



# **PreciseFlex<sup>TM</sup> 400 Robot**

## **User Manual**

**Part Number 0000-DI-00010, Revision D**



# Brooks Automation

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B	EC154084	April 19, 2024	Divided the document into two manuals: a user manual and a service manual.	M. Ashenfelder

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# 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.

 <b>DANGER</b> Read the Safety Chapter	
<p>Failure to review the <i>Safety</i> chapter and follow the safety warnings can result in serious injury or death.</p> <ul style="list-style-type: none"><li>• All personnel involved with the operation or maintenance of this product must read and understand the information in this safety chapter.</li><li>• Follow all applicable safety codes of the facility as well as national and international safety codes.</li><li>• Know the facility safety procedures, safety equipment, and contact information.</li><li>• Read and understand each procedure before performing it.</li></ul>	

## Authorized Personnel Only

This product is intended for use by trained and experienced personnel. Operators must comply with applicable organizational operating procedures, industry standards, and all local, regional, national, and international laws and regulations.

## 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

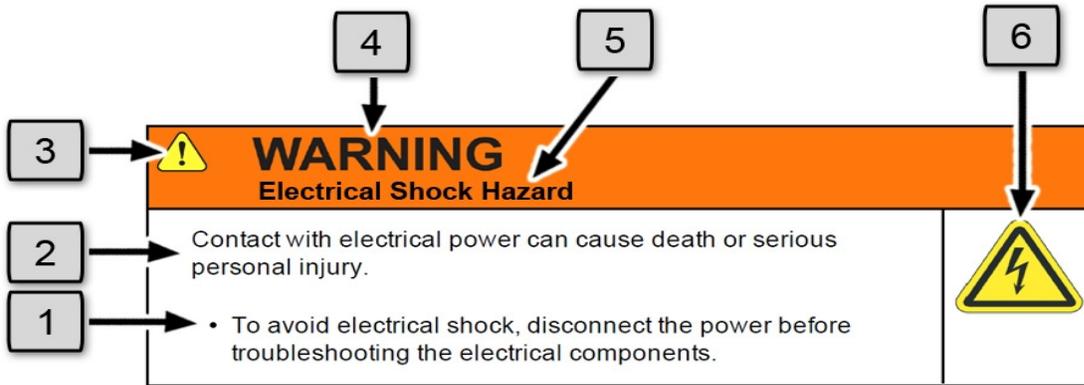
## Signal Words and Colors

Signal words and colors inform of the level of hazard.

	<p>Danger indicates a hazardous situation which, if not avoided, <b>will result in serious injury or death.</b></p> <p>The Danger signal word is white on a red background with an exclamation point inside a yellow triangle with black border.</p>
	<p>Warning indicates a hazardous situation which, if not avoided, <b>could result in serious injury or death.</b></p> <p>The Warning signal word is black on an orange background with an exclamation point inside a yellow triangle with black border.</p>
	<p>Caution indicates a hazardous situation or unsafe practice which, if not avoided, <b>may result in minor or moderate personal injury.</b></p> <p>The Caution signal word is black on a yellow background with an exclamation point inside a yellow triangle with black border.</p>
	<p>Notice indicates a situation or unsafe practice which, if not avoided, <b>may result in equipment damage.</b></p> <p>The Notice signal word is white on blue background with no icon.</p>

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

## General Safety Considerations

 <b>WARNING</b> Software	
<p>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.</p> <ul style="list-style-type: none"> <li>• Only operate the robot with its covers installed.</li> <li>• Guarantee that safety controller features are in place (for example, an emergency stop button and protective stop).</li> <li>• Regularly test safety components to prove that they function correctly.</li> </ul>	 

 <b>WARNING</b> <b>Robot Mounting</b>	
<p>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.</p> <ul style="list-style-type: none"><li>• Always mount the robot on a secure test stand, surface, or system before applying power.</li></ul>	

 <b>WARNING</b> <b>Do Not Use Unauthorized Parts</b>	
<p>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.</p> <ul style="list-style-type: none"><li>• Do not use unauthorized parts.</li><li>• Confirm that the correct robot application is being used.</li></ul>	

 <b>WARNING</b> <b>Magnetic Field Hazard</b>	
<p>This product contains magnetic motors that can be hazardous to implanted medical devices, such as pacemakers, and cause personal harm, severe injury, or death.</p> <ul style="list-style-type: none"><li>• Maintain a safe working distance of 30 cm from the motor when with an energized robot if you use a cardiac rhythm management device.</li></ul>	

 <b>CAUTION</b> <b>Unauthorized Service</b>	
<p>Personal injury or damage to equipment may result if this product is operated or serviced by untrained or unauthorized personnel.</p> <ul style="list-style-type: none"><li>• Only qualified personnel who have received certified training and have the proper job qualifications are allowed to transport, assemble, operate, or maintain the product.</li></ul>	

 <b>CAUTION</b> <b>Damaged Components</b>	
<p>The use of this product when components or cables appear to be damaged may cause equipment malfunction or personal injury.</p> <ul style="list-style-type: none"><li>• Do not use this product if components or cables appear to be damaged.</li><li>• Place the product in a location where it will not get damaged.</li><li>• Route cables and tubing so that they do not become damaged and do not present a personal safety hazard.</li></ul>	

 <b>CAUTION</b> <b>Inappropriate Use</b>	
<p>Use of this product in a manner or for purposes other than for what it is intended may cause equipment damage or personal injury.</p> <ul style="list-style-type: none"><li>• Only use the product for its intended application.</li><li>• Do not modify this product beyond its original design.</li><li>• Always operate this product with the covers in place.</li></ul>	

 <b>CAUTION</b> <b>Seismic Restraint</b>	
<p>The use of this product in an earthquake-prone environment may cause equipment damage or personal injury.</p> <ul style="list-style-type: none"> <li>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.</li> </ul>	

## Mechanical Hazards

 <b>CAUTION</b> <b>Pinch Point</b>	
<p>Moving parts of the product may cause squeezing or compression of fingers or hands resulting in personal injury.</p> <ul style="list-style-type: none"> <li>Do not operate the product without the protective covers in place.</li> </ul>	

 <b>WARNING</b> <b>Automatic Movement</b>	
<p>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.</p> <ul style="list-style-type: none"> <li>Follow safe practices for working with energized products per the facility requirements.</li> <li>Do not rely on the system software or process technology to prevent unexpected product motion.</li> <li>Do not operate the product without its protective covers in place.</li> <li>While the collaborative robotics system is designed to be safe around personnel, gravity and other factors may present hazards and should be considered.</li> </ul>	

 <b>CAUTION</b> <b>Vibration Hazard</b>	
<p>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.</p> <ul style="list-style-type: none"><li>• Before energizing, ensure the robot is bolted to a rigid metal chamber or stand.</li></ul>	

## Mechanical Hazards

 <b>WARNING</b> <b>Potential Robot Movement</b>	
<p>The product has the potential for automatic motion that may cause death or serious injury.</p> <ul style="list-style-type: none"><li>• Avoid working inside the movement path or under extended components.</li><li>• Use physical barriers to prevent injury when working in the movement path.</li></ul>	

 <b>WARNING</b> <b>Moving Mechanisms</b>	
<p>Moving mechanisms do not have obstruction sensors and can cause death or serious injury.</p> <ul style="list-style-type: none"><li>• Be aware of the potential movement area of the product whenever power is applied.</li><li>• Never place any part of your body between the robot arms and fixed surfaces.</li><li>• Do not operate the robot without the guards and protective covers in place and all safety interlocks enabled.</li></ul>	 

 <b>WARNING</b> <b>Unplanned Robot Motion</b>	
<p>Brooks motion software and motion processor are not safety certified to protect the user from unplanned or faulty automatic robot motion which may cause death or serious injury.</p> <ul style="list-style-type: none"> <li>• Be aware that unplanned robot motion may occur.</li> <li>• Know and stay out of the robot's range of motion.</li> <li>• Place physical barriers to prohibit others from entering the working range of the robot.</li> <li>• Follow safe practices for working with energized robots.</li> <li>• Do not rely on the system software or processor technology to prevent unexpected robot motion</li> </ul>	 

 <b>WARNING</b> <b>Entrapment</b>	
<p>Entrapment by this product can cause death or serious injury. To avoid entrapment by this product, follow these steps:</p> <ul style="list-style-type: none"> <li>• Assess the product and identify any components that may cause entrapment.</li> <li>• Ensure safety personnel is observing any procedure that may create an entrapment hazard.</li> <li>• Beware of any moving parts.</li> </ul>	 

 <b>CAUTION</b> <b>Pinch Point</b>	
<p>Moving parts of the product may cause squeezing or compression of fingers or hands resulting in personal injury.</p> <ul style="list-style-type: none"> <li>• Do not operate the product without the protective covers in place.</li> </ul>	

## Electrical Hazards

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

 <b>DANGER</b> Electrical Shock Hazard	
<p>Contact with electrical power can cause personal harm and serious injury.</p> <ul style="list-style-type: none"><li>• To avoid electrical shock, disconnect the power before troubleshooting the electrical components.</li><li>• Check the unit's specifications for the actual system power requirements and use appropriate precautions.</li><li>• Never operate this product without its protection covers on.</li></ul>	

 <b>WARNING</b> Electrical Burn	
<p>Improper electrical connection or connection to an improper electrical supply can result in electrical burns resulting in equipment damage, serious injury, or death.</p> <ul style="list-style-type: none"><li>• Always provide the robot with the proper power supply connectors and ground that are compliant with appropriate electrical codes.</li></ul>	

 <b>WARNING</b> Electrical Fire Hazard	
<p>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.</p> <ul style="list-style-type: none"><li>• Use a fire extinguisher designed for electrical fires (Class C in the US and Class E in Asia).</li><li>• It is the facility's responsibility to determine if any other fire extinguishers are needed for the system that the robot is in.</li></ul>	

## 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

 <b>CAUTION</b> <b>Heavy Lift Hazard</b>	
<p>Failure to take the proper precautions before moving the robot could result in back injury and muscle strain.</p> <ul style="list-style-type: none"> <li>• Use a lifting device and cart rated for the weight of the drive or arm.</li> <li>• Only persons certified in operating the lifting device should be moving the product.</li> </ul>	

 <b>CAUTION</b> <b>Tipover Hazard</b>	
<p>This product has a high center of gravity which may cause the product to tip over and cause serious injury.</p> <ul style="list-style-type: none"> <li>• Always properly restrain the product when moving it.</li> <li>• Never operate the robot unless it is rigidly mounted.</li> </ul>	

 <b>CAUTION</b> <b>Trip Hazard</b>	
<p>Cables for power and communication and facilities create trip hazards which may cause serious injury.</p> <ul style="list-style-type: none"><li>• Always route the cables where they are not in the way of traffic.</li></ul>	

## Emergency Stop Circuit (E-Stop)

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

 <b>WARNING</b> <b>Emergency Stop Circuit</b>	
<p>Using this product without an emergency stop circuit may cause personal injury.</p> <ul style="list-style-type: none"><li>• Customer is responsible for integrating an emergency stop circuit into their system.</li><li>• Do not override or bypass the emergency stop circuit.</li></ul>	

## Recycling and Hazardous Materials

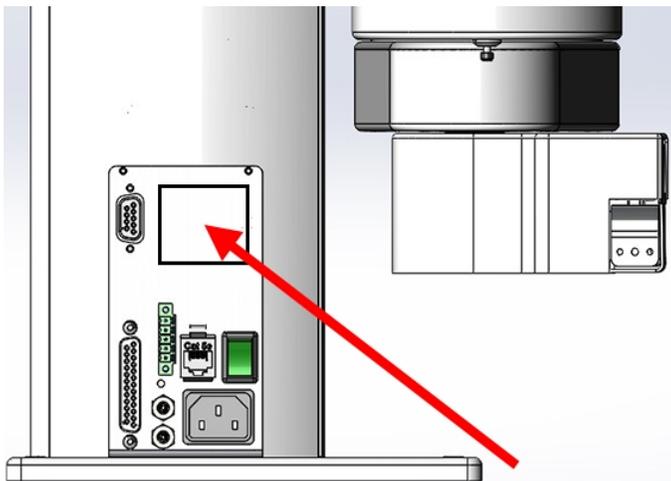
Brooks Automation complies with the EU Directive 2002/96/EU Waste Electrical and Electronic Equipment (WEEE).

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.com](mailto:support@preciseflex.com).

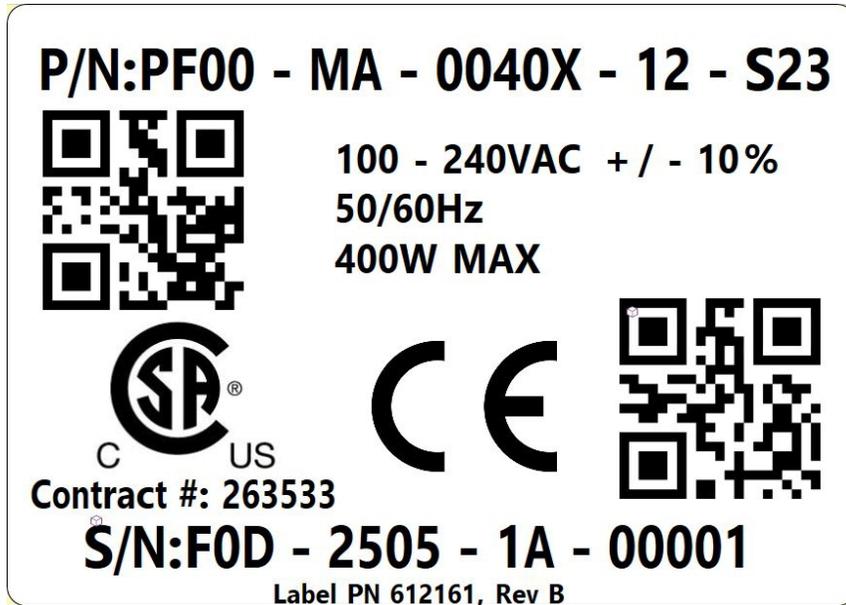
## 2. Overview

### 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**



Sample robot product label

## Example Sections from the Product Label

### Product Number

**P/N:PF00 - MA - 0040X - 12 - S23**

In the example above, the first line of the label -- Product Number (P/N) -- describes:

- PF00 = PreciseFlex 400
- MA = Machine Assembly
- 0040 = PreciseFlex 400
- X = Extended reach
- 12 = 1160 mm Z Stroke
- S23 = 23 Newton Servo Gripper

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

[\*\*\*the first four digits]

**AAAA** [1st set of four digits]

CODE	PRODUCT
PP00	PrecisePlace 100
PP0S	PrecisePlace 100 (w/ Servo Gripper)
PF0S	PreciseFlex 400
PF30	PreciseFlex 3400
PFC0	C-Series
PF0X	Linear Rail
<b>BB</b> [1st set of two digits]	
CODE	TYPE
MA	Machine Assembly, an assembly of individual components
<b>CCCC</b> [2nd set of four digits]	
CODE	TYPE
0040	PreciseFlex 400 or 3400
0003	PreciseFlex c3
0005	PreciseFlex c5
0008	PreciseFlex c8A
0001	PreciseFlex c10
<b>D</b> [1st single digit]	
CODE	ARM LENGTH
0 / S	Standard
X / L	Extended / Long
A	Articulated
<b>E or EE</b>	
NUMBER	AXIS SIZE
4	400 mm Z Stroke
7	750 mm Z Stroke
12	1160 mm Z Stroke
05	500 mm Z stroke
10	1000 mm Z stroke

14	1420 mm Z stroke
10	1.0 m rail
15	1.5 m rail
20	2.0 m rail
<b>FF</b> (Optional)	
<b>CODE</b>	<b>Description</b>
LV	Low Voltage
<b>GGGG</b> (Optional)	
[empty]	ISO flange
s23	23 Newton servo gripper
v23	23 Newton Vision Gripper
s23D	23 Newton dual servo gripper
s60	60 Newton servo gripper
v60	60 Newton Vision Gripper

**S/N:F0D - 2505 - 1A - 00001**

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

- F0D = PreciseFlex 400, Revision D
- 25 = Two-Digit Year Code
- 05 = Two-Digit Month Code
- 1A = Revision
- 00001 = Robot Unit Build Number

Refer to the Serial Number (SN) table below for detailed information about the Serial Number naming scheme.

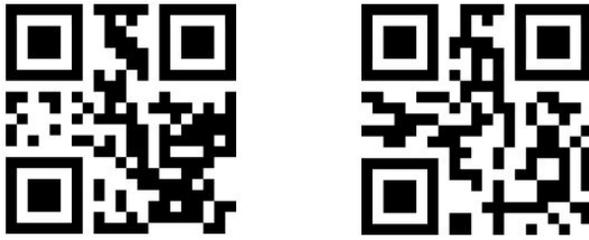
The robot serial number follows the scheme: **AAA** - **BBCC** - **EF**-**GGGG**. Refer to the table below to decode this scheme.

**AAA** [1st three digits]

CODE	MODEL
P00	PrecisePlace 100
P0S	PrecisePlace 100 (w/ Servo Gripper)
F0C/F0X	PreciseFlex 400
F0D	PreciseFlex 400, Revision D
F3C	PreciseFlex 3400
C03	PreciseFlex c3
C05	PreciseFlex c5
C8A	PreciseFlex c8A
C10	PreciseFlex c10
FC0	C-Series
FXB	Linear Rail
<b>BBCC</b>	
CODE	MFG DATE CODE (START DATE)
BB	Two-Digit Year Code
CC	Two-Digit Month Code
<b>EF</b>	
Code	Revision Code
E	Major Rev Code
F	Minor Rev Code Valid for Rev Code 9J and up
<b>GGGGG</b>	
G	Sequential Production Number

# Contract #: 263533

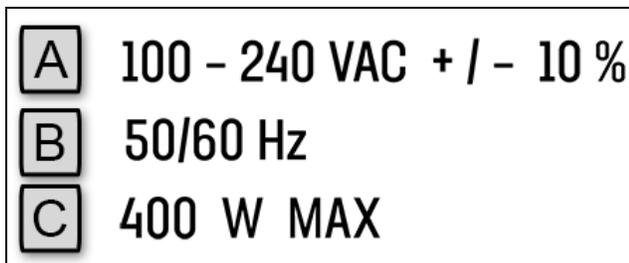
Brooks Automation's contract ID within the CSA group



QR codes linking to product number and serial number



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

---

## System Description and Overview

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

---

The PreciseFlex 400 robot (rev D) is a 4-axis robot that includes an embedded Guidance 4-axis motion controller, a 48 VDC motor power supply, and a 24 VDC logic power supply located inside the base of the robot. It may include a servo gripper and servo gripper controller.

The Z-axis of this robot is available with a vertical travel of 400, 750, or 1160 mm. The robot is designed for tabletop mounting and can carry a payload of up to 500 grams with an IntelliGuide servo gripper, or 1.2 kg without a gripper. These robots are quiet, with smooth operation, very reliable, and have excellent positioning repeatability. The robot axes are powered by brushless DC motors with absolute encoders. These robots are ideal for automating applications in the Life Sciences, Medical Products, Semiconductor, and Electronics industries.

Communications and hardware interfaces are included, for example RS-232 serial interface, RS-485 serial interface, Ethernet interface, and a number of digital input and output signals. The robot can be purchased with various peripherals.

The controller is programmed by means of a PC connected through Ethernet. There are three programming modes:

1. Embedded Language mode where the robot is programmed from Guidance Development Studio with:
  - GP Flow, an intuitive no-code, point-and-click application builder
  - GPL, a powerful, full-featured object oriented scripting language
2. a Digital I/O (PLC) mode, an Embedded Language mode
3. a PC Control mode where the PC issues commands to the robot via the TSC API.

When programmed in Embedded Language or PLC 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 browser-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.

When IntelliGuide Vision is used, there is an embedded iPC in the gripper that processes vision instructions. IntelliGuide Vision can be configured from Guidance Development Studio. During runtime, vision processes can be initiated from GP Flow, GPL, or TCS API.

## Release History

The PreciseFlex 400 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 (12 mm replaced 9 mm), 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.

Revision C was discontinued in June 2025 when Revision D was introduced. Revision D, designated by Serial Numbers F0D-wwww-xy-zzzzz, was released in the summer of 2025, consisting of a new controller processor that is 3X faster, 8X more memory, and built in digital I/O signals (8 inputs and 8 outputs). This robot revision also supports GPL 5.XX.

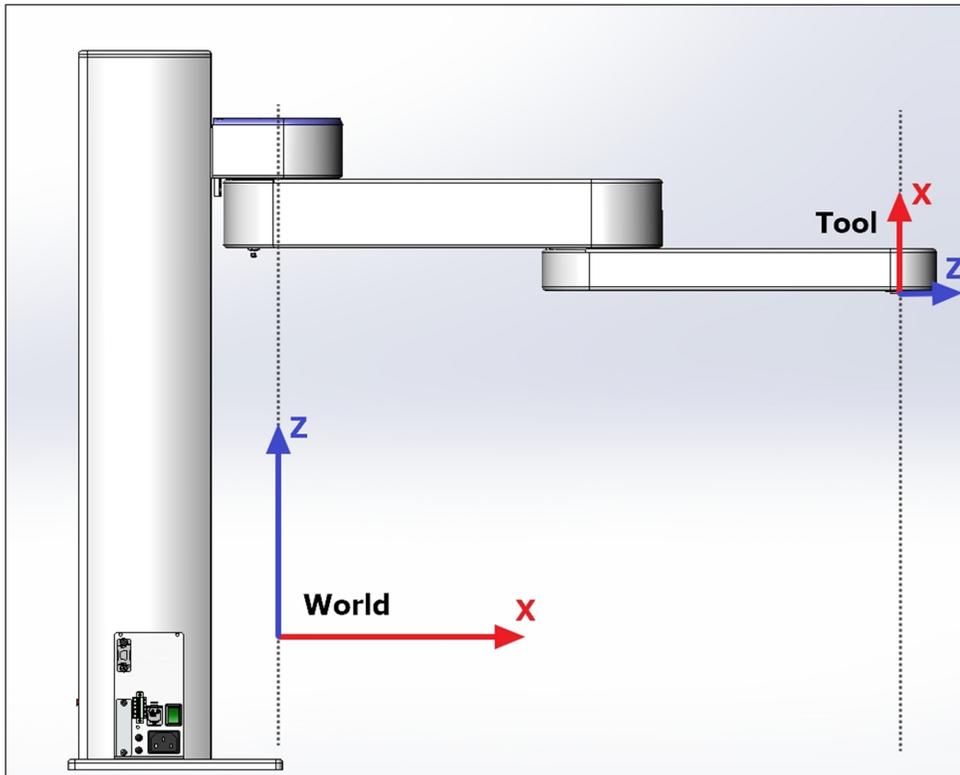
## System Diagram and Coordinate System

The robot operates using two key coordinate systems: World and Tool. The World coordinate system serves as the foundational reference point for all other coordinates. The Tool coordinate system is derived from the World coordinate system and represents the position and orientation of the robot's tool center point. Refer to the graphics below for a visual representation.

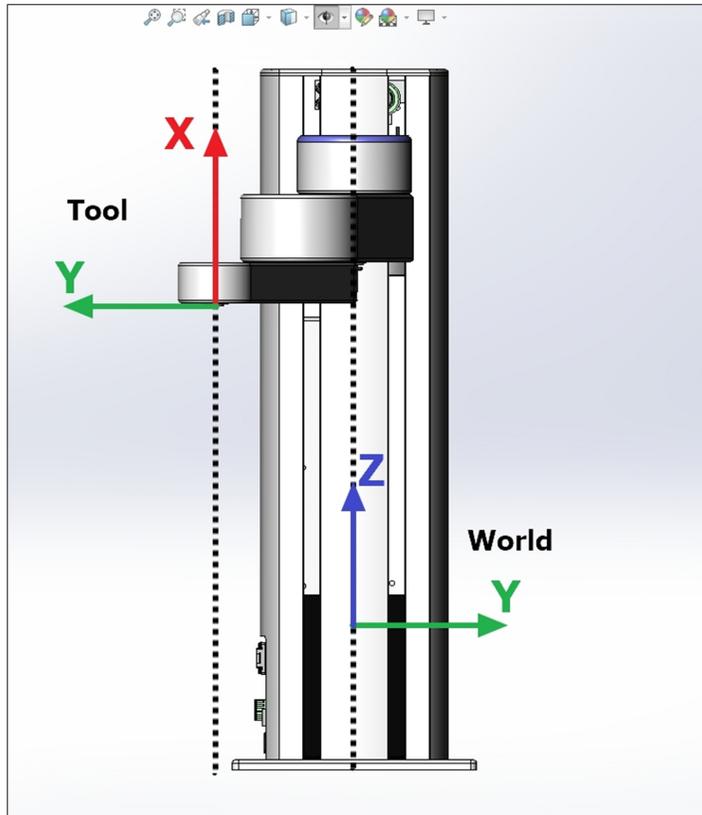
The Joint Coordinate system refers to how individual robot joints, or axes, move. While in Joint mode, only one joint will move at a time.

### World Coordinate System

The center of the World coordinate system is called the World Origin. It is commonly referred to as World (0,0,0,0,0,0) location. The location can be found where the center line of the robot's first rotary joint (for the PreciseFlex 400 that is the shoulder), intersects the plane of the robot's tool flange when the Z carriage is at its lowest point against the hard stop. This location may be different for other robot models.



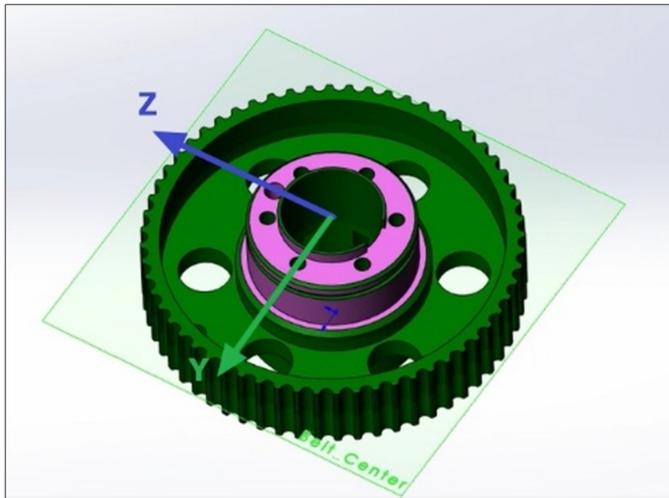
PreciseFlex 400 robot coordinate system - World



PreciseFlex 400 robot coordinate system - World

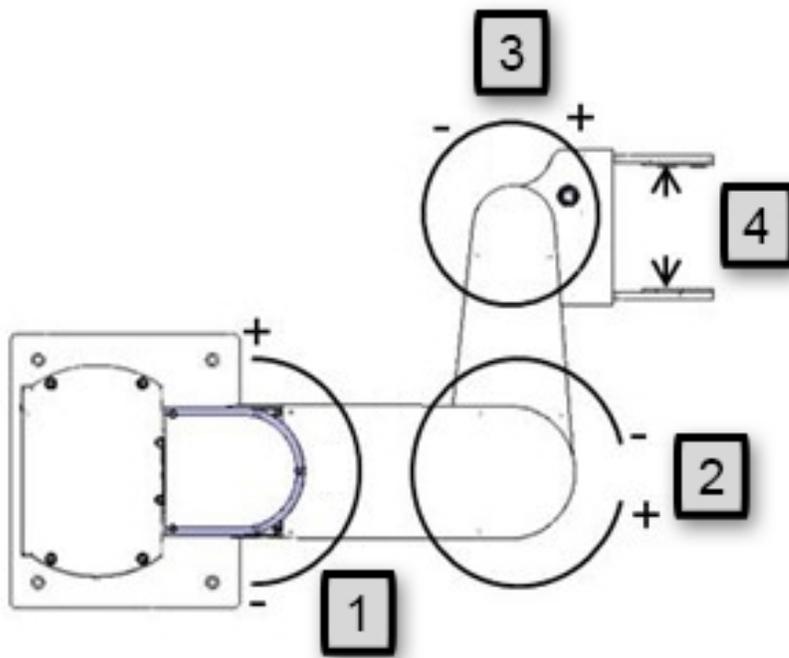
## Tool Coordinate System

The center of the Tool coordinate system is called 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 pulley

### Robot Joint Motion



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

Number	Axis	Description of Motion
<b>J3</b>	Wrist	Rotates +/- 970°
<b>J4</b>	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 the 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.

## J2

When the Inner Link is centered on its range of motion, the J2 rotary axis (shoulder) 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 pass 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 work cells.

## 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 servo 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. Pressing this button when 24 VDC power is on will release the Z-axis brake. 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.

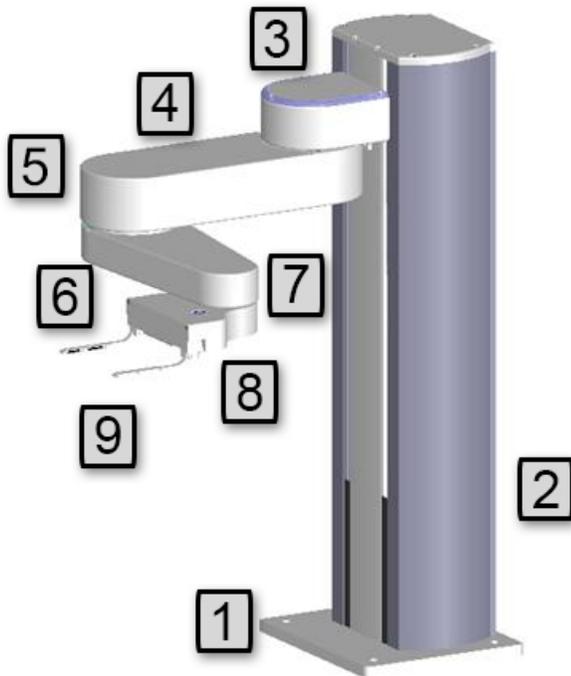
 <b>WARNING</b> Crush Hazard	
<p>Releasing the Z Axis brake causes the Z axis to fall due to gravity which may lead to death or personal injury.</p> <ul style="list-style-type: none"><li>• Only properly trained personnel should perform the Z Brake Release Procedure.</li><li>• Support the Z axis during release to avoid additional hazards.</li></ul>	

## System Components

### PreciseFlex 400 Robot

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

The PreciseFlex 400 robot is a 4-axis robot that may include a servo or pneumatic gripper.

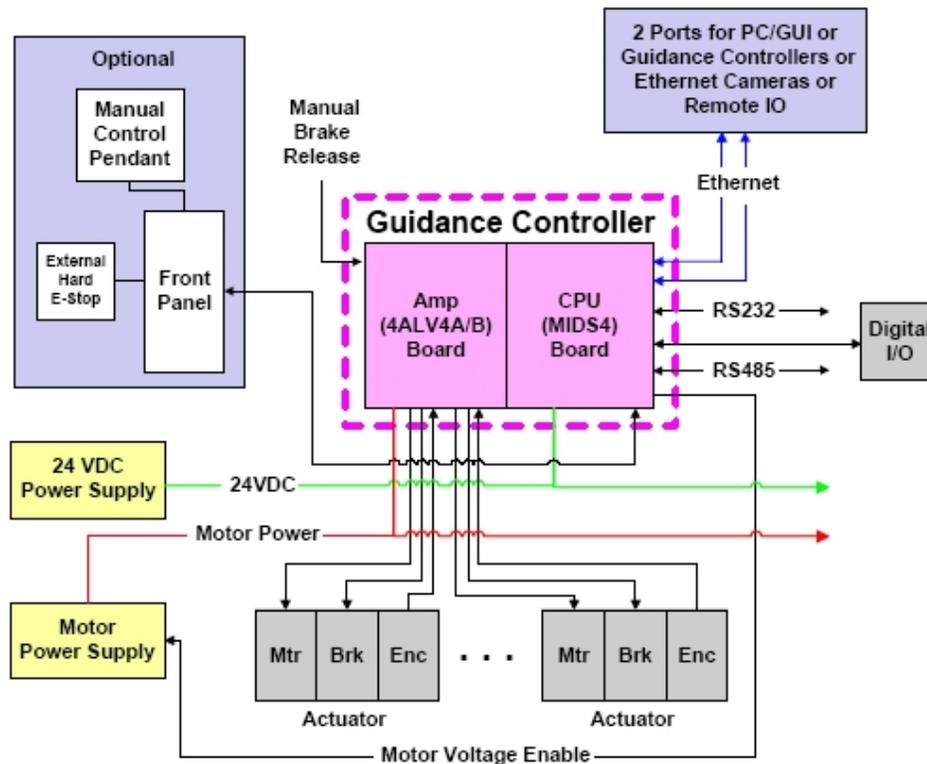


### PreciseFlex 400 Robot Details

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
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	IntelliGuide servo gripper mechanism
9	Fingers	Fingers for grasping Titer Plates

## Robot Controller

The robot's controller and power supplies are embedded into the robot Z column. The controller and power supplies are shown in the system diagram below.



For detailed information on the controller including interfacing information, see the *Guidance Controller User Manual*

## Linear Rail

The PreciseFlex 400 robot may be attached to an optional linear rail, in 1000 mm, 1500 mm and 2000 mm travel distances, extending the robot's horizontal reach.



See the *Linear Axis User Manual* for more information.

## Remote Control, E-Stop Box, and Manual Control Pendant

An external E-stop Box and portable Manual Control Pendant, which includes an E-stop button, are available as accessories to the PreciseFlex 400 robot. 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 Pendant can be plugged directly into the 9-pin D-sub 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 D-sub connector and each of these units provides the hardware signals to permit power to be enabled and disabled.



E-Stop Box



Manual Control Pendant

## AC Power Input

The PreciseFlex 400 robot accepts a range of AC input from single-phase 90 V to 264 V.

 <b>DANGER</b> High Voltage	
Disconnect AC power before removing covers or servicing the robot To prevent exposure to high voltage levels,	

## Digital I/O Embedded

The PreciseFlex 400 robot is provided with digital input and output (Digital I/O) signals to interface with peripheral devices. This includes 8 input and 8 output signals at base of robot for general devices in the workcell, and 3 input and 2 output signals at robot outer link for tooling I/O.

## Digital I/O Expansion

When the PreciseFlex robot is used with a linear rail, the GIO module can be added, providing Digital I/O signals at the linear rail end cap.

## IntelliGuide™ Servo Grippers

The PreciseFlex 400 robot can be ordered with an optional IntelliGuide s23 servo gripper. The IntelliGuide s23 gripper has a stroke of 60 mm and gripping force of 23 N. The gripper is ideal for

labware or small parts handling. When ordered with the robot, the gripper is installed at the factory. See the *IntelliGuide Gripper User Manual* for more details.

## IntelliGuide™ Vision Grippers

The PreciseFlex 400 robot can be ordered with an optional IntelliGuide v23 vision gripper. The IntelliGuide v23 gripper has similar specifications are the IntelliGuide s23 gripper, in addition to two 5 MP cameras and an embedded PC. The gripper is ideal for labware or small parts handling. When ordered with the robot, the gripper is installed, and the cameras are calibrated, at the factory.

See the *IntelliGuide Gripper User Manual* for more details.

## Machine Safety

### Safety and Agency Certifications

PreciseFlex robots 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 10218-1:2025](#) (formerly ISO 10218-1:2011) and [ISO 10218-2:2025](#) (formerly 10218-2:2011) *Robots for Industrial Environments, Safety Requirements*, [ISO/TS 15066](#) *Robots and Robotic Devices – Collaborative Robots*, and [ISO 13849-1:2023](#) (formerly ISO 13849-1:2006) *Safety of machinery — Safety-related parts of control systems*.

### 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, operators must 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 PreciseFlex 400 has 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 robot's working volume. Refer to the [ISO 10218-2:2025](#) (formerly 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.

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## Voltage and Power Considerations

The PreciseFlex 400 robot has an input voltage range of 100 to 240 VAC, +/- 10%, 50/60 Hz. The embedded robot controller has two DC power supplies, a 24 VDC power supply for the processor and user I/O and a separate 48 VDC motor power supply.

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  $\mu$ s) may not exceed 2000 V phase to ground, as per EN61800-3:1996. 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 inside the range of these hard stops.

The wrist axis has a slip ring when the IntelliGuide gripper is installed, allowing continuous rotation. However, soft-limit stops constrain rotation to plus or minus 970 degrees.

The robot has absolute encoders with battery backup. When robot power is turned off, the encoders keep track of joint positions. If the wrist axis is rotated manually beyond the 970-degree software limit stops, it will be necessary to manually 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 browser-based operator interface. (See the *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.

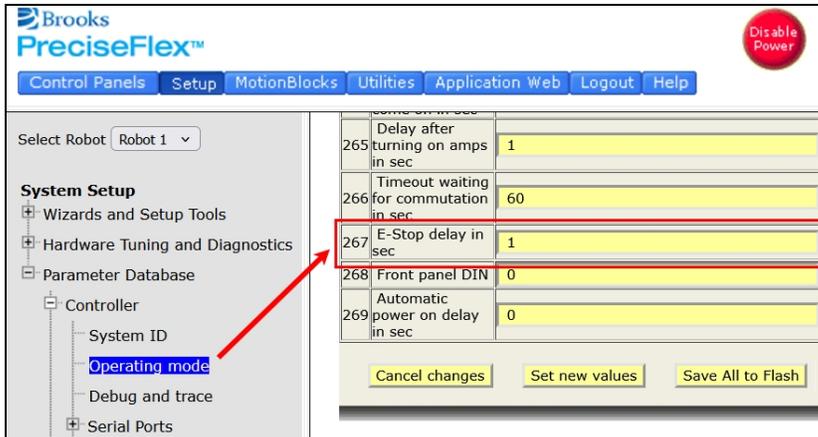
This function is like a "Hard E-stop" except that soft E-stop leaves High Power enabled to the amplifiers and is therefore used for less severe error conditions. Leaving power enabled is beneficial in that it prevents the robot axes from sagging and does not require high power to be manually re-enabled before program execution and robot motions are resumed. This function is also like 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 browser-based interface, go to **Admin > 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 1 ms.



**PreciseFlex 400 controller browser interface**

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 0.12 G, or 1250 mm/sec<sup>2</sup>. 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, 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.



**Z-axis brake release switch**

## 3. Installation

### Setup and Operation

1. Unpack the PreciseFlex robot.
2. Mount the robot.
3. Add or remove a gripper (optional). See the *IntelliGuide Gripper User Manual*.
4. Connect the power.
5. Connect the PreciseFlex robot to a PC or tablet, and open the browser-based interface (shown below).
6. Run the robot. See [Accessing the Controller Interface](#).

### Unpacking and Handling Instructions

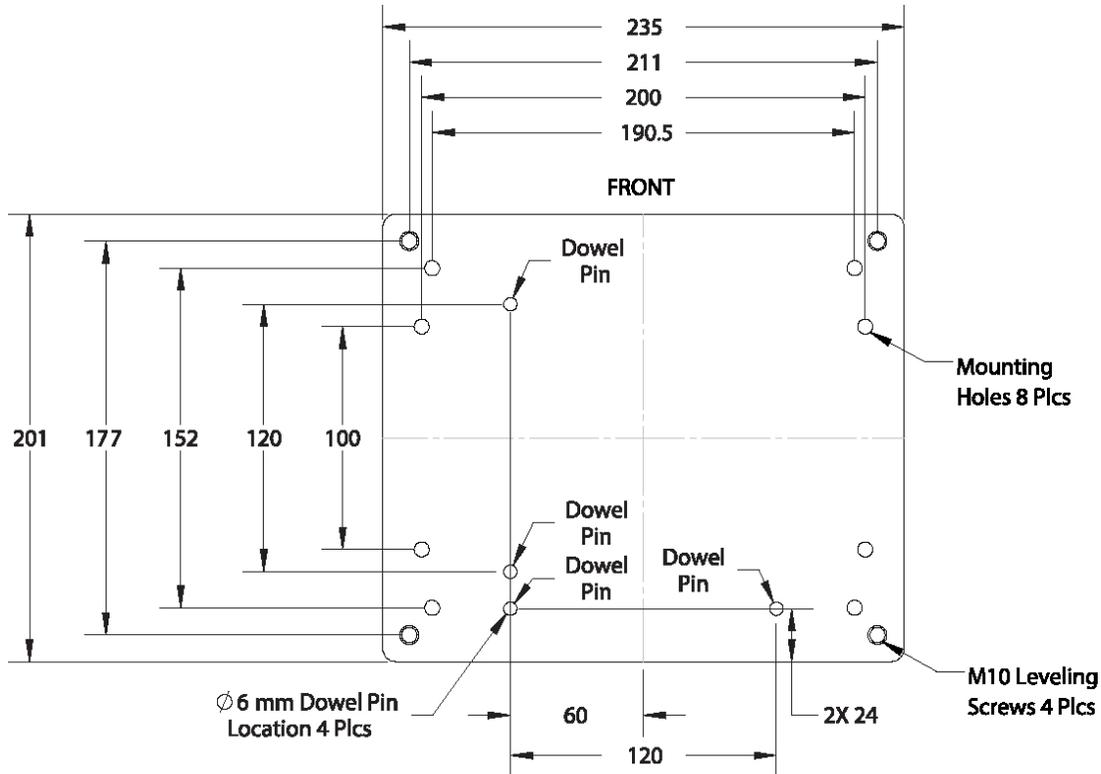
PreciseFlex robots are shipped in wooden crates with international ratings and foam inserts to protect the robots. Since the robots can weigh 25 kg or more, two people should move the robot to the installation location.

 <b>CAUTION</b> <b>Heavy Lift Hazard</b>	
<p>Failure to take the proper precautions before moving the robot could result in back injury and muscle strain.</p> <ul style="list-style-type: none"><li>• Use a lifting device and cart rated for the weight of the drive or arm.</li><li>• Only persons certified in operating the lifting device should be moving the product.</li></ul>	

## Mounting of Robot

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 surface. The Linear Rail contains mounting patterns for both M6 and ¼-20 screws.

PreciseFlex robots must be attached to a rigid surface that can withstand lateral forces of 200 N without moving or vibrating. The robot base has an integrated bolting pattern to accommodate (4) M6 socket head cap screw (SHCS) mounting screws located as shown below.

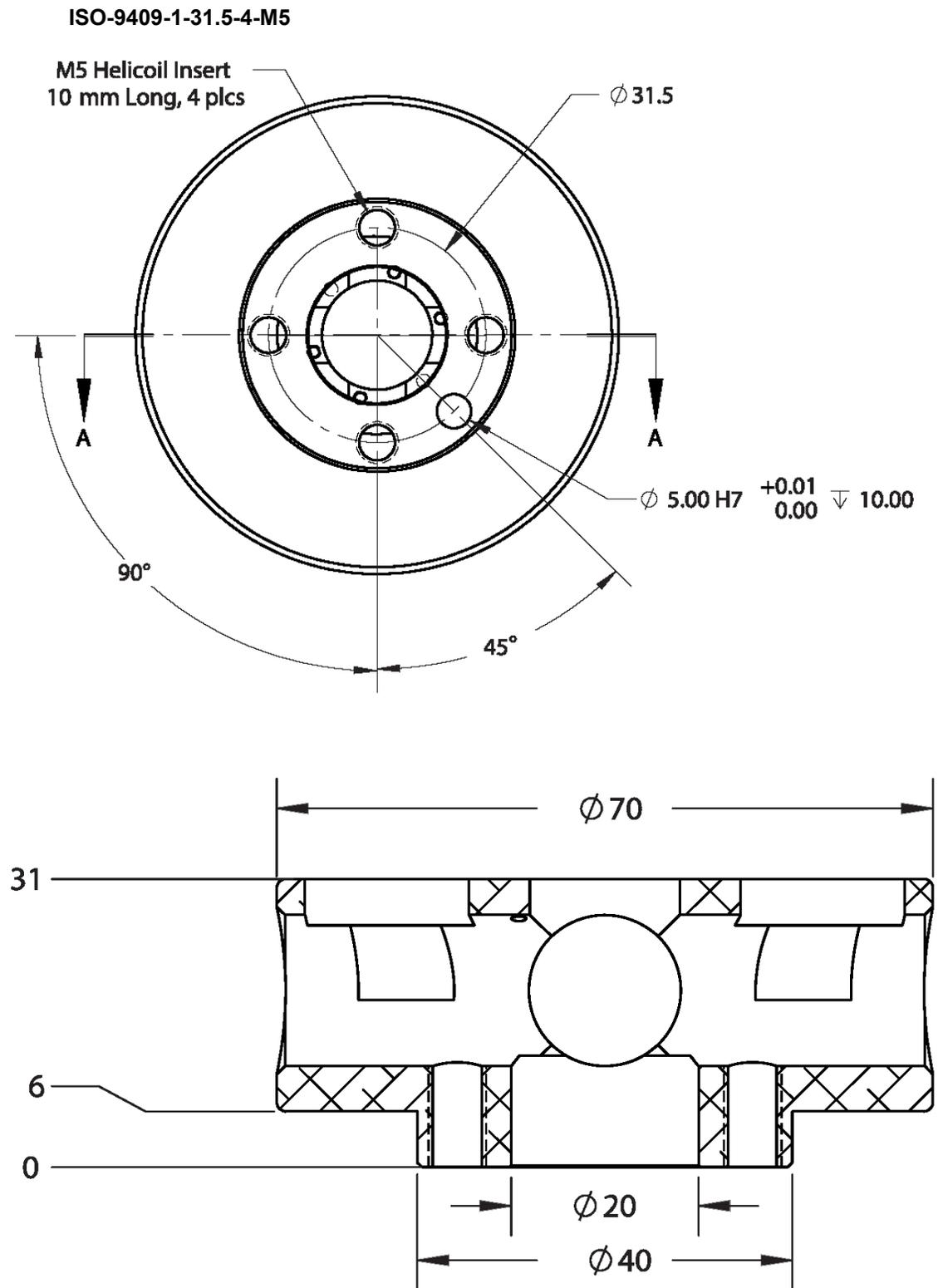


## Gripper/Tool Mounting

PreciseFlex robots are typically supplied with an IntelliGuide servo or vision gripper. The outer link has a tool flange for users to attach 3rd-party 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 slip ring are consumed by the IntelliGuide gripper, so any additional I/O wiring will have to be routed outside the robot wrist. For robots without the IntelliGuide 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 robot controller.

## ISO Flange for 3rd-Party End-of-Arm Tooling

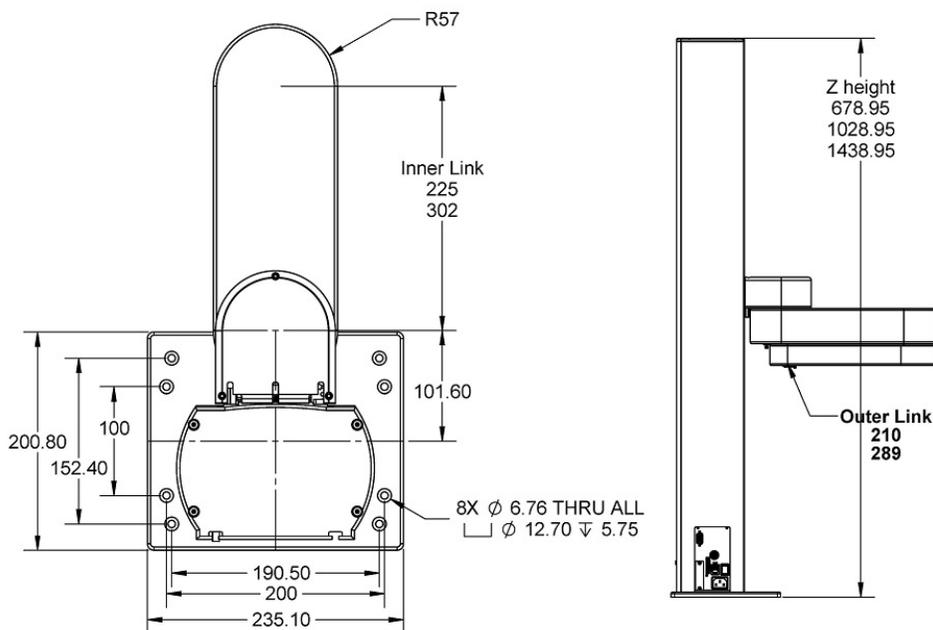


## IntelliGuide Gripper and Finger Mounting

When ordered with the robot, the IntelliGuide servo or vision gripper is installed at the factory. The gripper supports custom gripper fingers, which can vary with the application. See the IntelliGuide Gripper User Manual for more details.

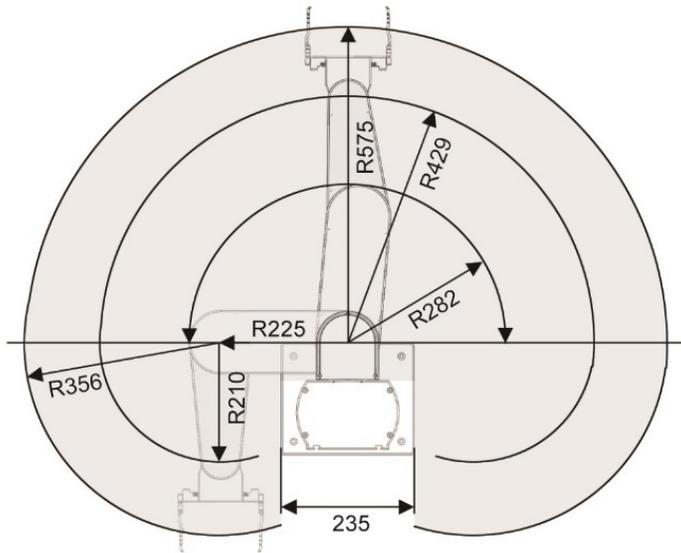
## Robot Dimensions

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

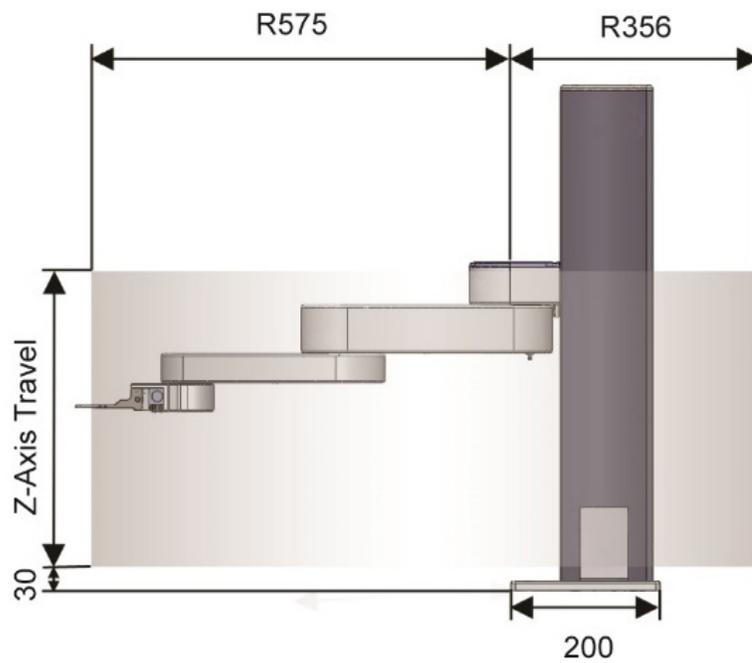


### System dimensions

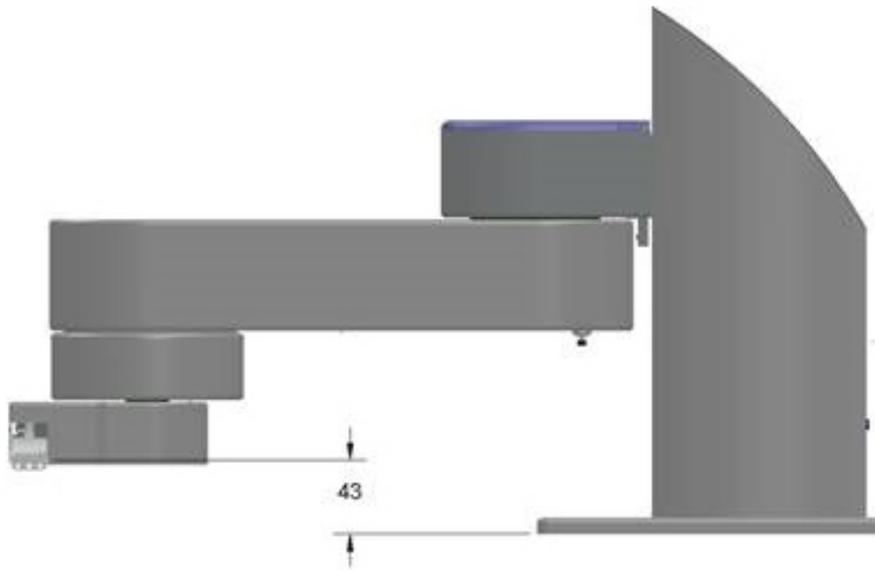
Mounting dimensions for Standard Reach are shown below. For XR robot, R575 increases to R731, and inner link length increases from 225 to 302 mm.



**Working volume**

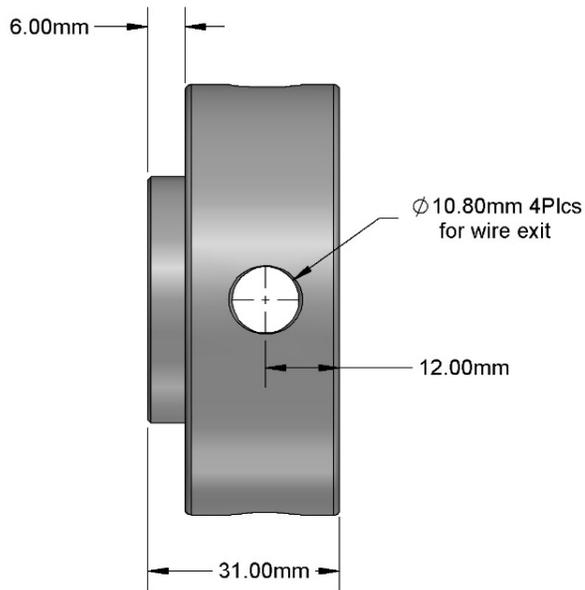
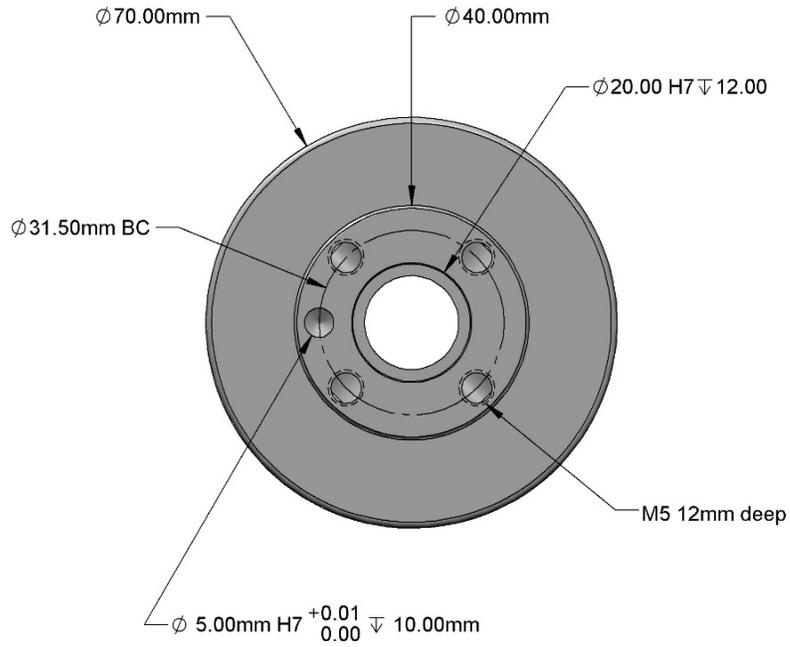


**Working volume**

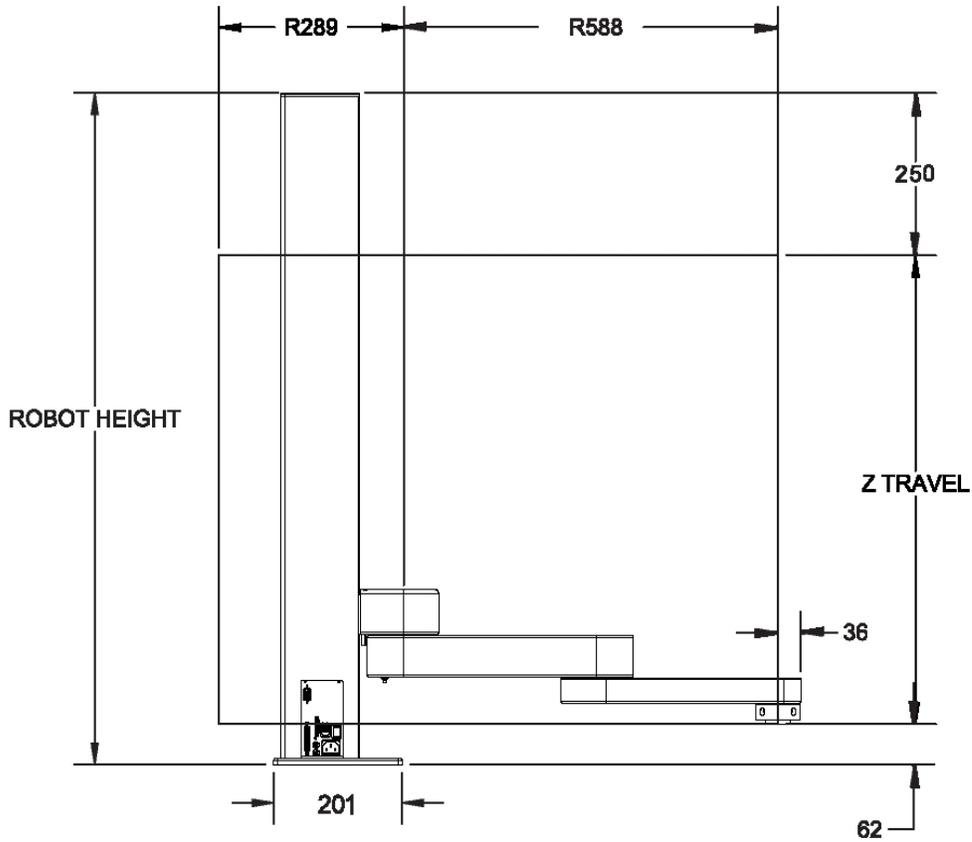


**Finger mount height from base, PreciseFlex 400**

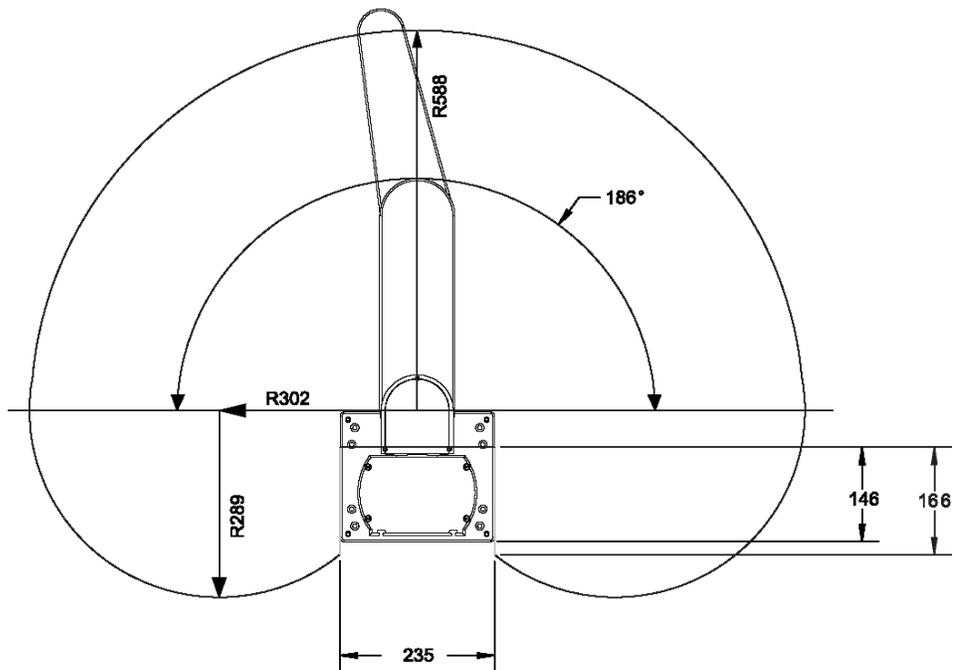




**ISO flange for 3rd-party end-of-arm tooling**



PreciseFlex 400 work envelope



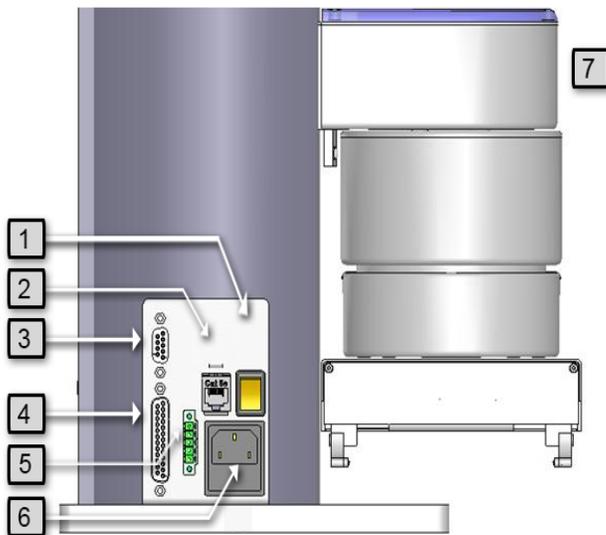
PreciseFlex 400 work envelope

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 includes:

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



Facilities Panel

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 manual-control pendant.

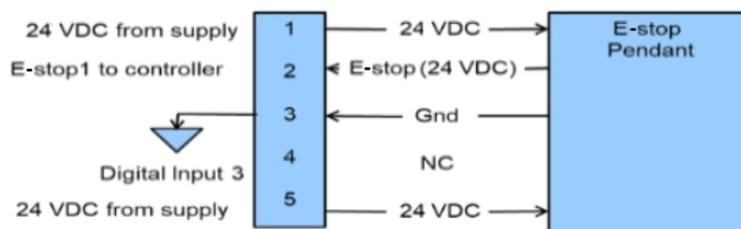
Annotation	Name	Description
4	25 Pin D-sub Connector	Digital I/O signals, 8 inputs, 8 outputs
5	E-stop Connector	E-stop and cell interlock signals
6	Power Entry Module	For IEC plug. Contains dual fuse drawer.
7	Power Status Light	Blinks to indicate power status

## AC Power Input

PreciseFlex robots have an input voltage 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.

## External E-Stop

An external E-stop switch can be connected to the robot at the green Phoenix E-stop connector (item 5 above) and the Manual Control Pendant 9-pin D-sub connector (item 3 above). This E-stop switch may be wired in series with other E-stop contacts.



An E-stop box is available as an option and can be plugged into either one of these two connectors. 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 D-sub connector that close the E-stop circuit. When the robot is mounted on a Linear Rail, the MCP Interface is extended to the end cap of the Linear Rail.

For applications requiring a hardware E-stop switch, an E-stop box can be purchased with the robot and plugged into the 9 pin D-sub connector at the robot base in the connector panel in the base casting. The E-stop box completes a circuit from Pin 1 (E-stop 1) to Pin 6 (FE Out 1) and from Pin 2 (E-stop 2) to Pin 7 (FE Out2) in this connector. If this circuit is not completed it is not possible to enable motor power to the robot. The FE Out signals allow each E-stop circuit to be toggled during the CAT3 startup sequence to make sure both circuits are working.

If no E-stop box or Manual Control Pendant is connected, jumpers must be connected between these four 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 manual control pendant can be plugged directly into the nine-pin D-sub connector mounted on the robot's Facilities Panel in the base of the robot.

The robot is shipped with a jumper plug in the nine-pin D-sub connector that satisfies 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 E-stop circuits.

## Digital Input and Output Signals

### Digital Input and Output Signals at the Robot Base

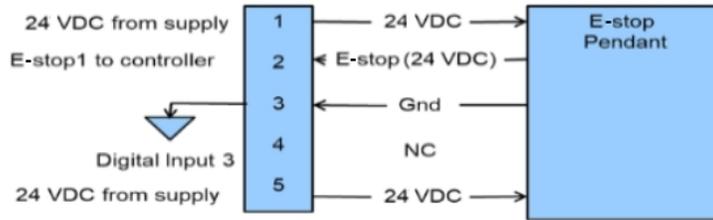
There are eight general-purpose, optically isolated digital input signals and eight digital output signals available at the robot base on the 25 pin D-sub connector. The inputs are set to sinking in the factory and can be changed in blocks of four by... The outputs are sourcing and cannot be changed.

### Digital Input and Output Signals at the Outer Link

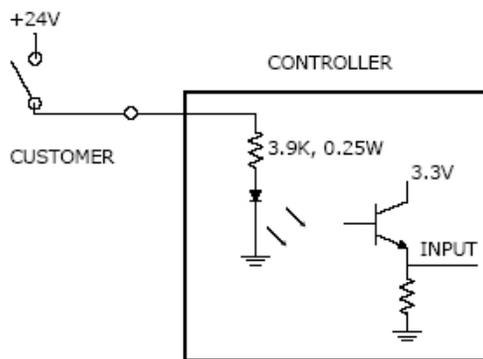
There are four general-purpose optically isolated digital input and four digital output signals available at the gripper control board in the robot outer link.

### Digital Input Signal on E-Stop Connector

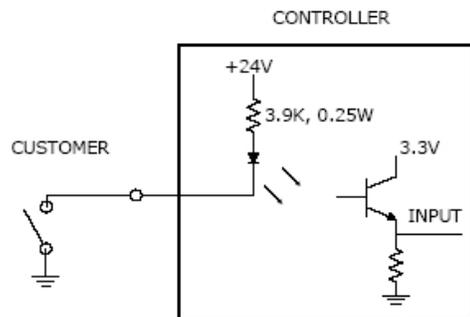
The PreciseFlex 400 robot provides one general-purpose optically isolated digital input signal at the Facilities Panel (in addition to those signals that are available at the Gripper Control Board). This line is accessed in the Phoenix 5-pin E-stop connector and is connected to Digital Input 3 in the controller.



This input signal can be configured as "sinking" or "sourcing." 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."



**Sinking digital input**



**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 Controllers User Manual*.

## Ethernet Interface

PreciseFlex robots include an Ethernet switch with two 10/100 Mbit Ethernet ports. This enables the robot to be interfaced with external Ethernet devices. 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 other Ethernet devices.

One Ethernet port is available via an external RJ45 connector at the robot base (item 2 above). This port is typically used to interface the robot to a PC. The second Ethernet port is available inside the inner link of the robot and can be used to connect items that are mounted on the robot. A PC connected to the Ethernet plug on the robot base can communicate with the robot's controller as well as the device connected to the other Ethernet port..

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

## RS-232 Serial Interface in the Robot Inner Link

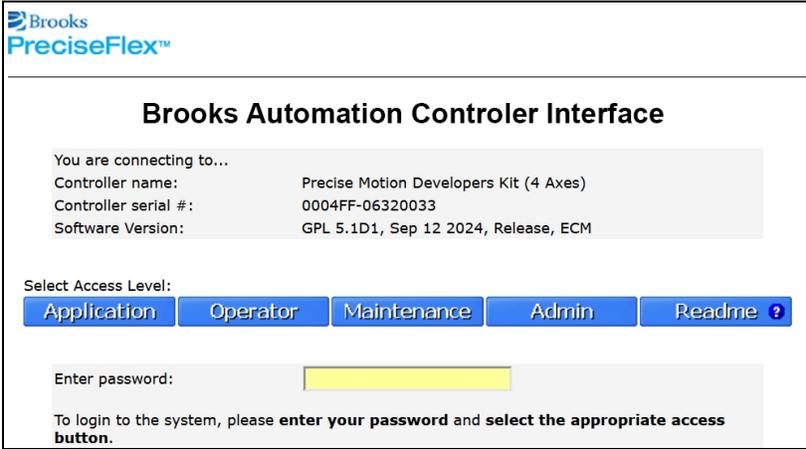
The PreciseFlex robot includes a standard RS-232 serial line equipped with hardware or software flow control. However, this port is only available from the inner link of the robot and is not brought out to any outside connector on this robot. This port can be used to communicate to the system serial 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).

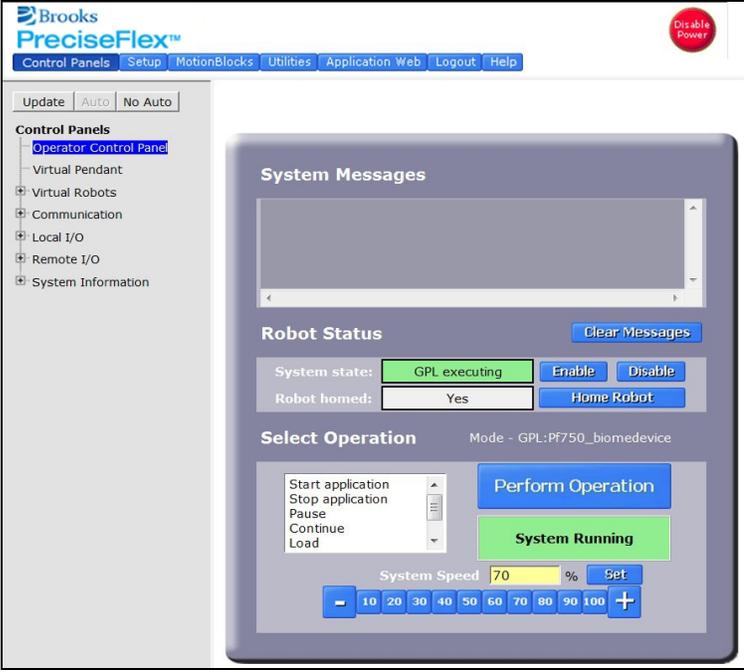
The connector for this interface is a standard RJ11 serial interface connector that has pin assignments compatible with standard PC "com" ports. For this robot it is only used for debugging and special service procedures.

# 4. Operation

## Getting Started

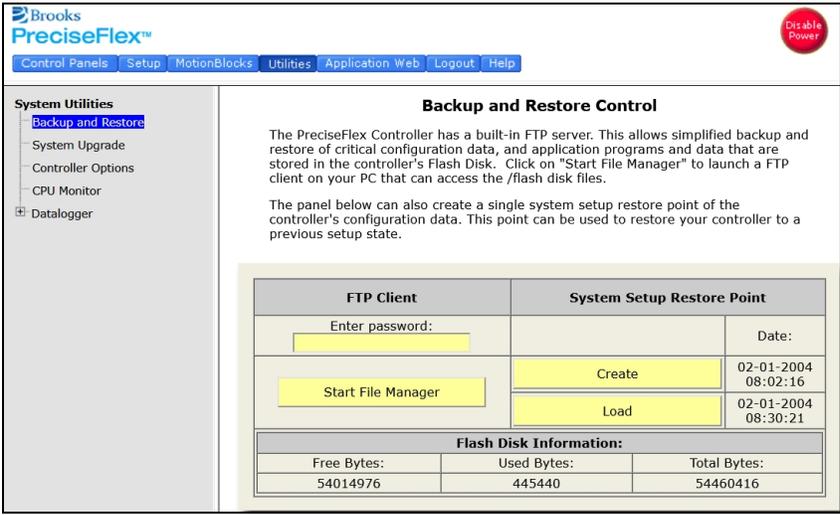
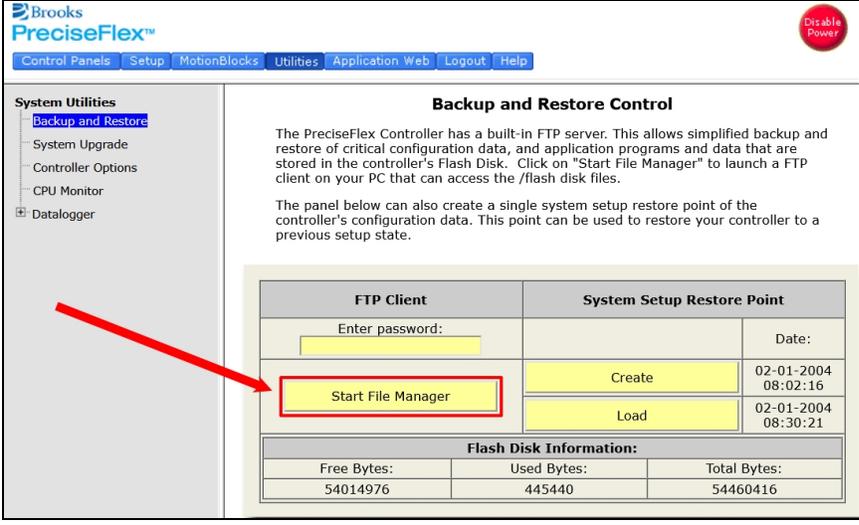
Many OEM customers run the PreciseFlex 400 using a PC to provide an application-specific operator interface. In order to update software in the controller, and view certain error messages, it is necessary to access the web server browser interface embedded in the controller.

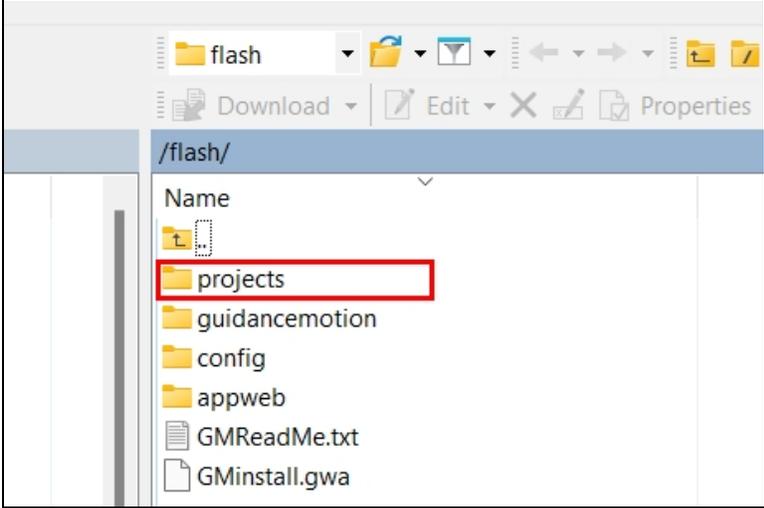
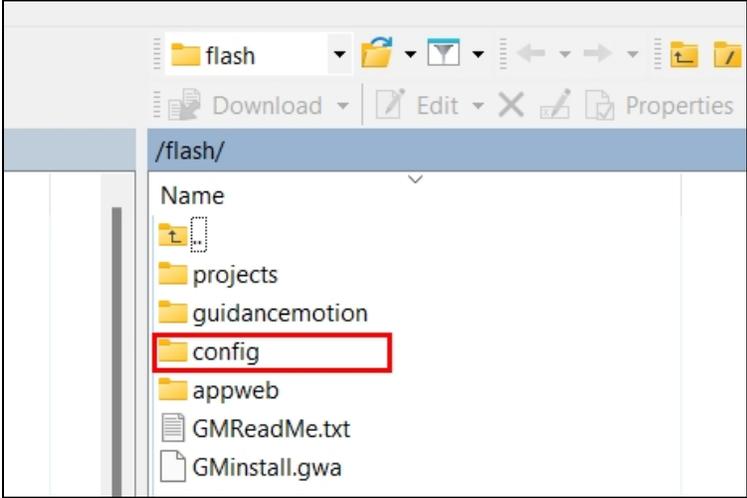
Step	Action
1.	<p>Open a browser in a PC that is connected to the robot via Ethernet. You must use the IP address of the robot controller to display the Brooks Automation Controller Interface.</p> <p>Two common IP addresses are 192.168.0.1 and 192.168.0.10. The PC LAN interface address must be configured correctly (for example 192.168.0.100, with subnet mask 255.255.255.0).</p> <p>It may be necessary to enter a password if a company has protected access to the Controller Interface.</p> 

Step	Action
2.	<p>Click <b>Admin &gt; Control Panels &gt; Operator Control Panel</b>.</p> 
3.	<p>If an application is running, the <i>System Running</i> panel will display in green. In order to run diagnostics, stop the application from running. Click <b>Stop Application</b> and then <b>Perform Operation</b>. This will stop the application from running.</p>
4.	<p>Click <b>Disable Power</b> to be sure motor power is off.</p> 
5.	<p>To load a new project (for example CAL_PP), click <b>Unload</b> and then <b>Perform Operation</b> before loading the new project into RAM.</p>

## Loading a GPL Project

If CAL\_PP or a different program needs to be loaded into the controller from an external computer, it can be done through the browser interface.

Step	Action
1.	<p>In the browser interface, select <b>Admin &gt; Utilities &gt; System Utilities &gt; Backup and Restore Control</b>.</p> 
2.	<p>Click <b>Start File Manager</b> to connect to an FTP utility.</p> 

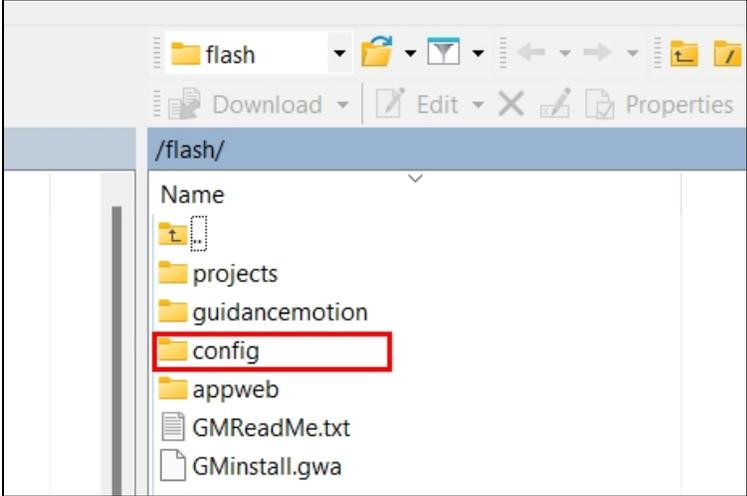
Step	Action
3.	<p>To load a project, open the <i>projects</i> folder and paste your <i>Project</i> folder into this area. There may be several other projects (programs) loaded into this folder, which is stored in flash ram in the controller. A <i>project</i> folder is a software folder that may have several files inside it. Load the entire folder, not just the files inside.</p>  <p>The screenshot shows a file explorer window with the address bar set to /flash/. The file list includes folders for projects, guidancemotion, config, and appweb, along with files GMReadMe.txt and GMinstall.gwa. The 'projects' folder is highlighted with a red rectangular box.</p>
4.	<p>To load or update PAC files, open the <i>config</i> folder and paste a backup copy of the PAC files into it. 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.</p>  <p>The screenshot shows the same file explorer window as in step 3. In this view, the 'config' folder is highlighted with a red rectangular box.</p>
5.	<p>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 "<a href="#">Calibrating the Robot: Setting the Encoder Zero Positions</a>" for an example on how to load and execute the CAL_PP program.</p>

## Web Server

### Updating Robot Configuration Files (PAC Files)

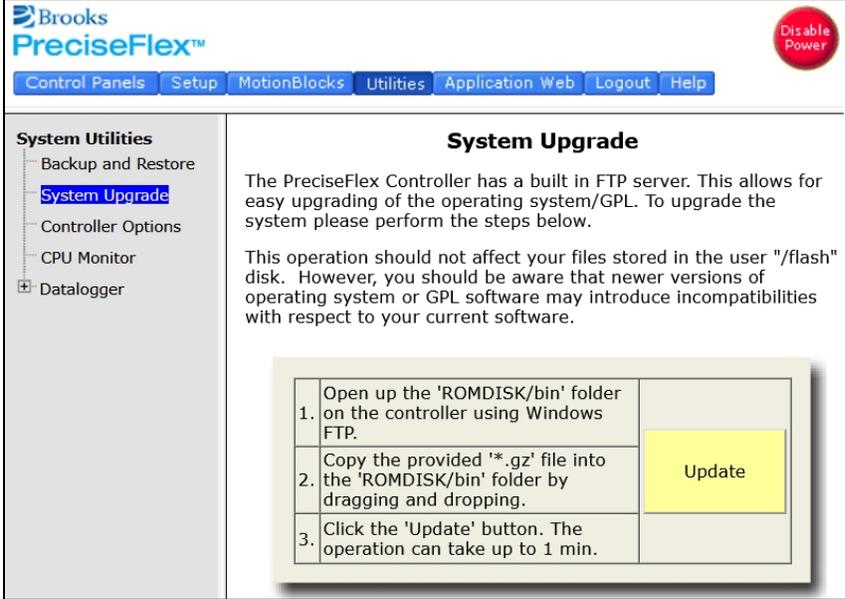
If CAL\_PP or a different program needs to be loaded into the controller from an external computer, it can be done through the browser interface.

See [Loading a GPL Project](#). Then perform the following procedure:

Step	Action
1.	<p>In the browser interface, open the <i>config</i> folder and paste a backup copy of the PAC files into it. 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.</p>  <p>The screenshot shows a browser-based file explorer interface. At the top, there's a breadcrumb path "/flash/". Below it, a list of files and folders is displayed. The folders listed are "projects", "guidancemotion", "config", and "appweb". The "config" folder is highlighted with a red rectangular box. Below the folders, two files are listed: "GMReadMe.txt" and "GMinstall.gwa". The interface includes standard file explorer icons like "Download", "Edit", and "Properties" at the top.</p>
2.	<p>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 <a href="#">Calibrating the Robot: Setting the Encoder Zero Positions</a> for an example on how to load and execute the CAL_PP program.</p>

## Updating Firmware and Operating System

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

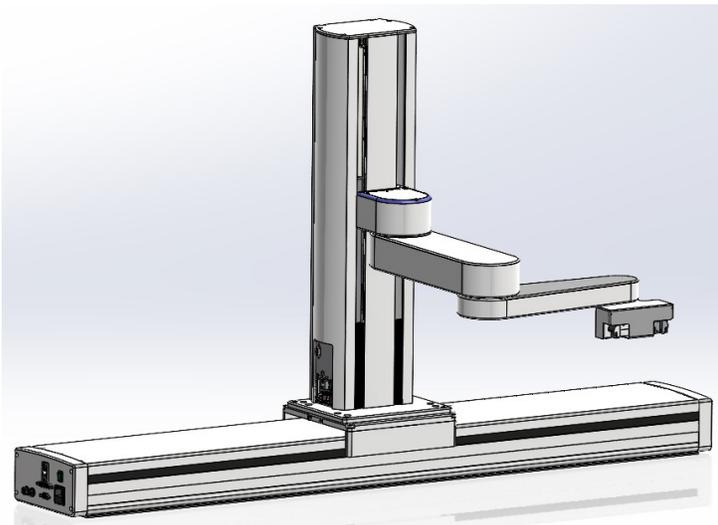
Step	Action
1.	Get the appropriate upgrade software from Brooks in the form of a .bin file. Email <a href="mailto:support_preciseflex@brooksautomation.com">support_preciseflex@brooksautomation.com</a> .
2.	<p>In the operator interface, go to the <b>Admin &gt; Utilities &gt; System Utilities &gt; System Upgrade</b> menu.</p> 
3.	<ol style="list-style-type: none"> <li>1. Click <b>Open ROMDISK/bin</b>. This will open an FTP window.</li> <li>2. Select <b>page</b> in the browser.</li> <li>3. Scroll to the bottom of the page menu.</li> <li>4. Click <b>Open site in Windows Explorer</b>. This will open a second ftp window in Windows. Paste the appropriate GPL or FPGA .bin file in this window.</li> </ol>
4.	Under item 3 in the <b>System Upgrade</b> menu, click <b>Select</b> . A pick list will open up. Highlight the upgrade code in this pick list and click <b>Select</b> again. The name of the file will appear in the filename field.
5.	In the menu, click on either <b>FPGA</b> or <b>GPL</b> 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.

## TCS API

The TCS (TCP Command Server) API is a method of controlling PreciseFlex robots from a PC. The TCS API is open source and can be used to send discrete commands to the robot and request status. With TCS API is used the PC issuing commands must be connected to the robot during runtime.

## Configuring a Linear Rail

The optional linear rail may be added to PreciseFlex 400 robots by placing the robot on the Linear Rail and plugging in the connectors from the Linear Rails 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 Rail. If a robot is installed on, or removed from, a linear rail, 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.



**PreciseFlex Robot Mounted on a 1 m Linear Rail**

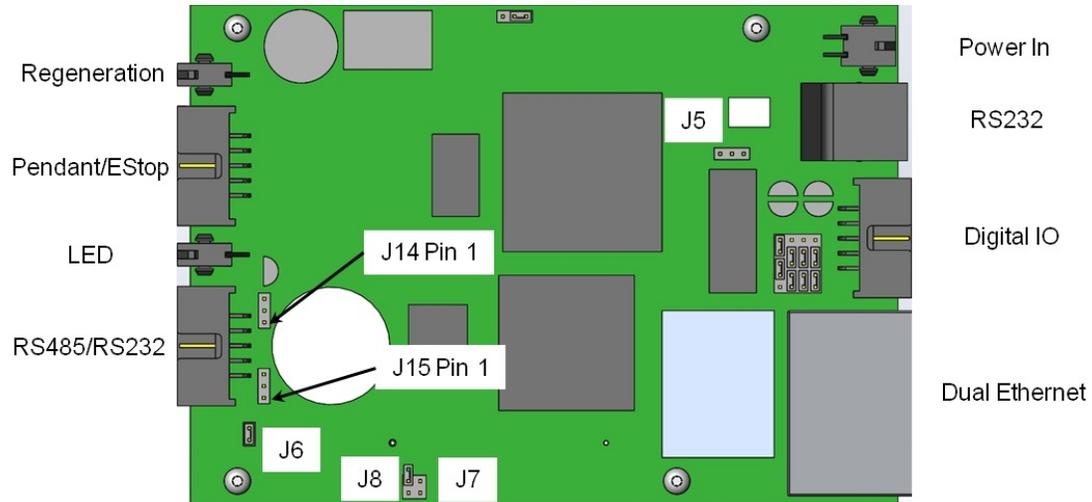
In addition, when adding a linear rail to a robot with a servo gripper for the first time, the J6 RS-485 termination jumper on the robot controller in the inner link of the robot must be removed, as the RS-485 bus is now extended to the end of the linear rail where an RS-485 jumper is installed. Failing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

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**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 I/O board in the end of the linear rail should provide the second termination.

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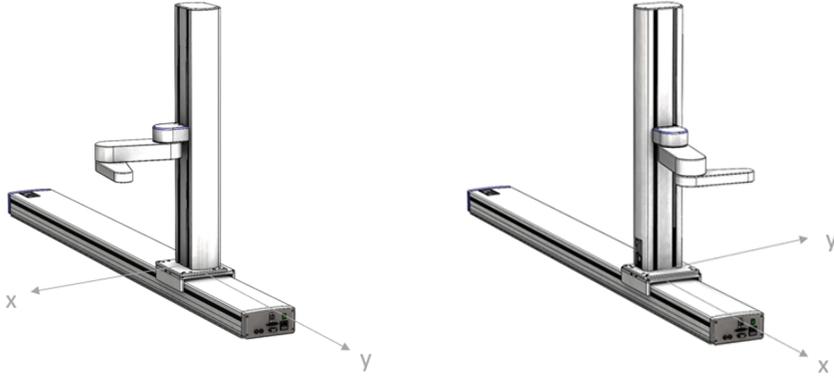
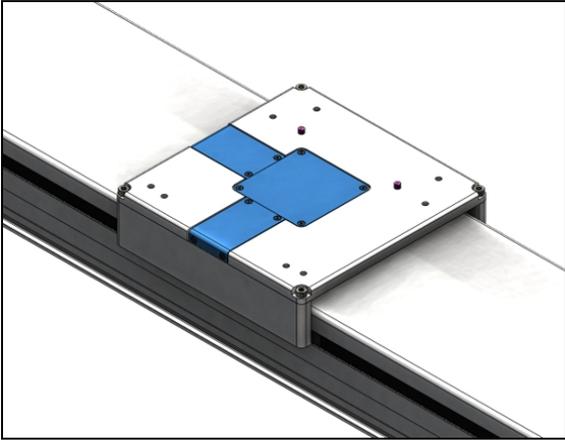
If the GIO is installed, J6 should be installed on the GIO and J6 should be removed from the GSB on the linear rail carriage. (See [Replacing the Linear Axis Controller](#) and [Installing the Optional GIO Board](#) for pictures.)



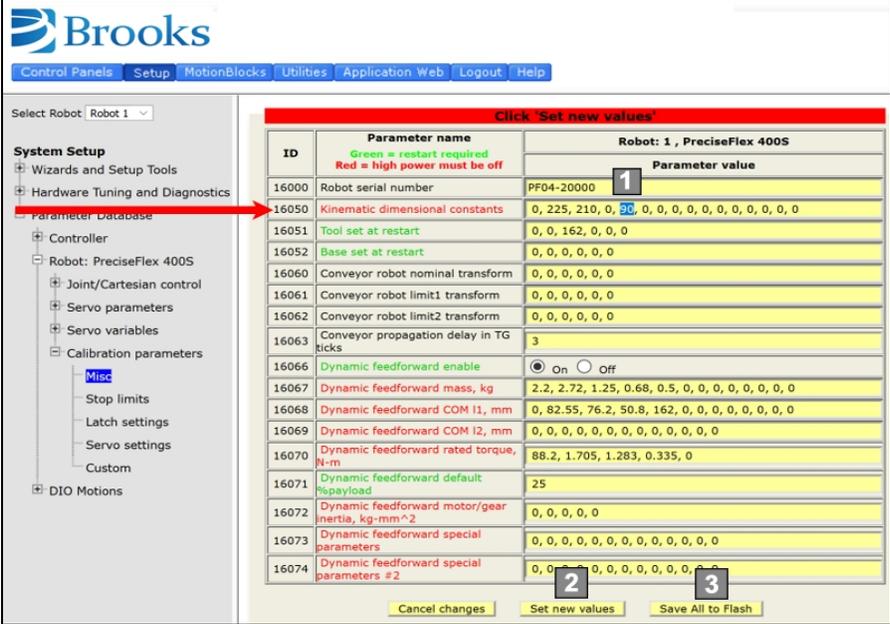
#### J6 jumper on the GSB

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 5<sup>th</sup> 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 5<sup>th</sup> parameter must be set to -90 (degrees).

Follow this procedure to install the Linear Axis.

Step	Action
1.	<p data-bbox="391 289 613 317">Choose orientation</p> <div data-bbox="418 380 1252 758"></div> <p data-bbox="407 810 813 873">0 degrees: Robot y-axis aligns with rail travel (moves "sideways")</p> <p data-bbox="867 810 1338 873">-90 degrees: Robot x-axis aligns with rail travel (moves "forward and backward")</p>
2.	<p data-bbox="391 928 1300 991">Route cables. If necessary, remove the covers on the carriage and re-route the cabling so that the connectors can reach the facilities panel.</p> <div data-bbox="391 1024 956 1465"></div>

Step	Action
<p>3.</p>	<p>Attach robot and cables. Mount according to chosen configuration. Attach power, Ethernet, and communication (DB9).</p> <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;">  <p>0 degrees</p> </div> <div style="text-align: center;">  <p>-90 degrees</p> </div> </div>
<p>4.</p>	<p>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.</p> 
<p>5.</p>	<p>Calibrate the robot. Follow standard procedure. The rail position is described in the Cal_pp dialogue.</p>

Step	Action
<b>6.</b>	<p>Set configuration parameter</p> <ol style="list-style-type: none"> <li>Set the 5th value of parameter 16050 to the chosen orientation (0 or -90)</li> <li>Click “Set new values”</li> <li>Click “Save All to Flash”</li> </ol> 
<b>7.</b>	<p>Wait 10 seconds and reboot the robot. After reboot, the rail is ready to use.</p>

The Linear Rail 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 Rail position is added to either the Y-axis or X-axis Cartesian position of the gripper. The Linear Rail 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 IntelliGuide Grippers

### Overview

The IntelliGuide s23 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 500 ms 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 PreciseFlex 400.

## 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 mm. The force is closer to 6 N in portrait mode and 8 N in landscape mode and 9-10 N 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 s23 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- 12 N 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 5<sup>th</sup> 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 PreciseFlex 400 servo gripper, the formula for determining the approximate gripper squeeze is  $7 \text{ N} + (\text{Rated Current}/1.26 \text{ Amps}) \times 18 \text{ N}$  for squeeze and  $(\text{Rated Current}/1.26 \text{ Amps}) \times 18 \text{ N} - 9 \text{ N}$  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  $12 \text{ N}/18 \text{ N} \times 1.26 \text{ A}$  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 s23 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.

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**NOTE:** The feedforward torque is not limited by these parameters, only the PID torque.

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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  $(\text{Spring force at position}) + ((-\text{Contents of } 10352) - \text{tcnts to oppose spring force}) / 4378 \times 18 \text{ N}$ , 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  $6\text{ N} + (3200-1600)/4378 \times 18\text{ N}$  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  $((\text{Contents of } 10351) - \text{contents to oppose spring force}) / 4378 \times 18\text{ N} - (\text{Spring force at position})$ . For example, in landscape mode the spring force is about 8N, and if the contents of 10351 are 5200, this value will be  $(5200-2200)/4378 \times 18\text{ N} - 8\text{ N}$  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 servo gripper includes a sensor to detect the gripper closed to hard stop position. The spring will return the gripper to this position if the 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 browser interface under **Admin > Control Panels > Remote I/O > Network Node 2 I/O**.

The screenshot shows the Brooks PreciseFlex web interface. The navigation menu on the left includes 'Control Panels', 'Setup', 'MotionBlocks', 'Utilities', 'Application Web', 'Logout', and 'Help'. Under 'Control Panels', there are sub-menus for 'Operator Control Panel', 'Virtual Pendant', 'Web Dialog', 'Robot Payload', 'Virtual Robots', 'Communication', 'Local I/O', and 'Remote I/O'. The 'Remote I/O' menu is expanded, showing 'EtherNet/IP I/O', 'RIO 1 Status', 'RIO 2 Status', 'RIO 3 Status', 'RIO 4 Status', 'Network Node 2 I/O' (highlighted), 'Network Node 3 I/O', and 'Network Node 4 I/O'.

The main content area is titled 'Network Node 2 I/O status panel'. It contains the following text: 'Remote network nodes can have up to 20 inputs and 20 outputs. The master node I/O is accessed in the 'Local I/O' area. Slave nodes start at 2 and go up to 8.'

Below the text is a table with two columns: 'Digital Inputs' and 'Digital Outputs'. Each column has 10 rows of input/output numbers. All cells in the table contain a red 'X'.

Digital Inputs				Digital Outputs			
210001	210002	210003	210004	200001	200002	200003	200004
210005	210006	210007	210008	200005	200006	200007	200008
210009	210010	210011	210012	200009	200010	200011	200012
210013	210014	210015	210016	200013	200014	200015	200016
210017	210018	210019	210020	200017	200018	200019	200020

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 database. 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 tcnts, 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.

# Appendices

## Appendix A: Product Specifications

### General Specifications

General Specification	Range
<b>PERFORMANCE</b>	
Payload	0.5 kg with IntelliGuide Gripper
Typical Speed at TCP	500 mm/sec
Max Acceleration	2000 mm/sec <sup>2</sup>
Repeatability	±0.090 mm
<b>RANGE OF MOTION</b>	
Joint 1 (Z-axis)	400, 750, 1160 mm
Joint 2	±93°
Joint 3	±168°
Joint 4	±960° with servo gripper
Horizontal Reach	579 mm, standard reach 734 mm, extended reach
<b>COMMUNICATIONS</b>	
General	100 Mb Ethernet, TCP/IP EtherNet/IP
Operator Interface	Web-based operator interface
Digital I/O	8 inputs, 8 outputs at base of robot optically isolated, 24 V @ 100 ma 2 in, 4 out for end-of-arm-tooling Remote I/O available
<b>FACILITIES</b>	
Power	90 to 264 VAC, auto selecting 50-60 Hz 100-250 watts typical operation
Controller Mounting	Embedded into robot base
Air Lines	Two, 3.2 mm OD, 1.6 mm ID, max pressure 500 kpa (75 psi)

General Specification	Range
Weight	Standard Reach/Extended Reach 20 kg/25 kg (400 mm Z-axis) 25 kg/30 kg (750 mm Z-axis) 30 kg/35 kg (1160 mm Z-axis)
<b>SOFTWARE</b>	
Programming	Guidance Programming Language (GPL) GP Flow TCS API (TCP Command Server)
Enhanced Functions	Hand Guiding (standard) Horizontal Compensation Z-Height Detection
<b>PERIPHERALS AND ACCESSORIES</b>	
General	IntelliGuide s23 Gripper Gripper Fingers for SBS plates, tubes, vials
Linear Rail	1.0, 1.5, and 2.0 M travel Speed up to 750 mm/sec Repeatability: ±0.05 mm
Vision	IntelliGuide v23 Gripper

## 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:

General Specification	Range and Features
Ambient temperature	0° C to 40° C
Indoor use only	
Storage and shipment temperature	-25° C to +55° C
Humidity range	10 to 75%, 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

General Specification	Range and Features
Approved Cleaning Agents	IPA, 70% Ethanol/30% water, H2O2 Vapor up to 1000 ppm
IP rating	11
IK impact rating	IK08: 5 Joule

## Appendix B: Preventative Maintenance

For support with preventative maintenance, addressing error codes, or service related issues contact [support\\_preciseflex@brooksautomation.com](mailto:support_preciseflex@brooksautomation.com).

The following preventative maintenance procedures should be performed at an interval of one to two years. For robots operating continuously 24 hours per day, 7 days a week at moderate to high speeds, a one-year interval is recommended. For robots with low duty cycles and low to moderate speeds, these procedures should be performed at least once every two years.

### 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 gets stiff, return it to the factory for bearing replacement.
Check second stage (long) Z belt for any squeaking	If noisy, add thick grease to the front and rear edge of the 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 <a href="#">Spare Parts List</a> .
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.

### PreciseFlex 400 PM Schedule by Revision Level and Date

Component	Expected Life	Action
<b>Revision A, Serial Numbers F0X...</b>		
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
Harness (any FFC cables)	4-10 years	Replace robot*
<b>Revision B, Serial Numbers F0B...</b>		

Component	Expected Life	Action
Slip ring	3-5 years	Replace component
Ethernet cable (flat black Startech)	2-4 years	Replace component
<b>Revision C, Serial Numbers F0C...</b>		
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.

### Linear Axis PM Schedule

Component	Expected Life	Action
<b>Revision A, Serial Numbers FXX...</b>		
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
<b>Revision B Feb 2015, Serial Numbers FXB...</b>		
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

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

## Appendix C: PreciseFlex 400 Spare Parts List

**NOTE:** Email [support\\_preciseflex@brooksautomation.com](mailto: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, and "D" 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.

Description	Part Number	Rev C	Rev D
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		

Description	Part Number	Rev C	Rev D
J4 30 W Motor Assembly	PF00-MA-00031		
J4 Belt for Standard Reach	PF00-MC-X0004		
J4 Belt for extended reach	PF00-MC-X0065		
PreciseFlex 400 s23 servo gripper with spring, without fingers	G1X0-EA-B1400-12A		
PreciseFlex 400 s23 servo gripper with brake, without fingers	PF00-MA-00115		
Finger claw assembly - s23 servo gripper fingers	PF0S-MA-00010		
G5400B controller with advanced kinematics license	G1XF-EA-B1400-12A		G5X0-EA-B5400
G1100T slave controller ("GSB3-SE") for gripper	G1X0-EA-T1101-4		389629-0005
G1100T slave controller ("GSB3-DIFF") for rail	G1X0-EA-T1101-4D		389629-0005
GIO digital I/O board with pigtails	GIO1-EA-01102		
24 VDC Supply	PS10-EP-24150		
48 VDC motor supply	PS10-EP-48400		605889
Slip Ring Harness Assembly, s23 brake gripper	PF04-MA-00002-E8	18Wire	
Slip Ring Harness Assembly, s23 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	602414-0011
J2 Motor Interface PCA	PF00-EA-00030		602414-0021
J3 Motor Interface PCA	PF00-EA-00035		602414-0031
J4 Motor Interface PCA	PF00-EA-00036	New	602414-0041

## Appendix D: Example Performance Level Evaluation

### Example Workcell Description

A PreciseFlex 400 robot 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.



Example PreciseFlex 400 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 PreciseFlex 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 PreciseFlex 400 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. 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 13849-1:2023](#) (formerly 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 [ISO 10218-1:2025](#), formerly EN/ISO 10218-1:2011).

## Appendix E: TUV Verification of PreciseFlex 400 Collision Forces



**Technical Report No. 72112676-001**  
**Rev. 0**  
**Dated: January 18, 2016**

Client: *Precise Automation*  
 47350 Fremont Blvd., Fremont, CA 94538

Manufacturing place: Jabil Industries  
 1565 S. Sinclair St., Anaheim, CA 92806

Test subject: Product: Collaborative Robot  
 Type: PF400

Test specification: *Maximum applied forces testing*

Purpose of examination:
 

- Verification of operation as a Collaborative Robot when applied as instructed by Precise Automation using the provided and confirmed force data included in this report.

The Force data and Settings information are provided so that the end-user has sufficient information to perform a Risk Assessment and determine how the robot may safely be used in a Collaborative application. In the table below, green cells indicate crushing forces less than 150N for manual control and impact forces less than 180N for free space and rigid surface collisions. Red cells indicate collision forces greater than 180N. The operation of the Robot was verified for safe operation in selected single fault failures. However, the overall reliability of the control system per applicable standards was not verified.

Test result: *positive*: The test subject was found to be in compliance with
 

- the requirements of the test specification

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PSS\_F\_09.07 Revision 3, Effective: 2015-02-17 Page 1 of 4 **TUV**®



**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	360 deg/s	720 deg/s	720 deg/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



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**

*NA*

**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*



**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

Handwritten signature of Rick Grumski in black ink.

Engineer: Rick Grumski

Handwritten signature of Chris Caserta in black ink.

January 18, 2016

Technical Report checked: Chris Caserta

## Appendix F: ISO/TS 15055: 2016, Biomechanical Limits

Online at iso.org: [ISO/TS 15055: 2016](https://www.iso.org/standard/72411.html).

Body region	Specific body area	Quasi-static contact		Transient contact	
		Maximum permissible pressure <sup>a</sup> $P_s$ N/cm <sup>2</sup>	Maximum permissible force <sup>b</sup> N	Maximum permissible pressure multiplier <sup>c</sup> $P_T$	Maximum permissible force multiplier <sup>c</sup> $F_T$
<i>Skull and forehead<sup>d</sup></i>	1 <i>Middle of forehead</i>	130	130	not applicable	not applicable
	2 <i>Temple</i>	110		not applicable	not applicable
<i>Face<sup>d</sup></i>	3 <i>Masticatory muscle</i>	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	
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	

<sup>a</sup> 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<sup>2</sup>. 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].

<sup>b</sup> 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.

<sup>c</sup> 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].

<sup>d</sup> Critical zone (*italicized*)

### Biomechanical Limits, Page 1 of 2

Body region	Specific body area		Quasi-static contact		Transient contact	
			Maximum permissible pressure <sup>a</sup> $p_s$ N/cm <sup>2</sup>	Maximum permissible force <sup>b</sup> N	Maximum permissible pressure multiplier <sup>c</sup> $P_T$	Maximum permissible force multiplier <sup>c</sup> $F_T$
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	

<sup>a</sup> 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<sup>2</sup>. 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].

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<sup>d</sup> Critical zone (*italicized*)

## Biomechanical Limits, Page 2 of 2