 is (Spring force at position) +((-<Contents of 10352>-<tcnts to oppose spring force>)/4378)X18 N, where 4378 is the number of tcnts corresponding to 1.26 A or the rated torque of the motor. For example, for portrait mode the spring force is about 6 N, and if the contents of 10352 are -3200, this value will be 6 N + (3200-1600)/4378)X18 N or about 12.5 N. If the value of 10352 is -1600, the squeeze will be 6 N which is the spring force only.

In a similar manner parameter 10351 can be used to limit the gripper opening force. In this case the value for the opening force is ((<Contents of 10351>-<tcnts to oppose spring force>)/4378)X18 N – (Spring force at position). For example, in landscape mode the spring force is about 8N, and if the contents of 10351 are 5200, this value will be (5200-2200)/4378X18 N -8 N or 4.3 N. Note that 5200 is about as low a value as anyone would want to use in landscape mode for parameter 10351, to ensure there is enough force to oppose the spring and open the gripper all the way to the homing position. For many cases, 10351 can be left at its default value of 0, in which case it is disabled.

End of Travel Sensor

The PreciseFlex 23 N EGripper includes a sensor to detect the gripper closed to hard stop position. The spring will return the gripper to this position if power is off and there is no plate in the gripper. This sensor is wired to Digital Input 2 on the Gripper Controller Board which can be read at Digital Input 210002. This input can be viewed in the Web Browser under Control Panels/Remote IO/Network Node 2 IO. At power up this sensor can be checked to determine if the gripper is fully closed, and thus not holding a plate. If the gripper is not fully closed it will be holding a plate, and the operator should be directed to remove the plate before homing the robot, which will open the gripper to the maximum hard stop. The 60 N servo gripper has an absolute encoder and position can be checked after homing, which does not move the gripper fingers.

Grip Test and Squeeze Check

It may be desirable to check if a plate is gripped by checking the gripping torque value. The output torque to the motor is available in Parameter 12304, value 5 in the parameter data base. For a non-spring gripper, this value varies between 0 and 4378 tcnts for a maximum gripper force of 18N. For a spring gripper, per above, for a portrait grip, the spring adds about 1600 tcnts to the squeeze and for a landscape grip, it adds about 2200 torque counts to the squeeze. Since this value is taken into account by the spring compensation and is offset from the torque commanded to the motor in Parameter 12304, when checking Parameter 12304 to determine squeeze the spring compensation must be subtracted from the torque value in Parameter 12304. For example, if the gripper is at the portrait position and not holding a plate, it must servo against the spring. In this case the value in Parameter 12304 will be about 1600 tcnts. To determine the effective squeeze torque, subtract 1600 tcnts from this value, which results in zero tcnts of squeeze force. If the value in 12304 is -2700, then the gripper motor is squeezing with -2700 tcnts, and the spring is adding -1600 tcnts, and the effective squeeze is -4300 tncts, or about 18 N. The exact spring compensation value is stored in field 5 of Parameter 12331. For the best accuracy in determining effective squeeze force at any gripper opening, subtract this value from the value in 12304.

Servo Gripper Controller Digital Inputs and Outputs

The Servo Gripper Controller PCA (GSB) adds three general optically isolated digital outputs and three general optically isolated digital inputs to the standard digital I/O found on the Guidance Controller. Like the other general inputs and outputs, they can be assigned for various control purposes during system setup, or they can be used directly by a GPL procedure.

Unlike the controller's standard digital I/O that are directly accessed on demand, these I/Os are scanned by the controller. The scanning period is nominally 4 milliseconds, so an application must be able to handle a delay of up to 4 milliseconds for signal changes to propagate through the system.

Effective with Revision 4 of the GSB board, two IO pins have optional assignments based on jumpers. J4 is connected to pins 2 and 3 to connect Digital Input 1 to pin 6 and is connected to pins 1 and 2 to connect pin 6 to a line that goes back to the controller RS-232 RXD input. J7 is connected

to pins 2 and 3 to connect Digital Output 3 to pin 3 and is connected to pins 1 and 2 to connect pin 3 to a line that goes back to the controller RS-232 TXD input. See Figure 5-2.

On the controller CPU board, two more jumpers must be correctly installed to connect RS-232 to the GSB. On the CPU board, shown below, J14 and J15 must be connected to pins 2 and 3 to connect the TXD and RXD inputs from the GSB to the serial inputs in the CPU. The factory configuration for J14 and J15 is connecting pins 1 and 2. This is because prior to Revision 4 of the GSB, the wires connected to these pins in the RS-485 cable were grounded, and if a user plugs in a GSB earlier than Revision 4, they will ground the RS-232 signals unless J14 and J15 are in their factory configuration. See Figure 5-3.
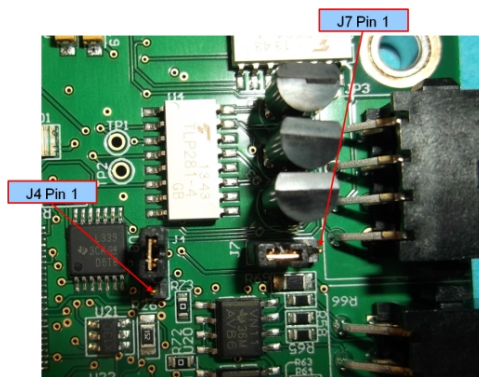
Figure 5-2: J4 and J7 on GSB Board
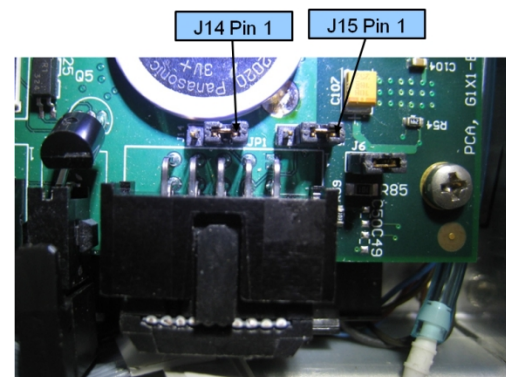
Figure 5-3: J14 and J15 on CPU Board

The GSB I/O signals are shown in Table 5-1.

Table 5-1: GSB I/O signals

Pin	GPL Signal Number	Description
1	200013	Digital Output 1
2	200014	Digital Output 2
3	200015	Digital Output 3 (LED Output or TXD, select with J7)
4		24 VDC output
5		GND
6	210001	Digital Input 1 (Pushbutton on some Electric Grippers or RXD, select with J4)
7	210002	Digital Input 2 (End of travel sensor option)
8	210003	Digital Input 3

Optional Pneumatic or Vacuum Gripper

It is possible to order robots with or without servo grippers. However, when changing from a servo gripper to a pneumatic or vacuum gripper, the PAC files in the robot must be changed to remove the servo gripper control configuration. Contact support_preciseflex@brooksautomation.com for help. Then, the cabling must be changed per below to support the IO signals to drive pneumatic or vacuum solenoids. See Figure 5-4 through Figure 5-8.

In the Revision C of the PF400, the motor interface board in the outer link can be connected by means of a flat ribbon cable to the controller digital inputs and digital outputs, providing support for both pneumatic and vacuum grippers where desired.

When the inner link end of this cable is plugged into the IO connector on the interface board on the side of the inner link, the innermost IDC connector on the end of cable in the outer link should be plugged into the J4 motor interface board. Conversely, when the inner link connector is plugged into the RS-485 connector on the robot controller in the inner link, the outermost IDC connector should be plugged into the GSB servo gripper control board in the outer link.

Figure 5-4: Inner Link Cable Position for IO Signals

Figure 5-5: Ribbon Cable with Dual Connectors in Outer Link
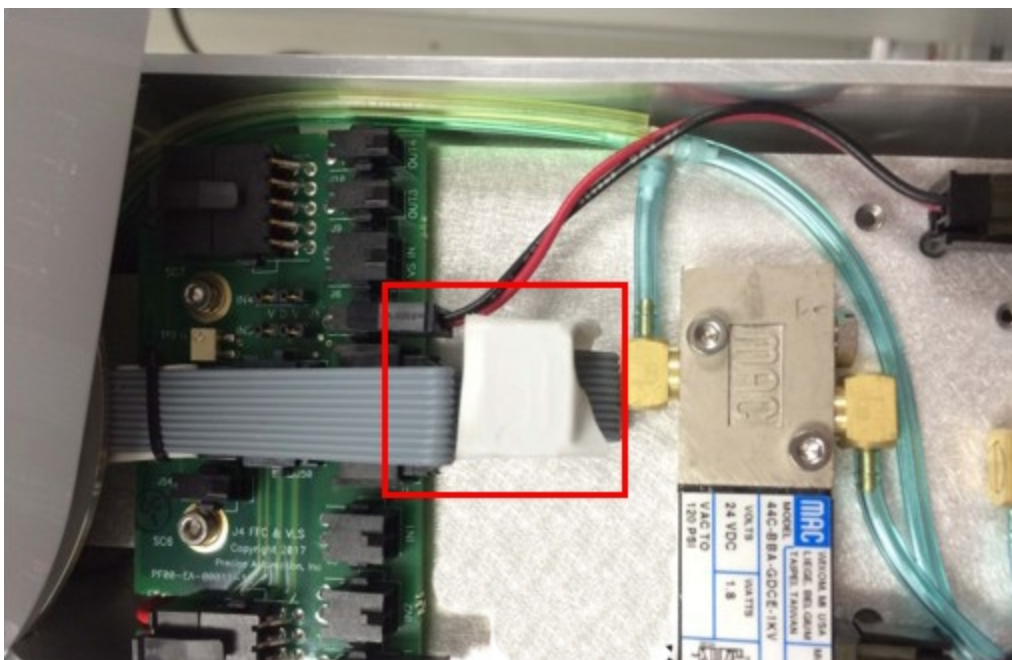
 Figure 5-6: Plug the Inside Connector into the J4 Motor Interface Board to Connect IO Signals. Tape Over the End of the Outside Connector.

While some grippers for OEM customers differ slightly from the following, in general for the pneumatic gripper controller digital output 1 will open the gripper. Controller digital input 1 goes high when the gripper is open and input 2 goes high when the gripper is closed. (See the section on controller digital input and output signals for the software assignments of these signals.)

For vacuum grippers, digital output 1 turns on vacuum and digital output 2 turns on blow off air. Digital input 4 goes high when vacuum is present.
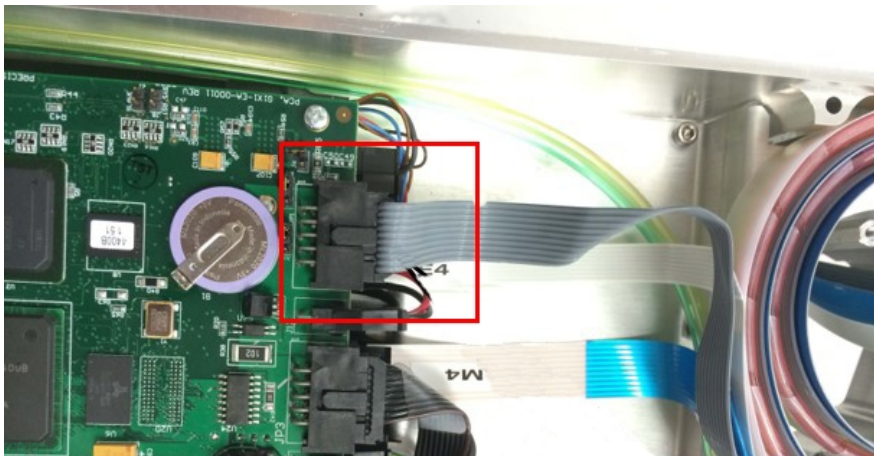
Figure 5-7: Inner Link Cable Position for RS485 Servo Gripper Signals
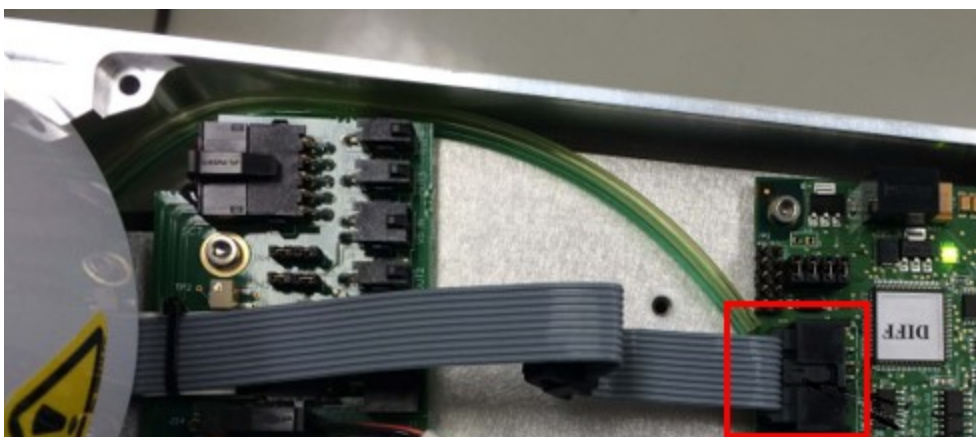
Figure 5-8: Outer Link Cable Position for RS485 Servo Gripper Signals

G1400B Dedicated Digital Outputs

The G1400B adds one dedicated digital output to the standard dedicated signals found in the Guidance Controller, as shown in Table 5-2.

Users normally do not need to modify the setting of the status lamp (IO 20) since the standard robot software typically manages this signal. However, this signal can be manually altered under program control via the GPL SIGNAL.DIO instruction. This is controlled by DOUT signal 20 (Table 5-2). If direct control of this signal is desired, DataID 235 should be set to 0 and signal number 20 should be controlled by program control.

Table 5-2: DOUT Signal 20

Signal Number	I/O	Label	Description
20	O		Outer Link status lamp. Set to 1 to turn on the lamp. Normally parameter "Power State DOUT" (DataID 235) is set to this signal number so that the Outer Link lamp displays the robot power state.

Appendices

Appendix B: Conditions of Acceptability

For use only in (or with) complete equipment, when the acceptability of the combination is determined by UL Solutions. The following items should be evaluated to determine the acceptability for use in the end product:

- These devices shall be installed in compliance with the requirements for enclosure, mounting, electrical spacing, and segregation of the end-use equipment.

- The power supply and drives in this report have been evaluated as a system and they shall be installed accordingly. The suitability of any other installation manner shall be determined in the end product application.

- The front face has not been evaluated as an ultimate or part of the overall enclosure.

- Wait 7 minutes after removal of power before servicing equipment for the system capacitance to discharge below a 50 VDC level.

- The input and output connectors are suitable for factory wiring only.

- The spacings have been evaluated to Pollution Degree 2.

- These devices are intended for installation in a Pollution Degree 2 environment.

- These models are suitable for operation in a surrounding air temperature of 40°C.

- This system, power supply and motor drives, are suitable for use on a circuit capable of delivering not more than 1,500 rms symmetrical amperes, 250 VAC maximum.

- The Motor Drive Series 6000 shall be provided with complete instructions as to how to replace the battery cell ending with the statement: "Dispose of used cell promptly. Keep away from children. Do not disassemble and do not dispose of in fire."

- Peak currents indicated in the nomenclature are temporary over-currents only, not intended for use as continuous ratings.

Appendix C: Product Specifications

General Specification	Range
PERFORMANCE	
Payload	0.5 kg including the Servo Gripper
Typical Speed at TCP	500 mm/sec
Max Acceleration	2000 mm/sec2
Repeatability	±0.090 mm
RANGE OF MOTION	
Joint 1 (Z-axis)	400, 750, 1160 mm
Joint 2	± 93°
Joint 3	± 168°
Joint 4	± 960° with servo gripper
Horizontal Reach	(Standard Horizontal Reach, with included Servo Gripper) 579 mm (Extended Horizontal Reach, with included Servo Gripper) 734 mm
COMMUNICATIONS	
General	100 Mb Ethernet, TCP/IP EtherNet/IP
Operator Interface	Web-based operator interface
Digital I/O	12 inputs, 8 outputs at base of robot optically isolated, 24 V @ 100 mA Remote I/O available
FACILITIES	
Power	90 to 264 VAC, auto selecting, 50-60 Hz 100-250 watts typical operation
Controller Mounting	Embedded into robot base
Weight	Standard Reach/Extended Reach 20 kg / 25 kg (400 mm Z-axis) 25 kg / 30 kg (750 mm Z-axis) 65 kg / 35 kg (1160 mm Z-axis)
SOFTWARE	

General Specification	Range
Programming	Guidance Motion (web interface) Guidance Programming Language (GPL) TCP Command Server (TCS)
Enhanced Functions	Hand Guiding (standard) Horizontal Compensation (compliant insertion) Z-Height Detection
PERIPHERALS AND ACCESSORIES	
General	23 N Servo Gripper Gripper Fingers for SBS plates, tubes, vials... Remote I/O (RIO)
Linear Rail	1.0, 1.5, and 2.0 M travel Speed up to 750 mm/sec Repeatability: ±0.05 mm
Vision	IntelliGuide Vision Gripper, 23 N
TEMPERATURE	
Indoor	For indoor use only
Ambient Temperature	0°C to 40°C
Humidity Range	10 to 75%, non-condensing, non-corrosive
Storage and Shipment Temperature	-25°C to +55°C

Appendix D: Environmental Specifications

NOTE: Our PreciseFlex robots are powered by 24 VDC and 48 VDC low-voltage DC power supplies with built-in overcurrent protection. For this reason, the PreciseFlex robots do not have an SCCR.

The PreciseFlex Robots must be installed in a clean, non-condensing environment with the following specifications:

Table 6-1: Environmental Specifications

General Specification	Range & Features
Ambient temperature	4º C to 40º C
Indoor use only	
Storage and shipment temperature	-25º C to +55º C
Humidity range	10 to 55%, non-condensing, non-corrosive
Altitude	Up to 3000 m
Voltage	100-240 VAC +/- 10%, 50/60 Hz
Mains cord rating, min	18 AWG, 3 conductor, 5 Amps min
Pollution Degree	2
Approved Cleaning Agents	IPA, 70% Ethanol/30% water, H2O2 Vapor up to 1000 ppm
IP rating	11
IK impact rating	IK08: 5 Joule

Appendix E: Spare Parts List

NOTE: Email support_preciseflex@brooksautomation.com for help replacing spare parts.

The part number format is:
- F0v-wwww-xy-zzzzz
- v - Major version - "X" for rev A; "B" for rev B; "C" for rev C
- wwww - Ship date,yymm, so 1207 means July 2012
- x is the controller rev
- y is the robot rev
- zzzzz - is a unique robot number.

Table 6-2: Spare Parts List

Description	Part Number	Rev C PN
Absolute Encoder Battery Assembly	PF0H-MA-00057	
J1 Motor Assembly	PF00-MA-00028	
J1 Stage 1 Belt	PF00-MC-X0021	
J1 Stage 2 Belt 400 mm	PF00-MC-X0022	
J1 Stage 2 Belt 750 mm	PF00-MC-X0023	
J2 200 W Motor Assembly 9 mm Pulley (Rev A)	PF02-MA-00009	
J2 200 W Motor Assembly 12 mm Pulley (Rev B, C)	PF00-MA-00029	
J2 Belt 12 mm wide (Rev B, C)	PF00-MC-X0081	
J2 Cam Follower for 12 mm belt (set of 2) (Rev B)	PF00-MA-00024	
J2 Cam Follower for 12 mm belt (set of 2) (Rev C)	PF00-MA-00062	Thrust Washers
J3 Motor Assembly	PF00-MA-00030	
J3 Belt - Standard Reach	PF00-MC-X0035	
J3 Belt - Extended Reach	PF00-MC-X0066	
J4 30 W Motor Assembly	PF00-MA-00031	
J4 Belt for Standard Reach	PF00-MC-X0004	
J4 Belt for Extended Reach	PF00-MC-X0065	
PF400 23 N Servo Gripper with Spring, without fingers	G1X0-EA-B1400-12A	
PF400 23 N Servo Gripper with Brake, without fingers	PF00-MA-00115	
Finger Claw Assembly - 23 N servo gripper fingers	PF0S-MA-00010	
G1400B Controller with advanced kinematics license	G1XF-EA-B1400-12A	
G1100T Slave Controller ("GSB3-SE") for Gripper	G1X0-EA-T1101-4	
G1100T Slave Controller ("GSB3-DIFF") for Rail	G1X0-EA-T1101-4D	
GIO Digital IO Board with pigtails	GIO1-EA-01102	
24 VDC Supply	PS10-EP-24150	
48 VDC Motor Supply	PS10-EP-48400	
Slip Ring Harness Assembly, 23 N Brake Gripper	PF04-MA-00002-E8	18Wire

Description	Part Number	Rev C PN
Slip Ring Harness Assembly, 23 N Spring Gripper	397515	18Wire
Harness, FFC, J4 Motor	PF0H-MA-00002-02	
Harness, FFC, J4 Encoder	PF0H-MA-00020-2	
Harness, Gripper Controller	PF0H-MA-00014	
J1 Motor Interface PCA	PF00-EA-00034	New
J2 Motor Interface PCA	PF00-EA-00030	
MIDS Interface PCA	PF00-EA-00035	
J4 Motor Interface PCA	PF00-EA-00036	New

Appendix F: Preventative Maintenance

For help with preventative maintenance, addressing error codes, or any other issue, contact support_preciseflex@brooksautomation.com.

Every one to two years, the following preventative maintenance procedures should be performed. For robots that are continuously moving 24 hours per day, 7 days a week at moderate to high speeds, a one-year schedule is recommended. For robots with low duty cycles and low to moderate speeds, these procedures should be performed at least once every two years.

Table 6-3: Preventative Maintenance, Checklist & Procedures

Check List	Procedure If Problem Detected
Check all belt tensions	Re-tension if necessary
Check air harness tubing in elbow if present, and theta axis for any wear	Replace if necessary
Replace timing belt in optional linear axis	Typically every 6,000 hours of continuous operation
Check all joints in "free mode" for low bearing friction and any sticking.	If a bearing is getting stiff, return to factory for bearing replacement.
Check second stage (long) Z belt for any squeaking	If noisy, add thick grease to front and rear edge of belt if necessary. (Shell 222 XP or similar). Z timing belt can get stiffer over time (2-3 years) and occasionally start squeaking against pulley flanges.
Check if front cover is rattling	If so, check .125in ID by .062in thick O rings on dowel pins in base plate under front cover for any deterioration and replace if necessary.
Check Cam Followers on J2 timing belt for grease leaking or discoloration.	Replace if necessary. Note that earlier units had a 9 mm wide timing belt and later units (2014, 2015) have a 12 mm wide timing and the Cam Followers are different. See Spare Parts List.
Replace slip ring	For units with electric gripper shipped before April 2015, replace the slip ring. For units shipped after April 2015, replace the slip ring every third inspection test.

Table 6-4: PF400 PM Schedule by Revision Level & Date

Component	Expected Life	Action
Revision A, Serial Numbers F0X...		
Slip ring	1-3 years	Replace component
Ethernet cable (flat black Startech)	2-4 years	Replace component
J2 timing belt (9 mm)	2 years	Replace component
Motors with pulleys (bonded)	2-10 years	Replace assembly if bond broken

Component	Expected Life	Action
Harness (any FFC cables)	4-10 years	Replace robot*
Revision B, Serial Numbers F0B...		
Slip ring	3-5 years	Replace component
Ethernet cable (flat black Startech)	2-4 years	Replace component
Revision C, Serial Numbers F0C...		
Slip ring	3-5 years	Replace component
J2 timing belt	5 years heavy use	Replace component
Ethernet cable (flat black Startech before Nov 2017)	2-4 years	Teflon replacement 10 years

---

NOTE: *Because of EOL parts, this repair requires the replacement of a large amount of electronics and harnessing. Replacing the robot may be more cost effective.

Table 6-5: Linear Axis PM Schedule

Component	Expected Life	Action
Revision A, Serial Numbers FXX...		
Timing belt	6,000 hours/duty cycle*	Replace component
E-chain harnessing	2-4 years	Replace all cables
Ethernet cable	2-4 years	Replace component
Tape seals	2-4 years	Replace component
Tape seal rollers	2-4 years	Replace component
Revision B Feb 2015, Serial Numbers FXB...		
Timing belt	6,000 hours/duty cycle*	Replace component
E-chain harnessing	20,000 hours	Replace all cables
Ethernet cable before May 2017	2-4 years	Teflon replacement 10 years

*For example, if rail operates at 50% duty cycle, expected life is 12,000 hours

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NOTE: See the PreciseFlex 400 Service Procedures manual for detailed instructions on how to perform each inspection and maintenance operation.

Appendix G: Example Performance Level Evaluation

Example Workcell Description

A PF400 Plate Handler moves 80 gram plastic trays from storage racks to an instrument and back to the storage racks. Gripper is an electric parallel jaw gripper with maximum 23 N of gripping force for plastic trays and is spring loaded so it will not drop trays if power fails. Robot motion is programmed with approach point 50 mm above the instrument tray and final motion into instrument is made at 50 mm/sec. Lowest storage rack position is 50 mm above table surface. See the example workcell below in Figure 6-1.

Figure 6-1: Example PF400 Workcell, Courtesy of Biosero

Normal Operator Interaction with Robot

Teaching locations in workcell by hand guiding or teach pendant. Maximum robot forces under manual control from PF400 Table 1 are 60 N. Pausing robot and removing racks from workcell with no safety interlocks in workspace. Robot is stopped.

Possible Low Frequency (rare) Interaction with Robot

Untrained operator reaches into workcell while robot is moving and robot collides with operator. Maximum free space collision force from PF400 Table 1 is 80 N. Untrained operator reaches into workcell while robot is moving into instrument tray and hand is trapped between robot and instrument tray. From PF400 Table 1 max trapping force in downwards Z direction at 50 mm/sec (10% of max speed of 500 mm/sec) is 80 N. Performance Level: From the above, based on ISO 13849-1:2006:

S is S1, as possible operator collision forces will not injure operators.
F is F1 as normal operation does not involve collisions with robot.
P is P1 as the robot does not make unexpected motions.

So PL is "a," and even a Category B controller is sufficient, given the low speeds and small possible collisions forces involved which cannot injure an operator. (See 5.2.3 under EN/ISO 10218-1:2011).

Appendix H: TUV Verification of PF400 Collision Forces

Figure 6-2: TUV Verification of PF400 Collision Forces, Page 1 of 4

1 Description of the test subject

1.1 Function

Manufacturer's specification for intended use:
According to the user manual

Manufacturer's specification for predictive misuse:
According to the user manual

1.2 Technical Data: Witnessed Force Testing as a Collaborative Robot

PF400 Test Data
160112
PF400 standard length
PAC Files PreciseFlex 400S Handler Prod_B40

Configuration	J1	J2	J3	J4	J5	Rail	XYZ
10351	9000	0	0	0	0	0	
10352	-4500	0	0	0	0	0	
Peak current, tcnts	32767	31491	32767	19450	4004	22933	
PID Error (10352) % of peak	14%	100%	100%	100%	100%	100%	
Standard Config for crash tests	131	-52	112	299	80	-230	
Config J2 Rotation (max velocity)	131	-27	53	335	80	NA	
100% Joint Speed	500mm/s	360deg/s	720deg/s	720deg/s	400mm/s	750mm/s	
100% Joint Accel	3500	1500	2300	4000	10000	1000	
100% XYZ Speed							500
100% XYZ Accel							2500

	PF400 Collisions at Gripper								Z decel	
Speed	Manual Control			Free Space Collision			Rigid Surface Collision			100%	40%
	X	Y	-Z	X	Y	-Z .5kg	X	Y	J2 rot	-Z .5kg	-Z .5kg
100%	62	20	60	31	52	75	98	97	163	206	153
80%	61	20	57	31	43	77	85	76	116	175	135
60%	62	19	58	23	31	92	72	64	97	144	114
40%	61	20	57	22	32	79	60	37	68	112	101
20%	61	19	57	22	30	73	50	22	33	94	86
10%	58	29	57	22	29	66	46	22	21	79	75

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Figure 6-3: TUV Verification of PF400 Collision Forces, Page 2 of 4

Linear Rail Collisions at Z Column			
Speed	Manual	Free	Rigid
	X	X	X
100%	148	159	235
80%	149	162	205
60%	143	160	184
40%	141	168	177
20%	140	164	155
10%	140	157	150

2.   Order

2.1   Date of Purchase Order, Customer's Reference

January 4, 2016

2.2   Receipt of Test Sample, Location

N/A

2.3   Date of Testing and/or Evaluation

January 11 thru 12, 2016

2.4   Location of Testing and/or Evaluation

At Precise Automation, Fremont, CA

2.5   Points of Non-compliance or Exceptions of the Test Procedure and/or
Evaluation procedure.

Positive

3.   Test/Evaluation Results

3.1   Positive Test/Evaluation Results

- Operation safety during single failure
- Mechanical safety – Applied forces: Manual Control, Free Space Collision and
  Rigid Surface Collision

3.2   Points of non-compliance according to the test/evaluation specification

None

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Figure 6-4: TUV Verification of PF400 Collision Forces, Page 3 of 4

4. **Remark**

The user manual has been examined according to the minimum requirements described in the product standard. The manufacturer is responsible for the accuracy of further particulars as well as of the composition and layout.

4.1 **Remarks to Factory**

None

5. **Documentation**

None

6. *Summary*

TÜV America, Inc.
Product Safety Services

January 18, 2016

Engineer: Rick Grumski

Technical Report checked: Chris Caserta

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Figure 6-5: TUV Verification of PF400 Collision Forces, Page 4 of 4

Appendix I: Table A2 from ISO/TS 15066: 2016, Biomechanical Limits

Body region		Specific body area		Quasi-static contact		Transient contact	
				Maximum permissible pressure [a] p_s N/cm^2	Maximum permissible force [b] N	Maximum permissible pressure multiplier [c] P_T	Maximum permissible force multiplier [c] F_T
Skull and forehead [d]	1	Middle of forehead		130	130	not applicable	not applicable
	2	Temple		110		not applicable	
Face [d]	3	Masticatory muscle		110	65	not applicable	not applicable
Neck	4	Neck muscle		140	150	2	2
	5	Seventh neck muscle		210		2	
Back and shoulders	6	Shoulder joint		160	210	2	2
	7	Fifth lumbar vertebra		210		2	2
Chest	8	Sternum		120	140	2	2
	9	Pectoral muscle		170		2	
Abdomen	10	Abdominal muscle		140	110	2	2
Pelvis	11	Pelvic bone		210	180	2	2
Upper arms and elbow joints	12	Deltoid muscle		190	150	2	2
	13	Humerus		220		2	
Lower arms and wrist joints	14	Radial bone		190	160	2	2
	15	Forearm muscle		180		2	
	16	Arm nerve		180		2	

[a] These biomechanical values are the result of the study conducted by the University of Mainz on pain onset levels. Although this research was performed using state-of-the-art testing techniques, the values shown here are the result of a single study in a subject area that has not been the basis of extensive research. There is anticipation that additional studies will be conducted in the future that could result in modification of these values. Testing was conducted using 100 healthy adult test subjects on 29 specific body areas, and for each of the body areas, pressure and force limits for quasi-static contact were established evaluating onset of pain thresholds. The maximum permissible pressure values shown here represent the 75th percentile of the range of recorded values for a specific body area. They are defined as the physical quantity corresponding to when pressures applied to the specific body area create a sensation corresponding to the onset of pain. Peak pressures are based on averages with a resolution size of 1 mm^2. The study results are based on a test apparatus using a flat (1,4 × 1,4) cm (metal) test surface with 2 mm radius on all four edges. There is a possibility that another test apparatus could yield different results. For more details of the study, see Reference [5].

[b] The values for maximum permissible force have been derived from a study carried out by an independent organization (see Reference [6]), referring to 188 sources. These values refer only to the body regions, not to the more specific areas. The maximum permissible force is based on the lowest energy transfer criteria that could result in a minor injury, such as a bruise, equivalent to a severity of 1 on the Abbreviated Injury Scale (AIS) established by the Association for the Advancement of Automotive Medicine. Adherence to the limits will prevent the occurrence of skin or soft tissue penetrations that are accompanied by bloody wounds, fractures or other skeletal damage and to be below AIS 1. They will be replaced in future by values from a research more specific for collaborative robots.

[c] The multiplier value for transient contact has been derived based on studies which show that transient limit values can be at least twice as great as quasi-static values for force and pressure. For study details, see References [2], [3], [4] and [7].

[d] Critical zone (*italicized*)

Figure 6-6: Biomechanical Limits, Page 1 of 2

Body region		Specific body area	Quasi-static contact		Transient contact	
			Maximum permissible pressure a p_s N/cm^2	Maximum permissible force b N	Maximum permissible pressure multiplier c P_T	Maximum permissible force multiplier c F_T
Hands and fingers	17	Forefinger pad D	300	140	2	2
	18	Forefinger pad ND	270		2	
	19	Forefinger end joint D	280		2	
	20	Forefinger end joint ND	220		2	
	21	Thenar eminence	200		2	
	22	Palm D	260		2	
	23	Palm ND	260		2	
	24	Back of the hand D	200		2	
	25	Back of the hand ND	190		2	
Thighs and knees	26	Thigh muscle	250	220	2	2
	27	Kneecap	220		2	
Lower legs	28	Middle of shin	220	130	2	2
	29	Calf muscle	210		2	

a   These biomechanical values are the result of the study conducted by the University of Mainz on pain onset levels. Although this research was performed using state-of-the-art testing techniques, the values shown here are the result of a single study in a subject area that has not been the basis of extensive research. There is anticipation that additional studies will be conducted in the future that could result in modification of these values. Testing was conducted using 100 healthy adult test subjects on 29 specific body areas, and for each of the body areas, pressure and force limits for quasi-static contact were established evaluating onset of pain thresholds. The maximum permissible pressure values shown here represent the 75th percentile of the range of recorded values for a specific body area. They are defined as the physical quantity corresponding to when pressures applied to the specific body area create a sensation corresponding to the onset of pain. Peak pressures are based on averages with a resolution size of 1 mm^2. The study results are based on a test apparatus using a flat (1,4 × 1,4) cm (metal) test surface with 2 mm radius on all four edges. There is a possibility that another test apparatus could yield different results. For more details of the study, see Reference [5].

b   The values for maximum permissible force have been derived from a study carried out by an independent organization (see Reference [6]), referring to 188 sources. These values refer only to the body regions, not to the more specific areas. The maximum permissible force is based on the lowest energy transfer criteria that could result in a minor injury, such as a bruise, equivalent to a severity of 1 on the Abbreviated Injury Scale (AIS) established by the Association for the Advancement of Automotive Medicine. Adherence to the limits will prevent the occurrence of skin or soft tissue penetrations that are accompanied by bloody wounds, fractures or other skeletal damage and to be below AIS 1. They will be replaced in future by values from a research more specific for collaborative robots.

c   The multiplier value for transient contact has been derived based on studies which show that transient limit values can be at least twice as great as quasi-static values for force and pressure. For study details, see References [2], [3], [4] and [7].
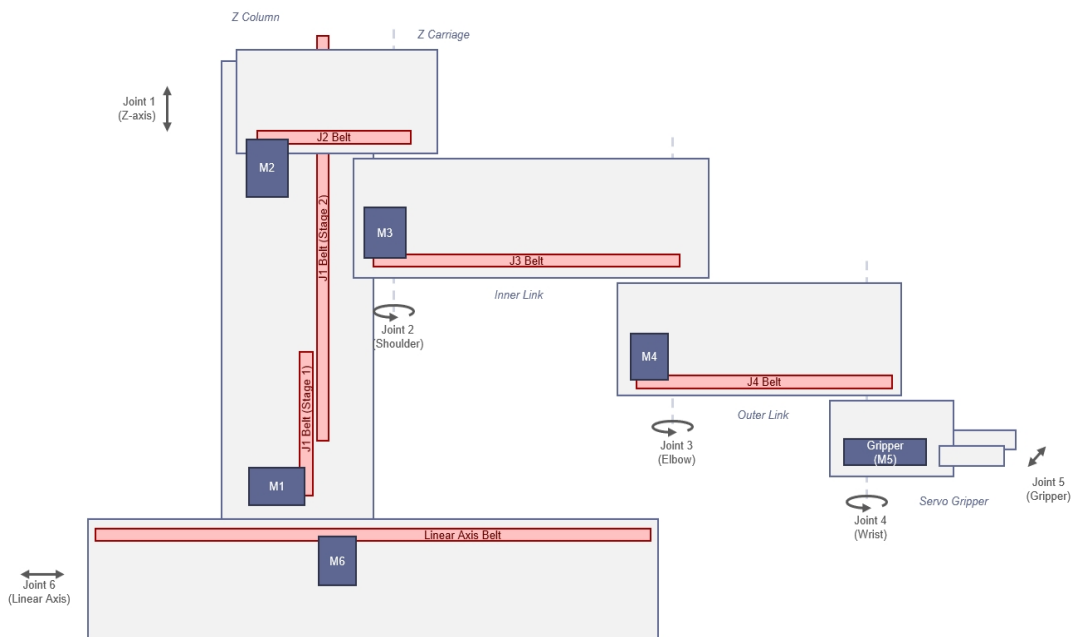
d   Critical zone (italicized)

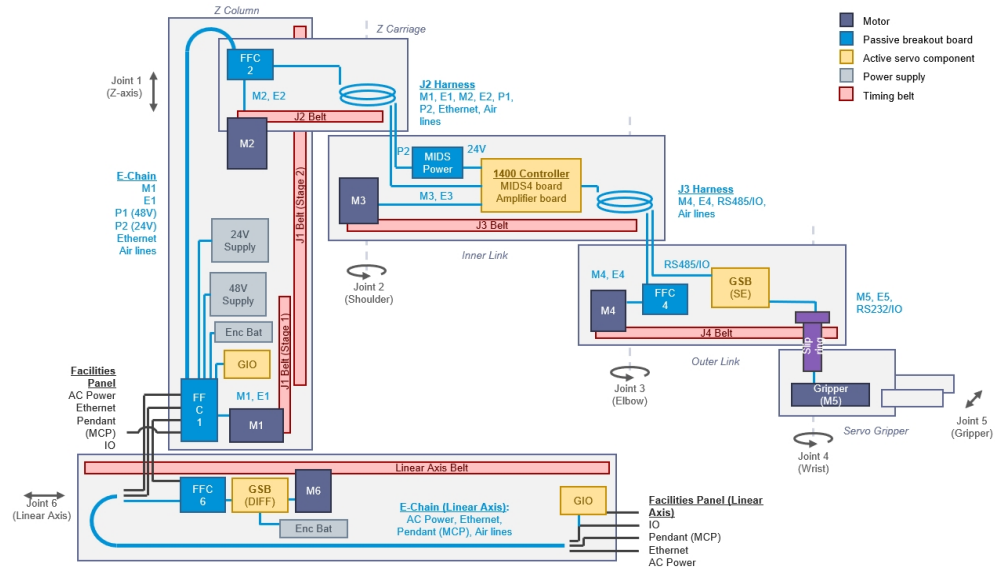**Figure 6-7: Biomechanical Limits, Page 2 of 2**

Appendix J: Robot Anatomy
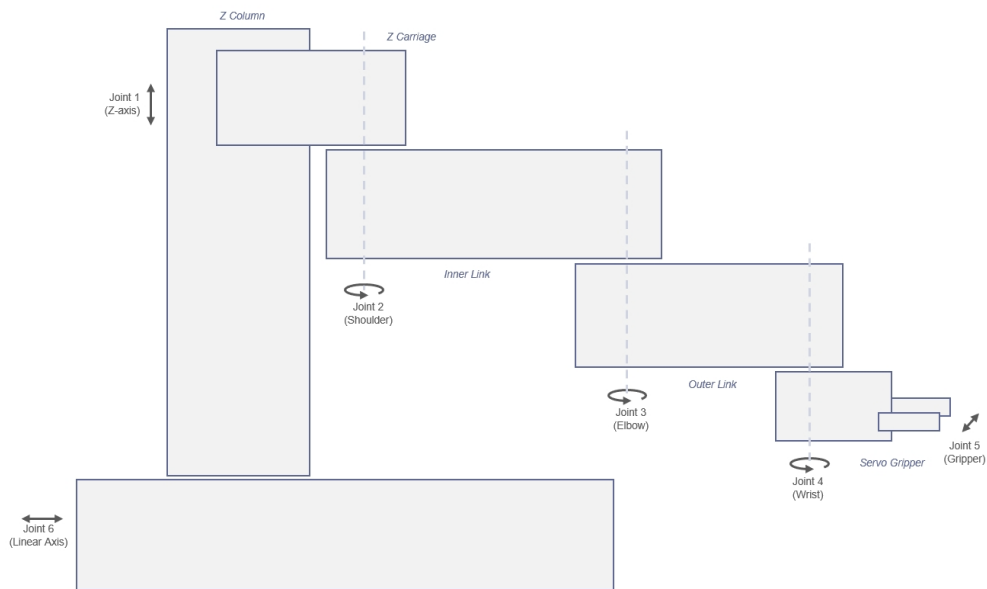
PreciseFlex 400 Anatomy – Joints

PreciseFlex 400 Anatomy – Belt Drives

PreciseFlex 400 Anatomy – Power

PreciseFlex 400 Anatomy - No Rail

PreciseFlex 400 Anatomy with Rail