PreciseFlex™ c10

PreciseFlex™ c8A

PreciseFlex™

c10 and c8A Collaborative Robots

User Manual

Part Number 629013, Revision C

Brooks Automation

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Revision History

Revision	ECO	Date	Action	Author
A	Agile release skipped	April 24, 2024	Released manual at Rev. A to follow standard Brooks technical publication styles.	M. Ashenfelder
B	EC154168	June 6, 2024	Released manual at Rev. B to follow standard Brooks technical publication styles	M. Ashenfelder
C	EC161832	February 18, 2024	Update on facilities panel, optional pneumatic gripper, system overview, IntelliGuide Vision, ISO flange for end-of-arm tooling graphic.	M. Ashenfelder

Table of Contents

1. Safety

Safety Setup

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

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

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 and ANSI Z535 standards.

Signal Words and Color

Signal words inform of the level of hazard.

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

Alert Example

The following is an example of a Warning hazard alert.
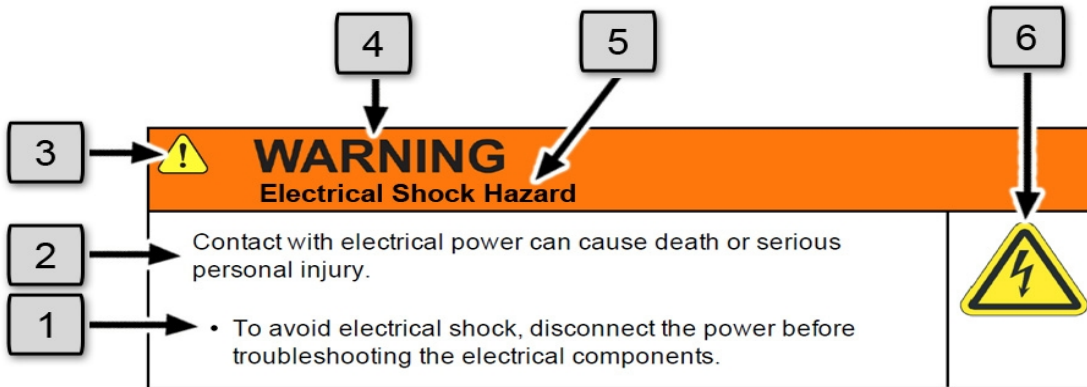
Number	Description
1.	How to Avoid the Hazard
2.	Source of Hazard and Severity
3.	General Alert Icon
4.	Signal Word
5.	Type of Hazard
6.	Hazard Symbol(s)

General Safety Considerations

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

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

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

⚠️ **WARNING**

Magnetic Field Hazard

This product contains magnetic motors that can be hazardous to implanted medical devices, such as pacemakers, and cause personal harm, severe injury, or death.

- Maintain a safe working distance of 30 cm from the motor when with an energized robot if you use a cardiac rhythm management device.

⚠️ **CAUTION**

Unauthorized Service

Personal injury or damage to equipment may result if this product is operated or serviced by untrained or unauthorized personnel.

- Only qualified personnel who have received certified training and have the proper job qualifications are allowed to transport, assemble, operate, or maintain the product.

⚠️ **CAUTION**

Damaged Components

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

- Do not use this product if components or cables appear to be damaged.
- Place the product in a location where it will not get damaged.
- Route cables and tubing so that they do not become damaged and do not present a personal safety hazard.

⚠️ **CAUTION**

Inappropriate Use

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

- Only use the product for its intended application.
- Do not modify this product beyond its original design.
- Always operate this product with the covers in place.

<table>
<tr><td colspan="2">

⚠️ **CAUTION**

Seismic Restraint
</td></tr>
<tr><td>

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

- The user is responsible for determining whether the product is used in an earthquake prone environment and installing the appropriate seismic restraints in accordance with local regulations.
</td><td>⚠️</td></tr>
</table>

Mechanical Hazards

<table>
<tr><td colspan="2">

⚠️ **CAUTION**

Pinch Point
</td></tr>
<tr><td>

Moving parts of the product may cause squeezing or compression of fingers or hands resulting in personal injury.

- Do not operate the product without the protective covers in place.
</td><td>⚠️</td></tr>
</table>

<table>
<tr><td colspan="2">

⚠️ **WARNING**

Automatic Movement
</td></tr>
<tr><td>

Whenever power is applied to the product, there is the potential for automatic or unplanned movement of the product or its components, which could result in personal injury.

- Follow safe practices for working with energized products per the facility requirements.

- Do not rely on the system software or process technology to prevent unexpected product motion.

- Do not operate the product without its protective covers in place.

- While the collaborative robotics system is designed to be safe around personnel, gravity and other factors may present hazards and should be considered.
</td><td>⚠️</td></tr>
</table>

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

Electrical Hazards

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

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

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

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

NOTICE	
Improper handling of the power source or connecting devices may cause component damage or equipment fire. • Connect the system to an appropriate electrical supply. • Turn off the power before servicing the unit. • Turn off the power before disconnecting the cables.	

Ergonomic Hazards

⚠ **CAUTION**	
Heavy Lift Hazard	
Failure to take the proper precautions before moving the robot could result in back injury and muscle strain. • Use a lifting device and cart rated for the weight of the drive or arm. • Only persons certified in operating the lifting device should be moving the product.	

⚠ **CAUTION**	
Tipover Hazard	
This product has a high center of gravity which may cause the product to tip over and cause serious injury. • Always properly restrain the product when moving it. • Never operate the robot unless it is rigidly mounted.	

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

Emergency Stop Circuit (E-Stop)

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

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

Recycling and Hazardous Materials

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

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

2. Introduction to the Hardware

Explanation of the Product Label

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

Location of the Product Label on the Facilities Panel at the Base of the Robot

P/N:PFC0 - MA - 00010 - 05
S/N:FC0 - 2404 - 9L - 04318

CSA

C   US   90 - 264 VAC + / - 10 %
Contract #: 263533   50/60 Hz
CE   400 W MAX
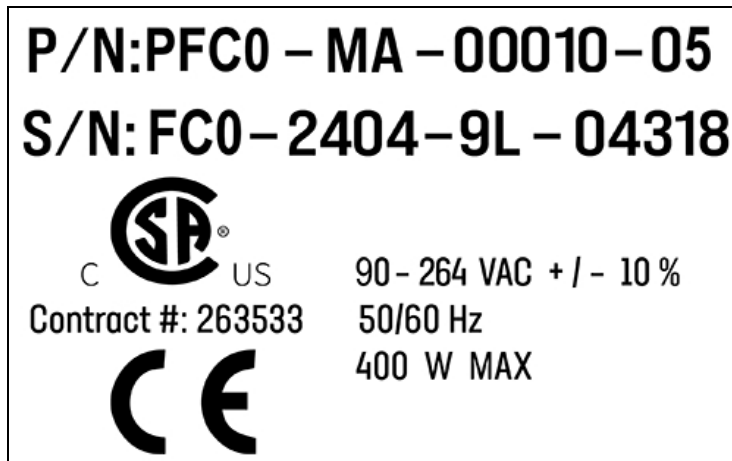
Sample Robot Product Label

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

P/N: PFC0-MA-00010-05

- PFC0 = PreciseFlex c10 or c8A
- MA = Machine Assembly
- PreciseFlex c10
- 05 = 500 mm Z stroke

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

S/N:FC0 - 2404 - 9L - 04318

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

- FC0 = PreciseFlex c10
- 24 = Two-Digit Year Code
- 04 = Two-Digit Month Code
- 9L = Major and Minor Revision Code
- 04318 = Sequential Production Number

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

Contract #: 263533

Brooks Automation's Contract ID within the CSA Group

The CE Marking affirms compliance with relevant EU legislation. See Standards Compliance and Agency Certifications for more information.

Robot Power Requirements

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

P/N - Part Number

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

AAAA	
CODE	**PRODUCT**
PFC0	C-Series
BB	
CODE	**TYPE**
MA	Machine Assembly
CCCC	
CODE	**TYPE**
PFC0	00010 = PreciseFlex c10 00008 = PreciseFlex c8A
D	
CODE	**ARM LENGTH**
0 / S	Standard
X / L	Extended / Long
E	
NUMBER	**AXIS SIZE**
05	500 mm Z Stroke
10	1000 mm Z Stroke
14	1420 mm Z Stroke

Serial Number (SN)

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

AAA	
CODE	**MODEL**
FC0	C-Series

BBCC	
CODE	**MFG DATE CODE (START DATE)**
BB	Two-Digit Year Code
CC	Two-Digit Month Code
EF	
Code	**Rev Code**
E	Major Rev Code
F	Minor Rev Code
GGGGG	
G	Sequential Production Number

Facilities Panel

The Facilities Panel is located at the base of the robot.
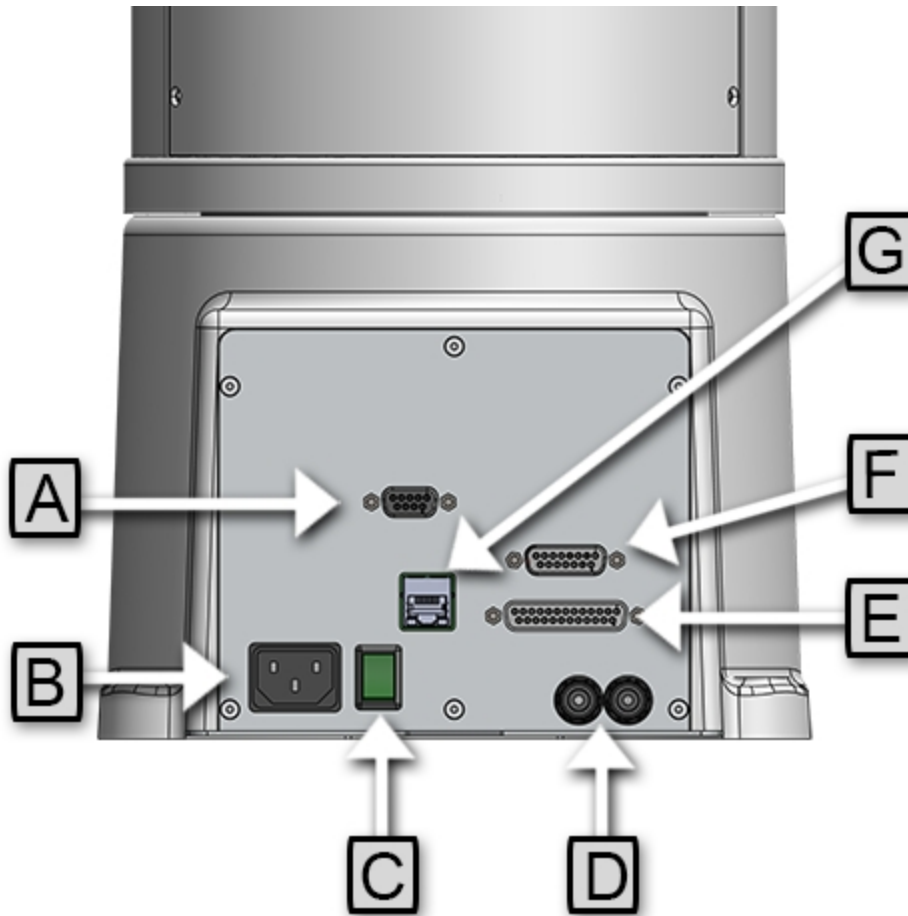
Facilities Panel key

Annotation	Name	Description
A	Pendant/E-Stop	9 Pin 2D Sub Connector. Contains RS-232 Serial Port, 24 VDC, E-Stop.
B	Power Entry Module	For IEC plug. Contains dual fuse drawer. - 100-240 VAC - 50-60 Hz - 500 W
C	Power Switch	Lighted Power Switch
D	Pneumatic Ports	For attaching air lines for user supplied pneumatic or vacuum tool-ing. A1 and A2 ports. See the *PreciseFlex Servo Grippers* user manual.
E	Digital IO	25 Pin D Sub Connector, 12 digital inputs, 8 digital outputs

Annotation	Name	Description
F	Accessory	15 Pin D Sub connector for optional accessories, including encoder input, switching the device for safety, RS-232 communication and RS-485 communication. Refer to Hardware Reference.
G	Ethernet Connector	For Ethernet to Computer Cable

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

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

Each of these interfaces is described in detail in the following sections. In addition, the robot's controller may contain additional interfaces (e.g. inputs or outputs).

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

If the pneumatic gripper option is ordered, two air lines are routed through the interior of the robot. At the Facilities Panel, these air lines are presented in a fitting on a sub plate mounted to the facilities panel. Two air lines are routed through the interior of the robot and are terminated at the end of and inside the outer link. When using these lines, clean, dry external air should be provided.

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

System Overview and Description

The PreciseFlex c8A and PreciseFlex c10 direct drive robots are offered as a 6-axis and 4-axis configuration, respectively. Both robots include embedded motion controllers, a 48 VDC motor power supply, and a 24 VDC logic power supply located inside the robot. In addition, they may optionally include an electric gripper and electric gripper controller, or solenoid valves to support pneumatic grippers.

The Z-axis of these robots is available with a standard travel of 500 mm, and optional travels of 1000 mm and 1420 mm. The PreciseFlex c8A can carry a payload of up to 8 kg and the PreciseFlex c10 can carry a payload up to 10 kg. These robots are extremely quiet and smooth, very reliable, and have excellent positioning repeatability. To achieve these results, the axes are powered by proprietary direct-drive motors. With these characteristics, these robots are ideal for automating applications in the Life Sciences, Medical Products, Semiconductor, Automotive, and Electronics industries.

In general, assuming a collaborative gripper with no sharp edges or other dangerous features, is attached to the robot, these robots can make horizontal motions at tip speeds up to 1.5 -2.0 m/sec and bump into a person in free space without causing a severe injury. For horizontal and vertical motions, the speed should be limited to 150 mm/sec when the robot comes within 100 mm of a rigid surface. See the section on "Safety Zones" for information on setting barriers in the working volume beyond which the robot must slow down.

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

The controller is programmed by means of a PC connected through Ethernet. There are four different ways to program PreciseFlex robots: with a PLC through Ethernet/IP or Modbus/TCP, a text-based programming language called Guidance Programming Language, a graphical programming mode called GP Flow and a PC controlled mode called TCS API. When programmed with a PLC, Guidance Programming Language, or GP Flow, the PC can be removed after programming is completed and the controller will operate standalone. The PC is required for operation with the TCS API, which is implemented through a command-server interface.

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

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

The optional IntelliGuide Vision Gripper is available in a light-duty 23 N squeeze version (the IntelliGuide v23) and a medium-duty 60 N squeeze version (the IntelliGuide v60) only for the c10 at this time. The IntelliGuide Vision Gripper includes an internal CPU, and the cabling to support it is installed inside the robot, eliminating the need for an external PC and external cables. See the *IntelliGuide Vision User Manual* for more information"

PreciseFlex c8A and PreciseFlex c10 Robots

For the PreciseFlex c8A and c10 robots, it is important to set the correct value for the payload in the Dynamic Feed Forward parameter 16071 (or use the GPL "Robot.Payload" property). The payload can also be set using the operator Web Interface (see "**Control Panels > Robot Rayload**"). This is very important prior to entering "Free Mode" as a drastically incorrect payload can cause the Z-axis gravity compensation to be incorrect and thus cause the Z-axis to start to move up or sag down, until the velocity restrict safety limit cuts in to stop any excessive speed.

For the PreciseFlex c8A, 100% equals 8 kg for the gripper and payload mass. For the PreciseFlex c10, 100% equals 10 kg for the gripper and payload mass. For lighter masses, this value should be reduced. Setting the payload correctly is important both for optimal dynamic performance of the robot and for proper gravity compensation, including "free" mode. For pick and place applications, the property "robot.payload" can be set by the application program to change the payload.

Also, it is important to set the correct tool X, Y, Z offset distance in mm in the first three values of parameter 16051 and tool Yaw, Pitch, and Roll in values 4-6 for the distance of the center of mass of the gripper and payload from the J6 axis of rotation. For example, for a horizontal tool, if the center of a 2 kg mass is 150 mm from the center of rotation of axis 4 (the wrist), this parameter should be set to 0, 0,150, 0, 90, 0 for the Dynamic Feed Forward calculations to compute the correct feed forward motor torques and achieve optimal performance. For a vertical gripper with the same offset, this parameter should be 0, 0, 150,0, 0, 0. The tool offset length must also be set in the Dynamic Feed Forward parameter 16068 value 8 for the PreciseFlex c8A and value 6 for the PreciseFlex c10. The tool mass in kg must be set in parameter 16067 value 8 for the PreciseFlex c8A and value 6 for the PreciseFlex c10 in order for the Dynamic Feed Forward to work properly.

Note that when setting the payload and gripper payload offset parameters in the database, these values must be entered, saved to flash, and the controller must be re-booted for them to take effect. See the software documentation about Parameters 16051, 16071, 16067, 16068, and the "Robot.Tool" and "Robot.Payload" properties for more a more detailed explanation.

System Diagram and Coordinate Systems

The major elements of the PreciseFlex c8A and PreciseFlex c10 robots and the orientation and origin of their World Cartesian coordinate systems are shown below.
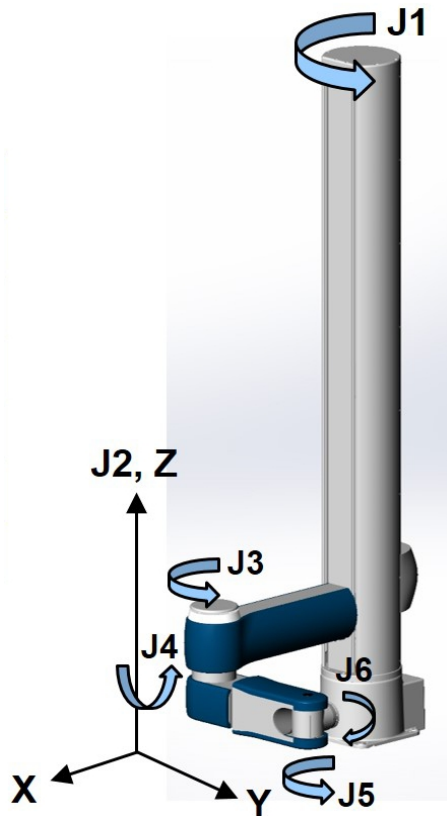
PreciseFlex c8A Six-Axis Direct Drive Robot

Axis	Travel
J1, Theta	± 168 degrees
J2, Z	500, 1000, 1420 mm
J3, Elbow	± 12 to +348 degrees
J4, Rotate	+ 100, - 220 degrees
J5, Pitch	± 110 degrees
J6, Rotate	± 295 degrees

The first axis of the robot, J1, rotates the robot column about the Z-axis. When inner link is closest to the bottom, the Z-axis is at its 0 position in the Joint Coordinate system and in the World Coordinate

system. As the robot arm moves upwards, both its joint position and the World Z Coordinate increase in value.

The Z column also contains the 24 VDC and 48 VDC power supplies. The main PreciseFlex controller is located inside the base housing of the robot, and joint controllers are located near the various joint motors, distributed throughout the robot. When the Inner Link is centered on its range of motion the J1 axis is at its 0-degree joint angle. A positive change in the axis angle results in a positive rotation about the World Z-axis.

The J3 rotary axis (elbow) rotates the outer link about the J3 axis. A positive change in the axis angle results in a positive rotation about the J3-axis. When the link is centered, it is at its 0-degree joint angle, however there is a hard stop at 10 degrees, so the link cannot reach the center position. The outer link can rotate underneath the inner link, allowing the robot to change configuration from a "left hand" robot to a "right hand" robot without swinging the J3 axis (elbow) through the zero position. This allows the robot to work in very compact workcells, and minimizes the radius to the payload, and therefore the kinetic energy of the payload, when moving across a workcell. This helps minimize potential collision forces.

The J4 rotary axis rotates the outer link about its axis. Its travel is asymmetric to allow J5 to be oriented +/- 180 degrees without hitting a J4 hard stop. The J5 pitch axis provides pitch control for the tool. The J6 rotary axis rotates the tool about the tool axis.
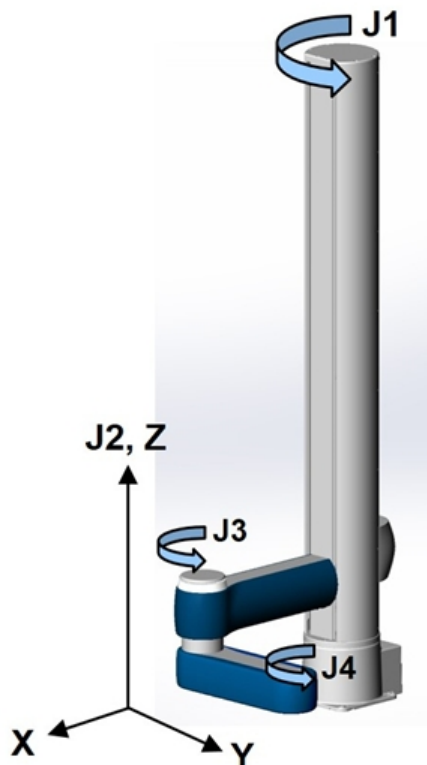
PreciseFlex c10 Four-Axis Direct Drive Robot

Axis	Travel
J1, Theta	± 168 degrees
J2, Z	500, 1000, 1420 mm
J3, Elbow	+12 to +348 degrees
J4, Rotate	+240, -240 degrees

For the PreciseFlex c10, the J4 axis is at the end of the outer link and is parallel to the J1 axis. A positive change in the J4 axis angle results in a positive rotation about the World Z-axis.

The outer link may include a gripper controller that provides control of the optional electric gripper. It is also possible to order the robot with a pneumatic gripper; in which case the outer link will house a solenoid to control air to the pneumatic gripper. A light bar is mounted at the top of the elbow and blinks once per second to indicate that the controller is operational and blinks four times per second when power is being supplied to the motors.

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

Power Supplies and Power Considerations

The PreciseFlex c8A and PreciseFlex c10 controllers require two DC power supplies: a 24 VDC power supply for the processor and user IO, and a separate 48 VDC motor power supply.

⚠️ **DANGER**
Electrical Shock
The 24 VDC power supply is an open frame electrical device that contains unshielded high voltage pins, components and surfaces. These products are intended to be mounted in a cabinet or machine chassis that is not accessible when AC line power is turned on.

The PreciseFlex c8A and PreciseFlex c10 robots' power supplies have an input range of 100 to 240 VAC, +/- 10%, 50/60 Hz. Inrush current can be as high as 40 Amps at 240 VAC for short periods of time. The power supplies are protected against voltage surge to 2000 Volts. Transient over voltage (< 50 µs) may not exceed 2000 V phase to ground, as per EN61800-31996. The power supplies have over-current protection, and over-voltage protection.

The robot consumes less than 500 Watts during normal operation. The peak power under maximum load and acceleration can reach 1000 W for a few seconds, but typical RMS power for most applications is less than 200 W RMS. With the motor power turned off the controller consumes about 20 Watts. With the motor power on and the Z brake released, the robot consumes about 80 Watts. The c8A running at 60% speed consumes about 150 Watts. These numbers may be useful when mounting this robot on mobile platforms.

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.

Energy Dump Circuit

The 48 VDC supply has a regulated output and an overvoltage protection circuit that is triggered if the voltage reaches 60 Volts. Rapid deceleration of the robot motors can generate a Back EMF voltage that can pump up the motor voltage bus. In order to avoid bus pump up, an Energy Dump Circuit is included in the base controller board and connected to the 48 VDC bus.

Remote IO Module (Ethernet Version)

For applications that require a large number of Inputs and Outputs, a Precise Remote IO (RIO) module may be purchased. The RIO interfaces to any PreciseFlex c8A and PreciseFlex c10 robot and its embedded PreciseFlex Controller via 10/100 Mb Ethernet and requires 24 VDC power. Up to four RIOs can be connected to a controller.

The basic RIO includes:

- 32 isolated digital input signals
- 32 isolated digital output signals
- One RS-232 serial line

An enhanced version of the RIO adds 4 analog input signals, a second RS-232 port, and one RS-422/485 serial port.

Enhanced RIO Module

Machine Vision Software and Cameras

The IntelliGuide Vision Gripper makes it easier to deploy PreciseFlex robots with vision. With IntelliGuide Vision, cameras and processor are embedded into the servo gripper. Currently compatible with the PreciseFlex c10 robot..

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

Brooks offers two grippers with vision integrated in the gripper. See the *IntelliGuide Vision* user's manual for more information.

Machine Safety

Safety and Agency Certifications

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

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

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

Standards Compliance and Agency Certifications

The PreciseFlex c8A and PreciseFlex c10 robots are intended for use with other equipment and are considered a subassembly rather than a complete piece of equipment on their own. They meet the requirements of these standards:

- ISO/TS 15066 / RIA TR R15.806
- EN ISO 10218-1-2011 *Robots for Industrial Environments, Safety Requirements*
- EN 60204-1 *Safety of Machinery, Electrical Equipment of Machines*
- EN 61000-6-2 *EMC Directive (Immunity)*
- EN 61000-6-4 *EMC Directive (Emissions)*

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

In addition to the above standards, the PreciseFlex c8A and PreciseFlex c10 robots have been designed to comply with the following agency certification requirements, and will carry the CE and CSA marks:

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

Moving Machine Safety

The PreciseFlex c8A and PreciseFlex c10 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. In Manual Control Mode, the robot's speed is limited to a maximum of 250 mm per second for safety. Operators must wear safety glasses when inside the robot's operating volume.

In Computer Mode, the robot can move quickly. The PreciseFlex c8A and PreciseFlex c10 robots have been designed to be "hand-safe" even in Computer Mode, and in some cases a risk assessment of the application may indicate that it can be used without operator safety screens. However, an operator must wear safety glasses at all times when within the robots working volume. Refer to the EN ISO 10218-2-2011 *Robots for Industrial Environments, Safety Requirements* for information on recommended safe operating practices and enclosure design for robots of various sizes and payloads.

Mechanical and Software Limit Stops

All joints have hard limit stops at the end of travel which are factory installed. The soft-limit stops must be set within the range of these hard stops. The wrist axis in the c10 has a slip ring when the electric gripper is installed, allowing +/- 240 degrees rotation. Since the robot has absolute encoders with battery backup, even if the robot is turned off, the encoders keep track of joint position. The joint position can be viewed either on the optional Manual Control Pendant, or in the Virtual Manual Control Pendant in the Web Based Operator Interface. See the *Guidance Controller Setup and Operation Quick Start Guide* for more information.

Stopping Time and Distance

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

Soft E-stop

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

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

If set, the **SoftEStop** 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 1.0 seconds. It may be adjusted by an operator with administrator privileges. On the web-based operator interface menu, go to Setup/Parameter Database/Controller/Operating Mode/ and set parameter 267 to the desired delay. If this delay is set to 0, the motor power will be disabled within 1 ms.

For the PreciseFlex c8A robot, the base rotation, elbow, and J6 axes do not have mechanical brakes. For the PreciseFlex c10 robot, the base rotation, elbow, and J4 axes do not have mechanical brakes. Therefore, leaving the motor power enabled for 1.0 sec allows the servos to decelerate the robot. The servos are set to decelerate the robot at 0.015 G or 1500 degrees/sec^2. If the robot is moving at a joint speed of 100 degrees/sec, the distance traveled will be about 30° to reach a full stop, and the time will be 0.66 sec. These settings provide a smooth deceleration and stop with full payload. If a faster deceleration is desired, contact Precise Collaborative Robotics application engineering to increase the deceleration setting for E-stop.

Safety Zones

For all robot types, "Safety Zones" can be defined that disable motor power and halt the motion of the robot if its tool center point (TCP) violates the requirements of a user defined 3D volume.

NOTE: Safety zones are implemented in software only.

Types of Safety Zones

These 3D safety zones can be used to:

1. Approximately model the volume of stationary objects or personnel working areas to prevent the robot from inadvertently entering this volume and causing a collision ("keep out zones").

2. Reduce the normal working volume of the robot to prevent the robot from reaching beyond prescribed boundaries and causing a collision ("stay within zones").

3. Verify that the robot's TCP speed (when in a specified volume) is below a specified limit so that the robot can be safely decelerated and stopped before it might pin an operator's hand to a hard surface with too high a force ("speed restrict zones").

As currently implemented, the "keep out zones" and "stay within zones" are provided as general safety features, but they do not meet the stringent Category 3 safety standards that require fail safe redundant logic. However, the "speed restrict zones" do provide the requisite redundancy and are in the process of being Category 3 certified. The "keep out zones" and "stay within zones" are collectively referred to as "uncertified zones" and the "speed restrict zones" are referred to as "certified zones".

The supported zone shapes are rectangular volumes, cylinders and spheres. To define a safety zone, the type of safety zone must be specified along with its origin and dimensions.

Rectangular Volume

Cylinder
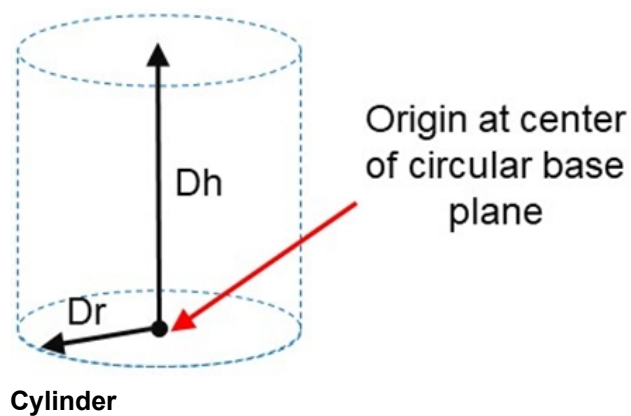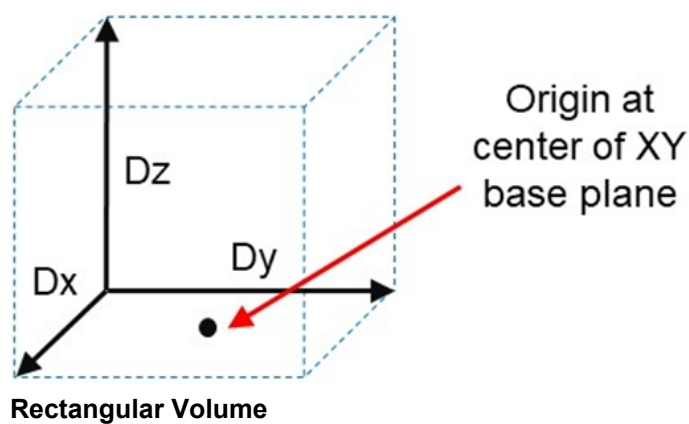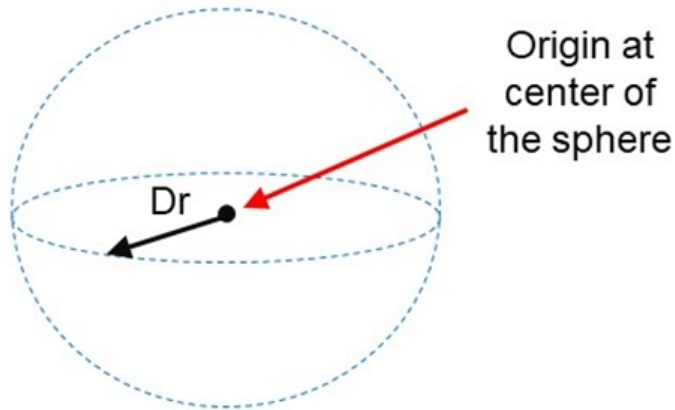
Sphere

For increased generality, uncertified zones can be arbitrarily positioned and rotated in all three dimensions. Due to implementation limitations, certified zones must be non-rotated rectangular volumes, which can be arbitrarily positioned. Up to 10 zones can be defined for each robot and any mix of certified and uncertified can be specified. Due to safety requirements, any new or modified zone specifications only go into effect after the controller is rebooted.

Safety Zone Violation Detection and Clearing

Uncertified safety zones are active in the following circumstances:

- Continuously during program-controlled motions of all types (straight line or arc Cartesian and joint interpolated).
- Continuously during manual (jog) control modes: World, Tool and Joint, but not free.
- Motion planning (final destinations only).
- Location object.KineSol method during conversions to either Cartesian or joint Locations.

Certified safety zones are only active during program-controlled motions (of all types) since this is the only circumstance where higher TCP speeds are possible.

When motor power is enabled and the robot's TCP is in violation of an uncertified safety zone, a program-controlled motion cannot be initiated. This condition can be cleared by disabling motor power and manually repositioning the robot or by manually jogging the TCP in World, Tool or Joint modes, so long as the jog motion reduces the safety zone violation distance. That is, jogging motions that increase the violation of a safety zone are not permitted.

> **NOTE:** Safety zone testing is based on the TCP of the robot. Therefore, it is very important that the position of the tool center point relative to the robot's tool mounting flange is set correctly. Please see the Robot.Tool property for information on defining the TCP.

Certified Speed Restrict Safety Zones

While the uncertified safety zones perform conventional tests on just the position of the TCP, there are two certified safety zones and these perform special tests to detect if the speed of the TCP exceeds a limit while the TCP is within the zone. The first certified safety zone tests if the Z downward speed of the TCP exceeds a specified limit. This safety zone was not implemented for the PreciseFlex 400 and PreciseFlex 3400 robots since their only intrinsically non-safe motion is a high-speed downward Z motion that could trap a person's hand between the tooltip and a fixed object or horizontal surface. The second certified safety zone tests if the horizontal, XY planar, speed of the TCP exceeds a specified limit. This test was developed for the PreciseFlex™ DD robots since robots can generate excessive speeds when moving horizontally.

For both of these tests, in order to satisfy the computational redundancy requirement of the Category 3 safety regulations, the shapes of these safety zones are limited to non-rotated rectangular volumes.

Please consult the user manuals for these PreciseFlex™ robots for when speed restrict safety zones must be defined to safely operate these mechanisms.

Configuring Safe Zones

Up to 10 safety zones can be defined per robot. Each of these zones is specified by filling in one of the Parameter Database IDs 16900 to 16909, which are labeled "Safety Zone: type, x/y/z/y/p/r, dim 1/2/3". Any combination of certified and uncertified safety zones can be specified. Each of these DataIDs consists of an array of 10 numbers and the first value defines the safety zone "type". Any DataID that has a zero "type" is ignored. The table below describes the possible safety zone types:

Safety Zone Type	Description
0	Undefined safety zone
1	Rectangular volume, keep out zone
2	Cylinder, keep out zone
3	Sphere, keep out zone
4	Rectangular volume, stay within zone
5	Cylinder, stay within zone
6	Sphere, stay within zone
7	Non-rotated rectangular volume, Z downward speed restrict zone
8	Non-rotated rectangular volume, XY speed restrict zone

This table describes the safety zone Data IDs. When any of these Data IDs are modified, the controller must be rebooted for the change to be put in effect.

Data ID	Parameter Name	Description
16900 to 16909	Safety Zone: type, x/y/z/y/p/r, dim 1/2/3	Each safety zone definition consists of an array of 10 values. The first value is the safety zone "type". The next six values define the position of the origin of the volume of interest and its orientation. This is specified as a standard Location value: x, y, z, yaw, pitch, roll. The final three values define the size of the volume of interest. For the permitted shapes, this is interpreted as: volume: Dx, Dy, Dz Cylinder: Dh, Dr, 0 Sphere: Dr, 0, 0 For example, for a downward Z non-rotated rectangular volume speed restrict safety zone, a single DataID should be specified as follows: 7, x, y, z, 0, 0, 0, Dx, Dy, Dz Where x, y, z are the coordinates of the center of the base of the rectangular volume and Dx, Dy, Dz are the dimensions of the volume, all in mm.

In addition, the DataID in the table below must be initialized to establish the maximum speed limits for the certified safety zones:

Data IDs

DataID	Parameter Name	Description
2740	Certified safety zone, max Z/XY spd mm/sec	These parameters define the maximum speeds that are permitted for the Certified Speed Restrict Safety Zones. The first value is the maximum downward Z speed (when within the safety zone) in mm/sec. Since this is a downward speed, it should be a negative value and defaults to -200. The second value is the maximum permitted speed in the horizontal XY plane (when within the safety zone), and defaults to 200 mm/sec.

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 J1, J3, and J6 axes on the PreciseFlex c8A, and the J1, J3, and J4 axes on the c10 do not have brakes, they may be freely pushed by the operator.

To release the Z brake, the operator may press the brake release switch, under the inner link, as long as 24 VDC is present. It is not necessary for motor power to be on for the brake release to work.

> *NOTE:* The J4 and J5 brakes on the PreciseFlex c8A are not released by the brake release switch to prevent unexpected sagging of the payload.

3. Installation Information

Setup and Operation

1. Unpack the PreciseFlex robot.
2. Mount the robot.
3. Add or remove a gripper (optional). See the *PreciseFlex Gripper* user manual.
4. Connect the power.
5. Connect the PreciseFlex robot to a PC or tablet, and open the interface.
6. Run the robot. See [Accessing the Web Server](#).

Unpacking and Handling Instructions

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

Tool Mounting

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

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

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

Mounting Instructions

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

Robot Base with Bolting Pattern
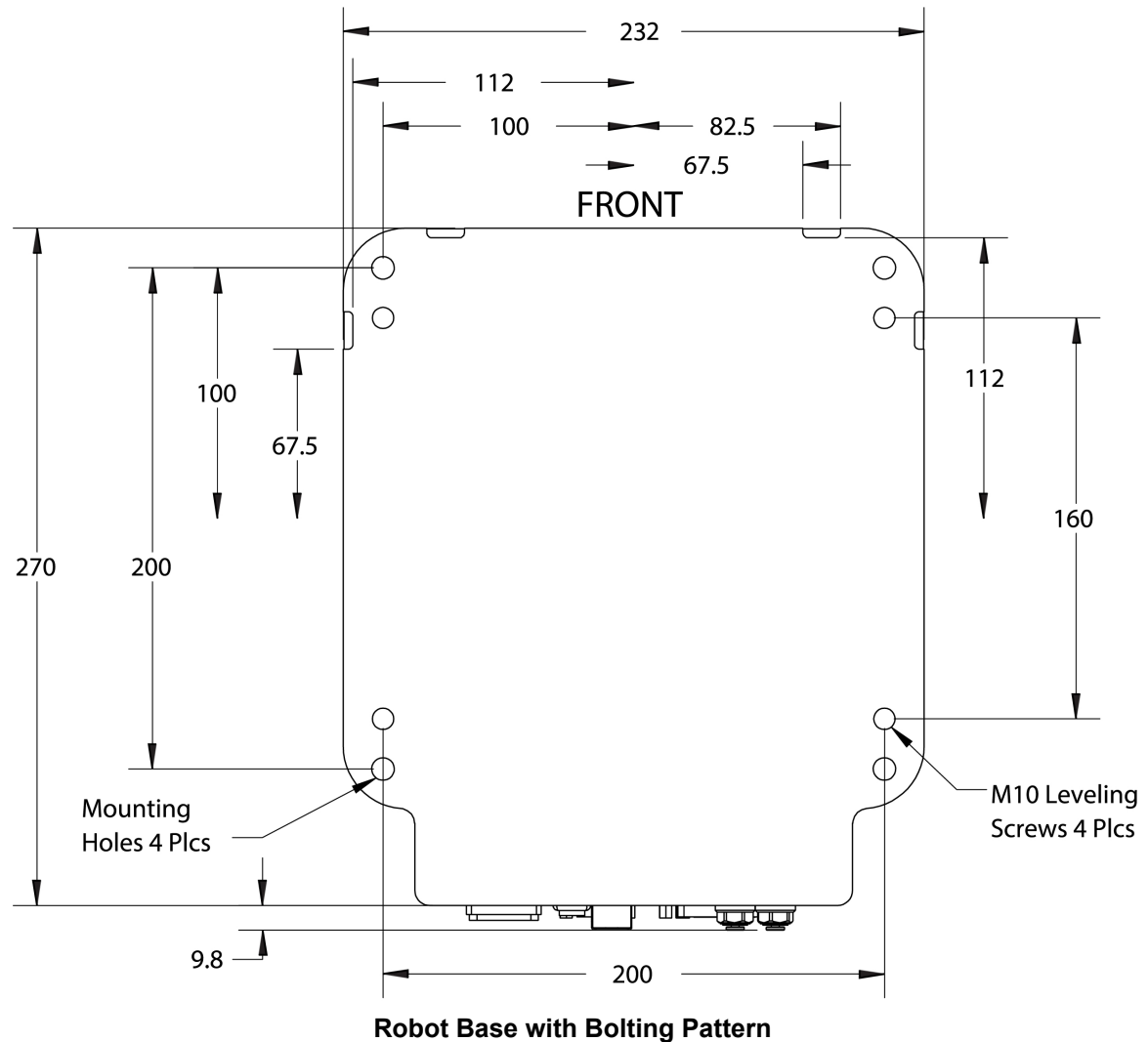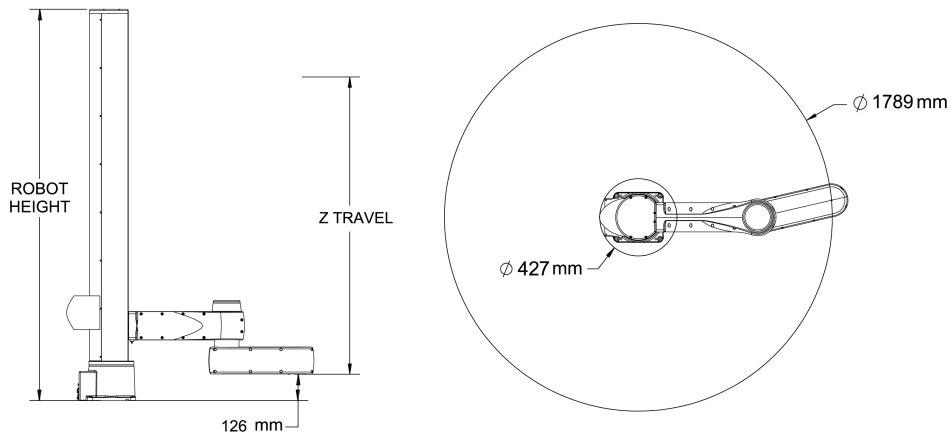
Work Envelope

ROBOT HEIGHT	Z TRAVEL
949 mm	500 mm
1449 mm	1000 mm
1869 mm	1420 mm

c10 Work Envelope
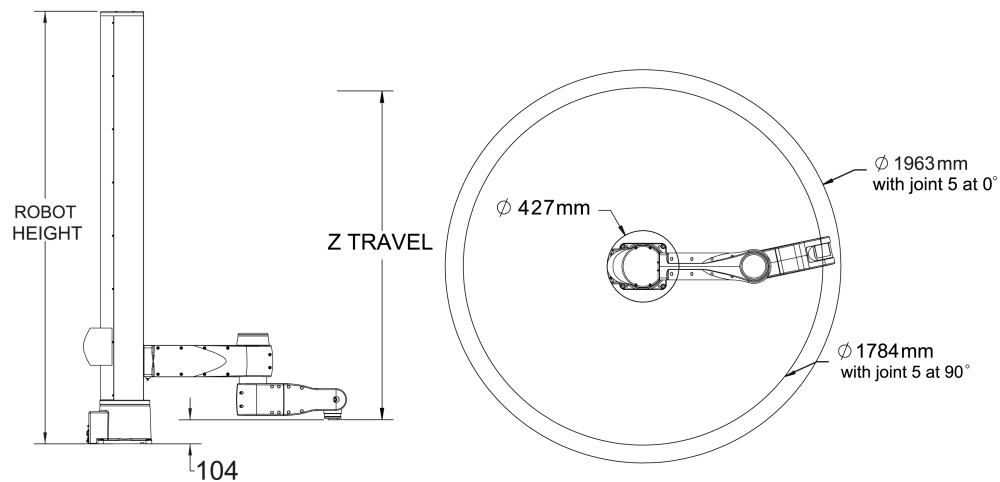
ROBOT HEIGHT	Z TRAVEL
949 mm	500 mm
1449 mm	1000 mm
1869 mm	1420 mm

c8A Work Envelope

ISO Flange for End-of-Arm Tooling
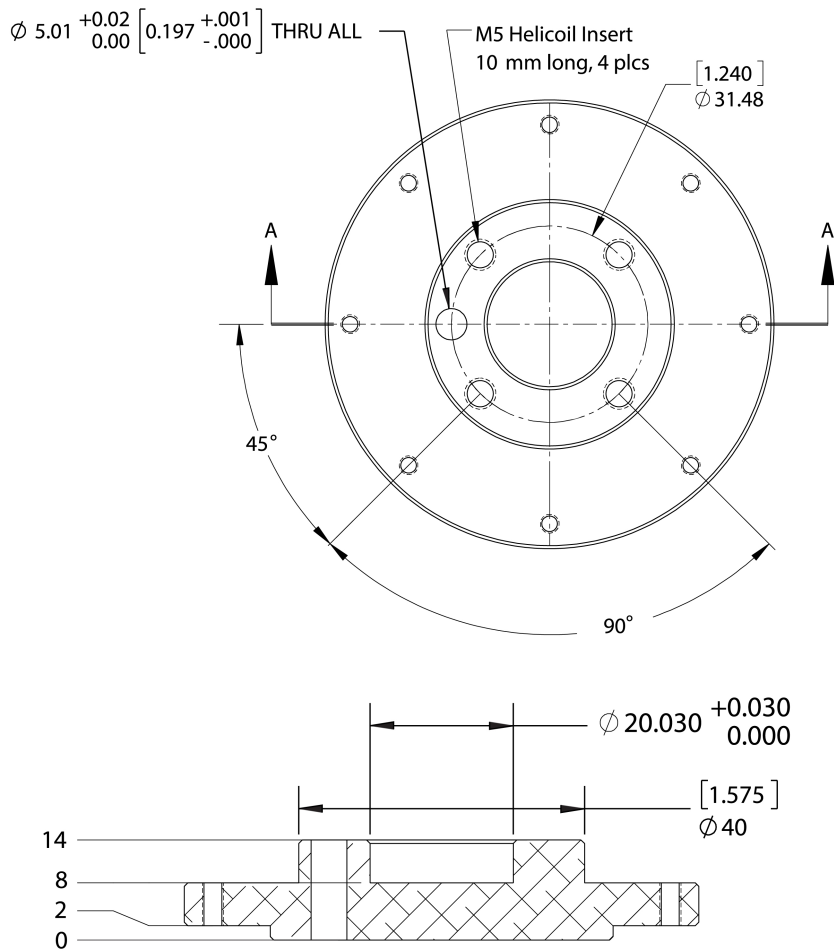
$\varnothing$ 5.01 $^{+0.02}_{0.00}$ [0.197 $^{+.001}_{-.000}$] THRU ALL

M5 Helicoil Insert
10 mm long, 4 plcs

[1.240]
$\varnothing$ 31.48

A

A

45°

90°

$\varnothing$ 20.030 $^{+0.030}_{0.000}$

[1.575]
$\varnothing$ 40

14

8

2

0

c10 ISO Flange

System Dimensions

All dimensions are in millimeters.

Arm Link Length for PreciseFlex c10 Robots

Base Alignment Notches

ROBOT HEIGHT	Z TRAVEL
949mm	500mm
1449mm	1000mm
1869mm	1420mm

Gripper Flange Mount Height PreciseFlex c10

ROBOT HEIGHT	Z TRAVEL
949mm	500mm
1449mm	1000mm
1869mm	1420mm
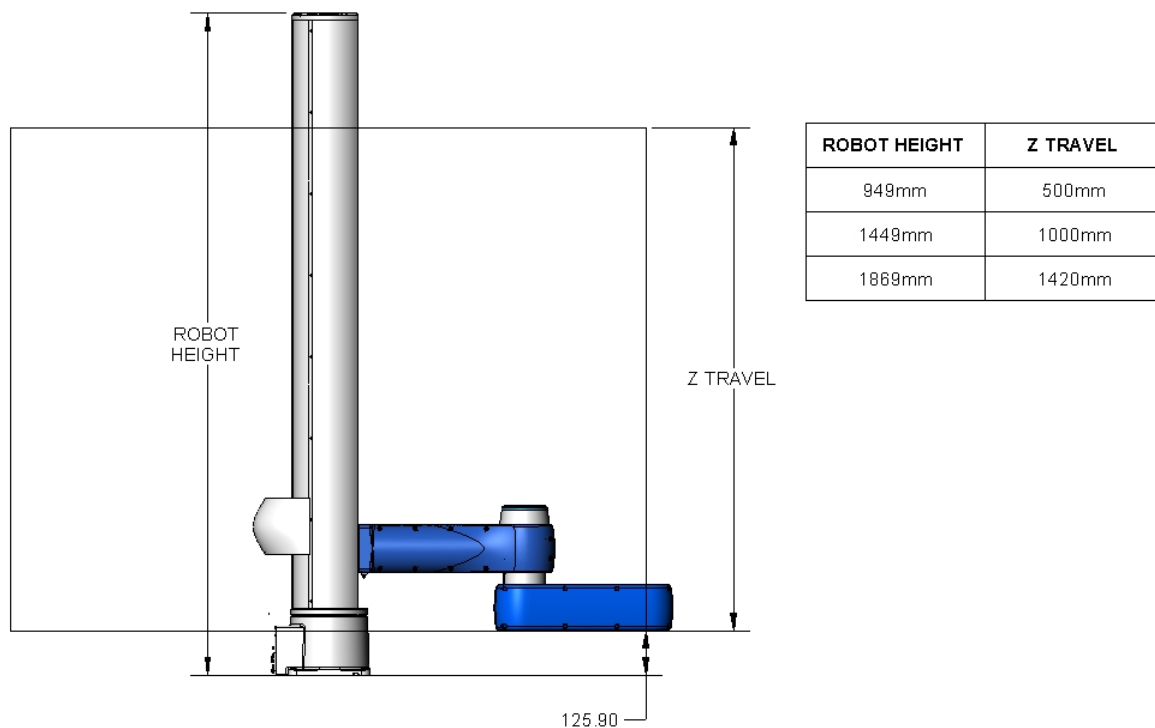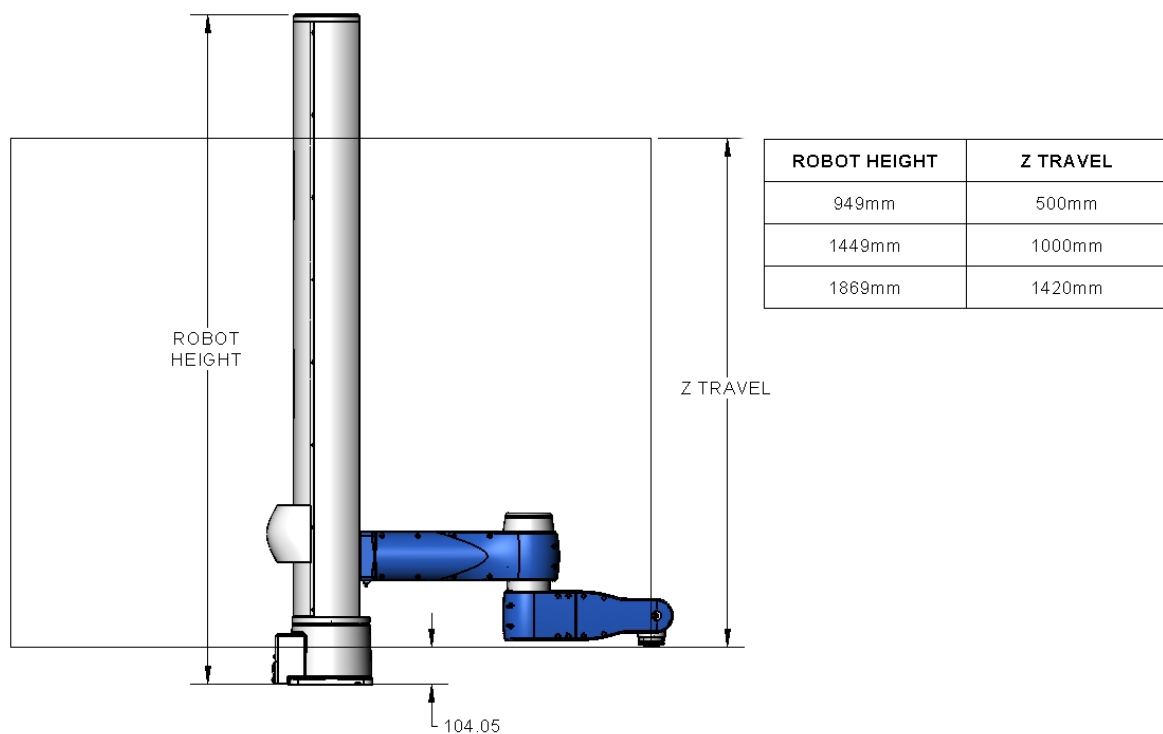
Gripper Flange Mount Height PreciseFlex c8A

Emergency Stop

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

Environmental Specifications

The PreciseFlex c8A and PreciseFlex c10 robots must be installed in a non-condensing environment. Tape seals for the vertical column are an optional order item for environments where fluid or particles may splash against the robot. For applications where the connector panel in the base may be exposed to conductive particles or fluid, it is recommended a panel cover splash hood be added to protect the connectors. With tape seals and a connector hood the robot is rated at IP52. Without these features the robot is rated at IP11. This robot is not intended for use in a washdown or heavy spray environment. See the detailed Environmental Specifications in the appendix for specific environmental limits.

4. Hardware Reference

E-stop Connector

For users that wish to have a hardware E-stop button, Brooks offers an E-stop box or a portable hardware manual control pendant that includes an E-stop button. The E-stop box can be plugged into the 9 pin D-Sub connector 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 satisfy these requirements. Unlike the Digital IO circuits, the E-stop circuit cannot be configured as "Sourcing" or "Sinking." If a remote signal (for example from a PLC) is used to trigger E-stop, it should be wired to a relay that closes the E-stop circuits.

MCP/E-stop Interface

The MCP interface includes the signals necessary to connect a Manual Control Pendant, or E-stop box. These signals are provided in a DB9 female connector mounted on the robot's Facilities Panel.

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

Pin Outs & Description

Pin	Description
1	E-stop_L1
2	E-stop_L2
3	RS232 RXD (Com 2)
4	24 VDC
5	NC
6	FORCE E-stop_L1 (Toggles E-stop Low at Start Up, Then High)
7	FORCE E-stop_L2 (Toggles E-stop Low at Start Up, Then High)
8	RS232 (Com2)
9	Ground
Interface Panel Connector Part No	DB9 Female Connector AMP 5747150-7
User Plug Part No	DB9 Male Plug Amp 1658655-1 (crimp) Pins 22-26AWG 745254-6

Fifteen-Pin D-Sub Signals

Pin	Description
1	24 VDC
2	48 VDC
3	Ground
4	RS-232 TXD (Com1)
5	OSSD1 (Output Signal Switching Device for Safety Devices)
6	RS-485+
7	A+ (Belt)
8	B+ (Belt)
9	48-VDC
10	Ground
11	RS-232 RXD (Com1)
12	OSSD2 (Output Signal Switching Device for Safety Devices)
13	RS-485
14	A- (Belt)
15	B- (Belt)
Interface Panel Connector Part No	DB15 Female Connector AMP 5747299-7
User Plug Part No	DB15 Male Plug Amp 1658656-1 (crimp) Pins 22-26AWG 745254-6

Digital Input and Output Signals

Digital Input Signals

The standard c8A and c10 robots provide twelve general-purpose optically isolated digital input signals at the Facilities Panel (in addition to those signals that are available at the Gripper Control Board). The input signals can be configured as "sinking" or "sourcing" in blocks of 4 by means of a software configuration setting. Set DataID 531 "DIN sink mode 1-4, 5-8, 9-12" to configure source vs. sink for digital input groups. 0 means sourcing, 1 means sinking. Output signals can be configured individually. Set DataID 530 "DOUT sink mode 1, 2, 3, 4, 5, 6, 7, 8" to configure source vs. sink for digital outputs. 0 means sourcing, 1 means sinking. Changing any of these values clears all 8 digital outputs. 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."
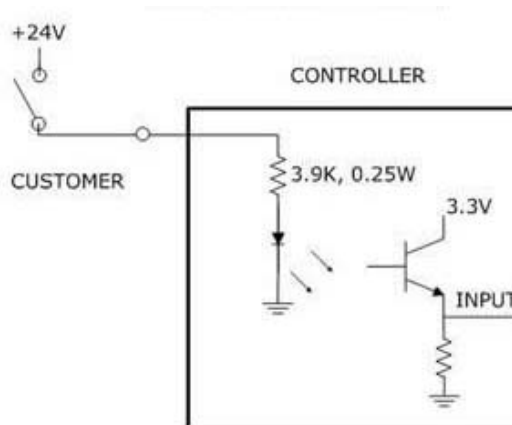
Sinking Digital Input
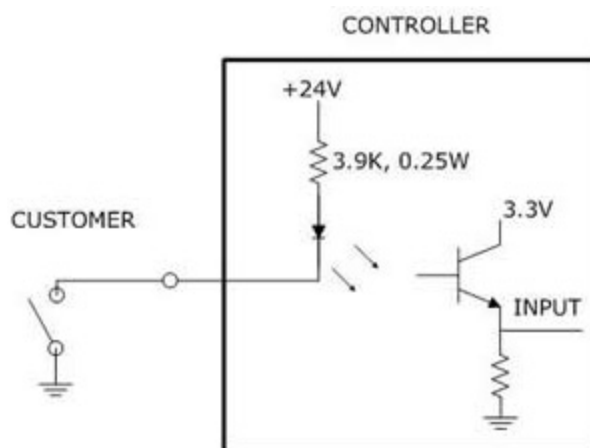
Sourcing Digital Input

Digital Output Signals

The c8A and c10 robot provides 8 general-purpose optically isolated digital output signals in the 25-pin D-Sub connector on the facilities panel. These output signals can be individually configured as "sinking" or "sourcing" by means of a software setting. (See above.) **As shipped from the factory, the output signals are configured as "sourcing,"** i.e. the external equipment must pull down an output pin to ground and the controller pulls this pin to 24 VDC when the signal is asserted as true.
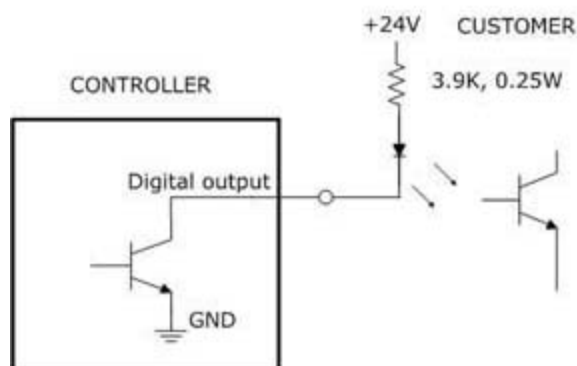
Sinking Digital Output

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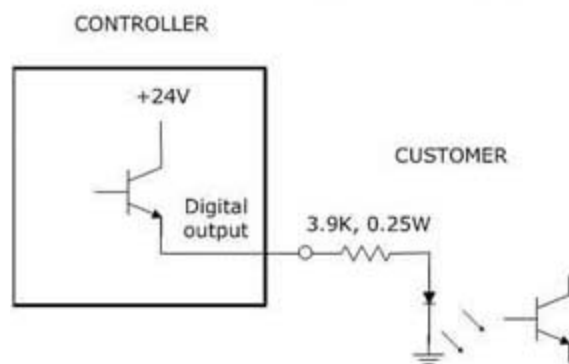
Sourcing Digital Output

The pin out for the c8A and c10 Digital Input and Output Connector and the corresponding GPL signal numbers are described in the following table.
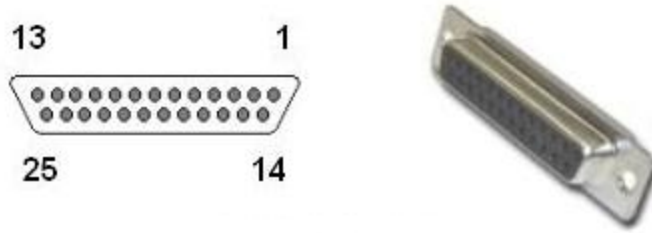
DB25 Female Connector

25-Pin D-Sub Signals

Pin	GPL Signal Number	Description
1		Ground
2	10001	Digital Input 1
3	10003	Digital Input 3
4	10005	Digital Input 5
5	10007	Digital Input 7
6	10009	Digital Input 9
7	10011	Digital Input 11
8		24 VDC
9	13	Digital Output 1
10	15	Digital Output 3
11	17	Digital Output 5
12	19	Digital Output 7
13		24 VDC
14		Ground
15	10002	Digital Input 2
16	10004	Digital Input 4
17	10006	Digital Input 6
18	10008	Digital Input 8
19	10010	Digital Input 10
20	10012	Digital Input 12
21		24 VDC
22	14	Digital Output 2
23	16	Digital Output 4
24	18	Digital Output 6
25	20	Digital Output 8
User Plug Part No		Amp 1658657-1, (crimp) Pins 22-26AWG 745254-6

Digital Inputs and Outputs with GSB4 and GSB4X

For each motor other the base motor, there is a slave amplifier that includes three sinking analog/digital inputs and three sourcing digital outputs (see table below). One digital output is dedicated for an LED light and has a 1,000 ohm resistor in series to limit the current. Three inputs and two outputs are available for application use. The digital inputs are each connected directly to Analog to Digital Converter inputs in the CPU, so they can be set by SW for 0-10 VDC analog inputs (future feature) or 24 VDC digital inputs (current release).

Pin	GPL Signal Number	Description
1	200013	Digital Output 1
2	200014	Digital Output 2
3	200015	Digital Output 3:LED driver (LED Out 3 Jumper Pins 2&3) OR TXD (Out 3 Jumper Pins 1&2)
4		24 VDC output
5		Ground
6	210001	Digital/Analog Input 1 (IN1 Jumper Pins 2&3) OR RXD (IN1 Jumper Pins 1 &2)
7	210002	Digital/Analog Input 2
8	210003	Digital/Analog Input 3
User Plug Part No		TE 794617-8, Pins 794610-1 (20-24AWG Tin)

Ethernet Interface

The PreciseFlex c8A and PreciseFlex c10 robots include an Ethernet switch that implements two 10/100 Mbit Ethernet ports. This capability was designed to permit the controller to be interfaced to multiple Ethernet devices such as other PreciseFlex controllers or robots, remote I/O units, and Ethernet cameras. The Ethernet switch automatically detects the sense of each connection, so either straight-through or cross-over cables can be used to connect the controller to any other Ethernet device.

Due to limited space on the Facilities Panel, only one of the two Ethernet ports is available via an external RJ45 connector. This external Ethernet port is typically used to interface the robot to a PC.

In this case, a PC that is connected to the Ethernet plug on the Facilities Panel can communicate with the robot's controller as well as receive images from an arm-mounted camera. (For the initial release of this robot, arm mounted cameras are not supported.)

If a camera is mounted in the workcell, an external Ethernet switch must be added to connect these cameras and the robot to a PC.

See the *Guidance Controller Setup and Operation Quick Start Guide* on https://www.brooks.com/support/brooks-preciseflex-support/motion-control/ for instructions on setting the IP address for the controller.

RS-232 Serial Interface

The c8A and c10 robots includes a standard RS-232 serial line equipped with hardware or software flow control. This port is available on the 15-pin D-sub connector on the connector panel in the base of the robot as COM1. 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/comnX1" within the Guidance Programming Language (GPL). Use the "/dev/comnX1" syntax for the command where X is the node number. For example, if you are using GSB_4 for the serial communication, the string should be "/dev/comn41".

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

It is possible to connect a bar code reader or other RS-232 serial device to the slip ring located in the robot gripper. In the GSB4 gripper, two IO pins have optional assignments based on jumpers. For J4 connect pins 2 and 3 to connect Digital Input 1 to pin 6 and connect pins 1 and 2 to connect pin 6 to a line that goes back to a CPU serial input where it is multiplexed onto RS-485 to connect back the main controller COM1 input. For J7 connect pins 2 and 3 to connect Digital Output 3 to pin 3 and connect pins 1 and 2 to connect pin 3 to a line that goes back to a CPU serial input where it is multiplexed onto RS-485 to connect back the main controller COM1 input. Serial data rate is limited to 9600 baud. (Not available in beta units)
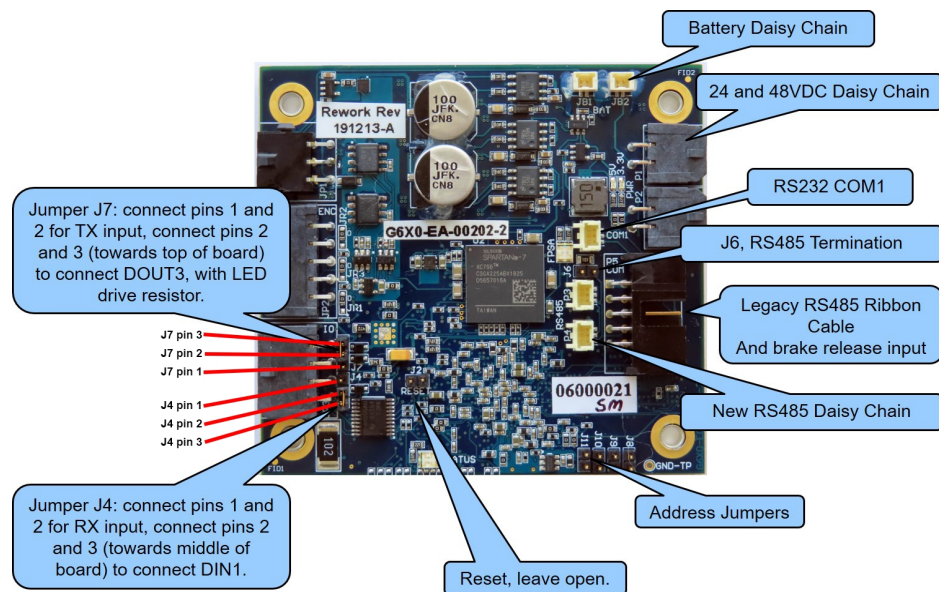
J4 and J7 on GSB4 Board

Refer to Slip Ring drawings in the Hardware Reference section for the slip ring connector pin assignments inside the grippers. The mating connector is TE (Amp) Micro Mate N Lok PN 794617-6 with contacts PN 1-794611-2. It is recommended that 24 V bar-code readers be used as the 5 V supply is very limited.

Several bar code readers that have been successfully implemented with PreciseFlex Robots are the following:

1. Keyence SR750, 1D and 2D, 24 VDC supply, 200 ma, 60 mm distance
2. Cognex DM50, DM60, DM70, 24 VDC supply, 500 ma, 45 to 110 mm distance
3. Omron/Microscan MiniHawk, 1D and 2D, 5 VDC supply, need converter from 24 VDC
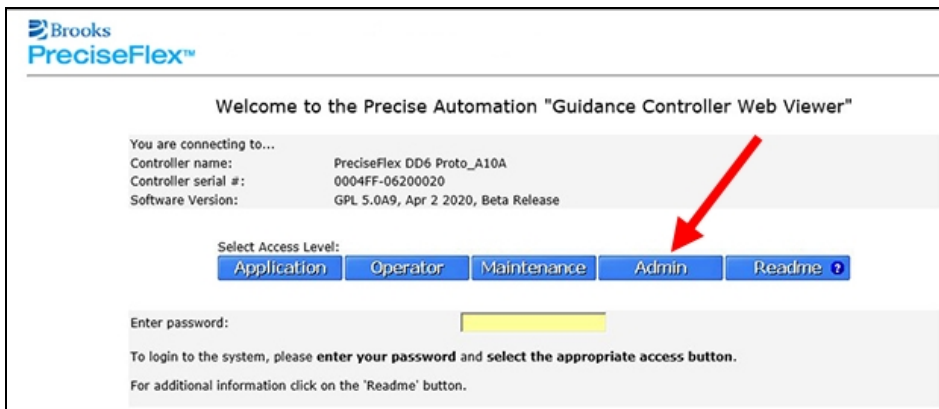
5. Software Reference

Accessing the Web Server

Many OEM customers run Brooks Robots 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 Interface embedded in the controller.

The Web Server Interface may be addressed by opening a browser in a PC, tablet, or smart phone that is connected to the robot via Ethernet. The user must know the IP address of the robot controller. Two common IP addresses are 192.168.0.1 and 192.168.0.10. The PC LAN interface address must be configured correctly (for example 192.168.0.100, with subnet mask 255.255.255.0). The Web Server Interface will display.

It may be necessary to enter a password if a company has protected access to the Web Interface. Once the password has been entered, click **Admin** to access all the features to perform system upgrades.

Web Server Interface

After clicking, **Admin**, the *System Setup* window will display.
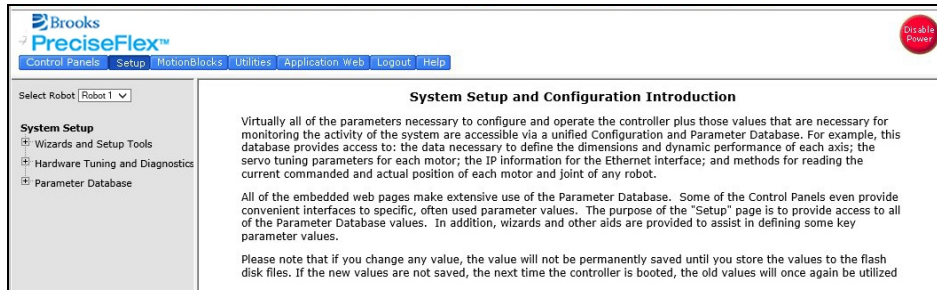
System Setup

Click the **Control Panels button** in the top bar, then click in the left navigation column, click **Operator Control Panel**. The *Operator Control Panel* window will display.
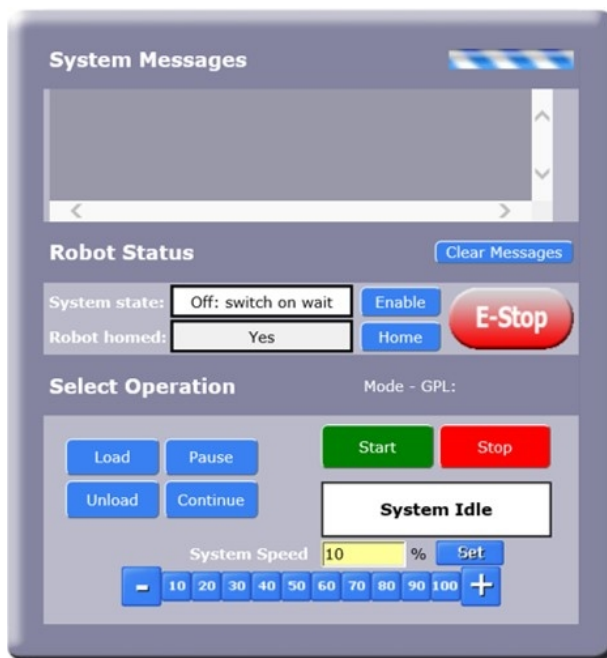
 Operator Control Panel

If an application is running, the *System Running* panel will display in green. In order to run diagnostics, the user must stop the application from running. Click **Stop**. This will stop the application from running. Click **Disable Power** to ensure that the motor power is off. To load a new project (for example CAL_PP), click **Unload** and then **Load** before loading the new project into RAM.

Robot Payload Control Panel
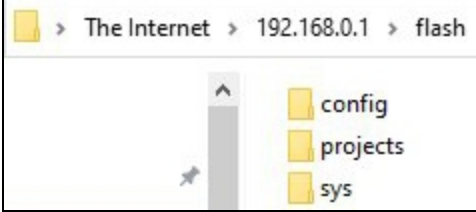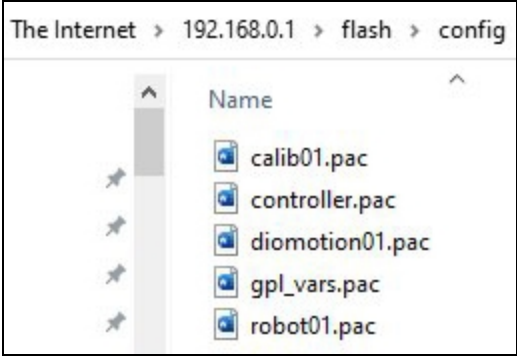
For optimal performance of direct drive robots, the correct robot payload must be entered into the control system. During manual control, select the **Control Panels > Robot Payload**, and in the **Set**
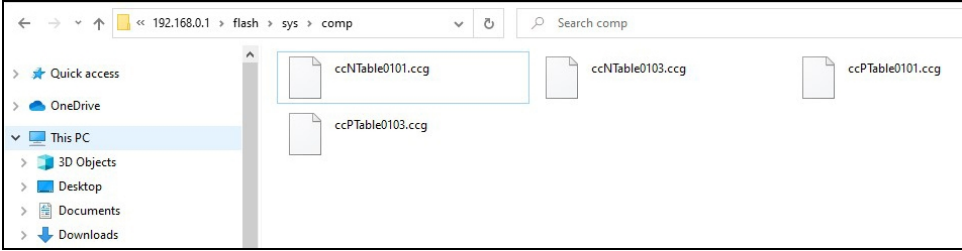
New Payload % (0 - 100) field, enter a value between 0 and 100. 100% represents a 10 kg payload for the c10 and an 8 kg payload for the c8A.
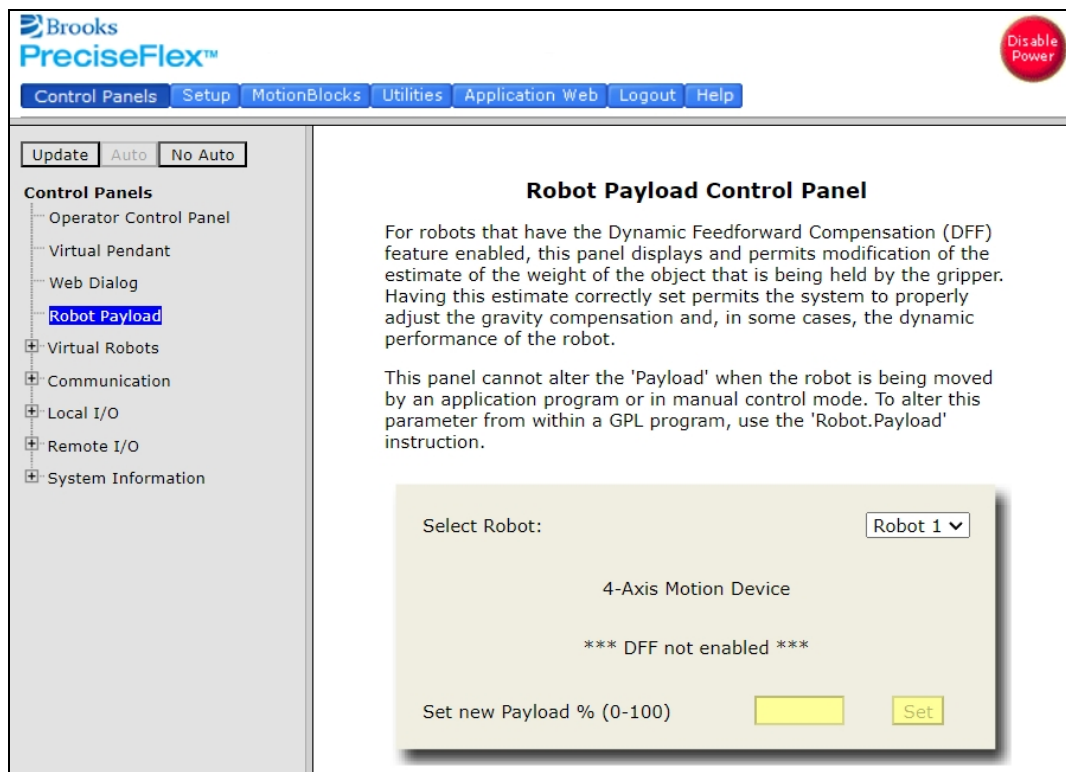
Loading a Project (Program) or Updating PAC Files

If CAL_PP or a different program needs to be loaded into the controller from an external computer, this may be done via FTP. Previous generations of GPL supported this process directly from the GPL Web Server, but Windows 10 and Edge no longer allow this. To load a project (program) or update PAC files, complete the following steps.

Step	Action
1.	Use the File Explorer to access the flash directly. For example, type **ftp://192.168.0.1/flash** in the File Explorer address line if the controller is set to the default address 192.168.0.1. Otherwise, use the controller IP address. This should bring up a window with the following files: > The Internet > 192.168.0.1 > flash config projects sys
2.	To load a GPL Project, such as CALPP, Open the **Projects** folder and paste the project folder into this area. There may be several other projects (programs) loaded into this folder, which is stored in flash ram in the controller. A project folder is a software folder than may have several files inside it. The entire folder must be loaded, not just the files inside.
3.	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.
4.	To load or update PAC files, open the **Config** folder and paste a backup copy of the PAC files into the **Config** folder. These files will all have a **.pac** extension. Wait at least 15 seconds after the copy is complete before turning off the controller. Reboot the robot after the new PAC files are installed for them to take effect. The Internet > 192.168.0.1 > flash > config Name calib01.pac controller.pac diomotion01.pac gpl_vars.pac robot01.pac
5.	If the updated PAC files are new, it is necessary to re-calibrate the robot and re-establish commutation reference. To re-calibrate the robot, use Cal_pp_revXX program which comes with the robot, or download the latest from Brooks support website. To re-establish commutation reference, copy the value of DataID 10775 from the original PAC files (if available) to the robot using web interface. Otherwise contact Brooks support to obtain a set of PAC files that are shipped with the robot to retrieve the value.

Step	Action
6.	To update the DD motor cogging compensation tables, go back up to the top-level directory and open the FLASH file, then open the sys file, then open the comp file. Paste the new cogging compensation tables into the comp file, wait 15 seconds, and then reboot the controller.

Updating GPL (System Software and Firmware)

GPL (the system software and firmware are now a single file in GPL 5.0 and later) may be upgraded in the field. To update GPL (system software and firmware), complete the following steps:

Step	Action
1.	Get the appropriate upgrade software from Brooks Automation in the form of a .gz file. Email support_preciseflex@brooksautomation.com
2.	Use the File Explorer to access the ROMDISK GPL storage area directly. Type **ftp://192.168.0.1/ROMDISK/bin** in the File Explorer address line.
3.	Paste the new GPL system file into this folder.

Step	Action
4.	In the browser, click the **Admin > Utilities** button at the top of the screen, then in the left navigation panel, click **System Utilities > System Upgrade**. 1. Open up the 'ROMDISK/bin' folder on the controller using Windows FTP. 2. Copy the provided '*.gz' file into the 'ROMDISK/bin' folder by dragging and dropping. 3. Click the 'Update' button. The operation can take up to 1 min. Update
5.	Wait until the Update Complete message appears. Then wait 15 seconds for the flash to store the data and reboot the controller for the new version of GPL to take effect.
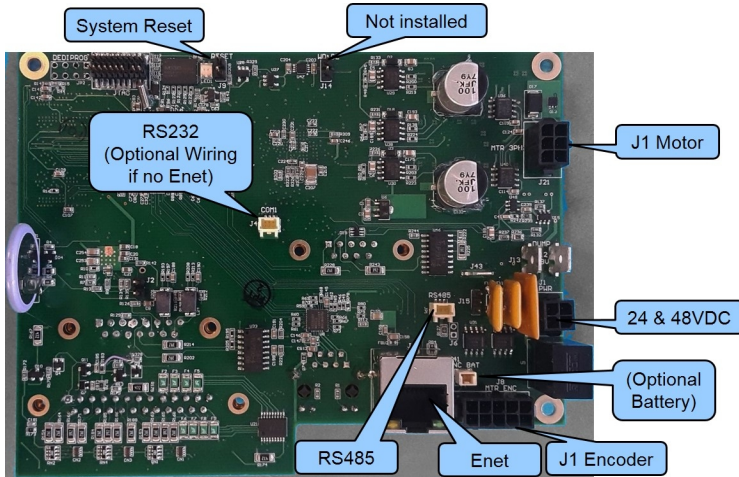
Recovering from Corrupted PAC Files

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

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

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

To configure the controller to boot up in recovery mode, complete the following steps:

Step	Action
1.	Obtain a set of backup PAC Files from Brooks or a local backup. Email support_preciseflex@brooksautomation.com for backup copies.
2.	Remove the screws holding the connector panel in the base of the robot to access the PCA.
3.	Move Jumper J9 (System Reset) so that it connects the two jumper posts. This will cause the factory default configuration files to be loaded at controller boot up.
4.	Cycle robot power to reboot the controller.
5.	Follow the procedure above for updating PAC files.

Appendices

Appendix A: Conditions of Acceptability

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

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

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

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

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

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

- The spacings have been evaluated to Pollution Degree 2.

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

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

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

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

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

Appendix B: c8A Product Specifications

General Specification	Range
PERFORMANCE	
Payload	8 kg
Max Cartesian Speed	500 mm/sec, horizontal plane, X/Y direction, 600 mm/sec, Z direction
Max Joint Speed	J1 200°/sec J2 600 mm/sec J3 360°/sec J4 360°/sec J5 200°/sec J6 360°/sec
Max Acceleration	5000 mm/sec2 with 6 kg payload
Repeatability	± 0.020 mm at tool flange center
RANGE OF MOTION	
Joint 1 (base)	± 168°
Joint 2 (Z-axis)	500, 1000, 1420 mm
Joint 3 (Elbow)	+12° to +348°
Joint 4	+100° to -120°
Joint 5	± 110°
Joint 6	± 295°
Horizontal Reach	(Horizontal Reach) 896 mm with Joint 5 at 90° (Horizontal Reach) 985 mm with Joint 5 at 0°
COMMUNICATIONS	
General	100 Mb Ethernet, TCP/IP EtherNet/IP Modbus/TCP
Operator Interface	Web-based operator interface
Digital I/O	12 inputs, 8 outputs at base of robot Optically isolated, 24 V @ 100 mA Remote I/O available
FACILITIES	
Power	90 to 264 VAC, auto selecting, 50-60 Hz 70-175 watts typical operation DC Power Option Available

General Specification	Range
Pneumatics	Two 3.2 mm OD (1.7 mm ID) airlines provided for end-of-arm-tooling 4.9 bar max (71 PSI)
E-Stop	Dual Channel
Controller Mounting	Embedded into robot base
Air Lines	Two, 3.2 mm OD, 1.6 mm ID, max pressure 500 kpa (75 psi)
Weight	46 kg (500 mm Z-axis) 55 kg (1000 mm Z-axis) 65 kg (1420 mm Z-axis)
Noise Level	< 50 dB(A)
SOFTWARE	
Programming	Programming via Guidance Development Studio (GDS) Guidance Programming Language (GPL) TCS API
Enhanced Functions	Hand Guiding Teaching (standard)
PERIPHERALS AND ACCESSORIES	
General	Remote I/O (RIO)
TEMPERATURE	
Indoor	For indoor use only
Ambient Temperature	0°C to 40°C
Humidity Range	10 to 75%, non-condensing, non-corrosive
Storage and Shipment Temperature	-25°C to +55°C

Appendix C: c10 Product Specifications

General Specification	Range
PERFORMANCE	
Payload	10 kg
Max Cartesian Speed	500 mm/sec in horizontal plane 600 mm/sec in z-direction
Max Joint Speed	J1 - 200°/sec J2 - 600 mm/sec J3 - 360°/sec J4 - 540°/sec
Max Acceleration	5000 mm/sec^2 with 6 kg payload
Repeatability	± 0.020 mm at tool flange center
RANGE OF MOTION	
Joint 1 (base)	± 168°
Joint 2 (Z-axis)	500, 1000, 1420 mm
Joint 3 (Elbow)	+ 12° to +348°
Joint 4	± 240°
Horizontal Reach	896 mm
COMMUNICATIONS	
General	100 Mb Ethernet, TCP/IP Modbus/TCP RS232 at end-of-arm
Operator Interface	Web-based operator interface
Digital I/O	12 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
FACILITIES	
Power	90 to 264 VAC Auto selecting, 50-60 Hz 100-250 watts typical operation
Pneumatics	Two 3.2 mmOD (1.7 mm ID) airlines provided for end-of-arm-tooling. 4.9 bar max (71 PSI)
E-Stop	Dual channel

General Specification	Range
Controller Mounting	Embedded into robot base
Weight	44 kg (500 mm Z-axis) 53 kg (1000 mm Z-axis) 63 kg (1420 mm Z-axis)
Noise Level	< 50 dB(A)
SOFTWARE	
Programming	Programming via Guidance Development Studio (GDS) Guidance Programming Language (GPL) TCS API
Enhanced Functions	Hand-guided teaching XY compliance (optional) Z-Height detection (optional)
PERIPHERALS AND ACCESSORIES	
General	IntelliGuide s23 gripper IntelliGuide s60 gripper IntelliGuide s23D gripper (Dual) Remote I/O (RIO)
Vision	IntelliGuide v23 Vision IntelliGuide v60 Vision
TEMPERATURE	
Indoor	For indoor use only
Ambient Temperature	0°C to 40°C
Humidity Range	10 to 75%, non-condensing, non-corrosive
Storage and Shipment Temperature	-25°C to +55°C

Appendix D: Environmental Specifications

The c8A and c10 Robots must be installed in a non-condensing environment with the specifications from the table below.

General Specification	Range & Features
Indoor use only	
Ambient temperature	4º C to 40º C
Storage and shipment temperature	-25º C to +55º C
Humidity range	10 to 90%, non-condensing
Altitude	Up to 2000 m
Voltage	100-240 VAC +/- 10%, 50/60 Hz
Mains cord rating, min	16 AWG, 3 conductor, 10 Amps min
Pollution Degree	2
Approved Cleaning Agents	IPA, 70% Ethanol/30% water, H2O2 Vapor up to 1000 ppm
IP Rating without Tape Seal Option	1P1X
IK Impact Rating	IK08: 5 Joule

Appendix E: Preventative Maintenance

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

	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.
Check second stage (long) Z belt for any squeaking.	If noisy, add thick grease to front and rear edge of belt if necessary. (Shell 222 XP or similar). Z timing belt can get stiffer over time (2-3 years) and occasionally start squeaking against pulley flanges.
Check if front cover is rattling.	If so, check .125 in ID by .062 in thick O rings on dowel pins in base plate under front cover for any deterioration and replace if necessary.
Replace slip ring in c10 if present.	For units with 23 N electric replace the slip ring every third inspection test, or 20,000 hours of operation.

Appendix F: Safety Circuits for the c8A and c10 Robots

NOTE: Note: (2 kg robot has redundant E-stop and 48 V power supply enabled)

	Safety Circuit	Startup Test 1	Redundant	Continuous Test	Diagnostic Coverage	MTTFdl, Years	Power Off On Failure	PL	Category Safety
1	Estop	Yes	Yes	Yes	99%	100	Yes	d	4

- Startup test forces E-stop, checks 48 V power disable, zero amp current.
- Dual E-stop circuits turn off amp enable and PWM.
- Dual E-stop circuits turn off 48 V power.
- Stopping robot with hand turns off amp enable, PWM, and 48 V.

	Safety Circuit	Startup Test 1	Redundant	Continuous Test	Diagnostic Coverage	MTTFdl, Years	Power Off On Failure	PL	Category Safety
2	Encoder Feedback	Yes	No	Yes	90%	59	Yes	d	4

- Startup test checks encoder communication, prevents mtr power if fault.
- Serial update at 8 kHz w checksum, comm check, accel check.
- Counter embedded in position word to confirm CPU read from FPGA,

	Safety Circuit	Startup Test 1	Redundant	Continuous Test	Diagnostic Coverage	MTTFdl, Years	Power Off On Failure	PL	Category Safety
3	CPU Monitor	Yes	Yes	Yes	99%	100	Yes	d	4

- Startup test forces CPU WD low, checks 48 V power disabled.
- Independent dual watchdog timers turn off amp enable, PWM and 48 V.
- Processor on safety board monitors main CPU. Disables 48 V if failure.

	Safety Circuit	Startup Test 1	Redundant	Continuous Test	Diagnostic Coverage	MTTFdl, Years	Power Off On Failure	PL	Category Safety
4	Position Envelope Error	Yes	Yes	Yes	90%	59	Yes	d	4

- Startup test checks encoder communication, prevents mtr power if fault.
- Serial update at 8 kHz w checksum, comm check, accel check.
- SW watchdog in servo loop turns off amp enable, PWM and 48 V.
- Counter embedded in position word to confirm CPU read from FPGA.

	Safety Circuit	Startup Test 1	Redundant	Continuous Test	Diagnostic Coverage	MTTFdl, Years	Power Off On Failure	PL	Category Safety
5	Power amp Fault	Yes	Yes	Yes	90%	100	Yes	d	4

- Startup test confirms zero current when motor power enabled (phase offset test).
- Excess current to ground or phase to phase triggers shutdown in 10 sec.
- Saturated PID current command triggers shutdown in .050 sec.
- Shorted transistor just locks up brushless motor.

	Safety Circuit	Start up Test 1	Redundant	Continuous Test	Diagnostic Coverage	MTTFdl, Years	Power Off On Failure	PL	Category Safety
6	Collab Force Limit	Yes	Yes	Yes	90%	SW	Yes	d	4

- Tests 2, 3, 4, 5 above test HW.
- Position envelope error triggers fault, turns off power at amp and 48 V.
- Current saturation triggers separate fault, turns off power at amp and 48 V.
- Monitor function with WD turns off power at amp and 48 V.
- Monitor and CPU WD tested at startup turning off 48 V.
- Asymmetric current limits limit Z force even with gravity load.

Appendix G: Example Performance Level Evaluation

Example Workcell description: A c10 moves 100-gram plastic trays from storage racks to an instrument and back to the storage racks. The 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 the instrument is made at 50 mm/sec. Lowest storage rack position is 50 mm above the table surface.

Example 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 are 105 N. Pausing robot and removing racks from workcell with 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 is 182 N, which is below free space collision for 500 ms maximum of 280 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 60 mm/sec (10% of max speed of 600 mm/sec) is 77 N.

Performance Level: From the above, based on ISO 13849-1:2006:

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

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

Appendix H: c10 - Test Methods for Measuring Forces and Pressures in Human-Robot Contact

Testing in this report is based on the publicly available specification ISO/PAS 5672:2023 *Robotics — Collaborative applications — Test methods for measuring forces and pressures in human-robot contacts*. This document is modeled on the Reporting Template of that ISO specification, Annex E.

Application

This Pick and place application includes a robot shown in the figure below. The robot's task is to pick up workpieces from the conveyor and transfer them to a target station.

Contact Hazards and Measuring Points: Contact Hazard 1

Pinch of the Hand When Robot Approaches Workpiece on the Station

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uring Forces and Pressures in Human-
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If a misaligned workpiece on the station is about to disturb the process, a human operator can try to correct the position of the workpiece by hand as the robot approaches it. This event of foreseeable misuse can lead to unintended contact with human. Since the robot approaches the workpiece slowly and the station constitutes an obstacle that hinders movement of the human body, the type of contact constitutes a pinch (load profile = quasi-static; spatial config = constrained).

Body regions that can be affected by the impact are lower arms and wrist joints and hands and fingers. Measurement method is a force sensor.

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Appendix H: c10 - Test Methods for Meas-
uring Forces and Pressures in Human-
Robot Contact

Possibly Endangered Body Locations

ID	Body Location	Force [N]		Contact type		
		QS	TR	Pinch	Impact	Crush
1	Lower arms and wrist joints	160 N	N /A	X	N/A	N/A
2	Hands and fingers	140 N	N/A	X	N/A	N/A

Measurement Results from Test of Body Location ID (1,2) – Height Detection Enabled. This method is done at the application level.

Speed	Auto adjusted by Z-Height detect functionality
Payload	4 kg
Notes	Default settings / Z-Height detection enabled
Start position	Angles(0,1100,215,-40)

End position	Angles(0,1001.5,215,-40)
Impact Position	Angles(0,981.5,215,-40)
Distance after impact	20 mm
Motion profile	Auto adjusted by Z-Height detect functionality

Criteria 1 (quality indicator for the measurement setup; ISO/PAS 5672:2023, 7.4)

Contact Phase	Relative Standard Deviation For	~ [%]	Threshold	Measurement Setup
Quasi-static	Force [N]	N/A	5	N/A
	Pressure [N/cm2]	N/A	10	N/A
Transient	Force [N]	2.178	5	OK
	Pressure [N/cm2]	N/A	10	N/A

Criteria 2 (Comparison of Sample Mean with the Biomechanical Limit for the Body Location Tested; ISO/PAS 5672:2023, 7.4)

Contact phase	Mean for	Units Measured (N)	Limit	Test
Quasi-static	Force [N]	N/A	N/A	N/A
	Pressure [N/cm2]	N/A	…	N/A
Transient	Force [N]	131.7	280/320	Passed
	Pressure [N/cm2]	N/A	…	N/A

Measurement Results from Test of Body Location ID (1,2) – Adjusted Negative Output Limit

Speed	10% (60 mm/sec)

Payload	4 kg
Notes	Adjusted negative output level for Z axis
Start Position	Angles (0,1100,215,-40)
End Position	Angles (0,1001.5,215,-40)
Impact Position	Angles (0,981.5,215,-40)
Distance After Impact	20 mm
Motion Profile	Accel/Decel: 100%/50% RampUp/RampDown: 0.15 InRange: 10 System Speed: 100%

Criteria 1 (Quality Indicator for the Measurement Setup; ISO/PAS 5672:2023, 7.4)

Contact Phase	Relative Standard Deviation for	~ [%]	Threshold	Measurement Setup
Quasi-static	Force [N]	0	5	OK
	Pressure [N/cm2]	N/A	10	OK / not OK
Transient	Force [N]	N/A	5	OK / not OK
	Pressure [N/cm2]	N/A	10	OK / not OK

Criteria 2 (Comparison of Sample Mean with the Biomechanical Limit for the Body Location Tested; ISO/PAS 5672:2023, 7.4)

Contact Phase	Mean for	Units Measured (N)	Limit	Test
Quasi-static	Force [N]	138	140/160	Passed
	Pressure [N/cm2]	N/A	N/A	N/A
Transient	Force [N]	N/A	N/A	N/A
	Pressure [N/cm2]	N/A	N/A	N/A

Contact Hazards and Measuring Points: Contact Hazard 2

Impact with Upper Body Extremity When Robot Approaches Station Where Operator Task is Being Performed

A robot or operator drops a workpiece at the assembly/inspection station. The operator tries to remove it while the robot approaches the station with another part, leading to unintended contact with the operator's shoulder, back, or upper arms. Since the human body can move freely (no obstacles near the station), the type of contact will constitute an impact (load profile = dynamic; special config = unconstrained).

Body locations that can be affected by the impact are back, shoulders, chest, upper arms, and elbow joints. The cell must be designed with a spatial configuration resulting in the human body being able to recoil at impact and being unconstrained. Robot lateral motion shall be at or below the shoulder level. Pinch and crush contact types are not considered for this contact hazard. Measurement method is a force sensor.

Possibly Endangered Body Locations

ID	Body Location	Force [N]		Contact Type		
		QS	TR	Pinch	Impact	Crush
1	Back & shoulder	N/A	F_T = 210x2	N/A	X	N/A
2	Chest	N/A	F_T = 140x2	N/A	X	N/A
3	Upper arms & elbow joints	N/A	F_T = 150x2	N/A	X	N/A

Measurement Results from Test of Body Location ID (1,2,3) – X Axis Cartesian Motion.

Speed	100% (600 mm/sec)
Payload	4 kg
Notes	X Axis Cartesian motion / Default settings
Start position	XYZ(250,-250,855,5,90,-180)
End position	XYZ(680,-250,855,5,90,-180)
Impact Position	XYZ(730,-250,855,5,90,-180)

Distance after impact	50 mm
Motion profile	Accel/Decel: 100%/100% RampUp/RampDown: 0.15 InRange: 10 System Speed: 100%

Criteria 1 (Quality Indicator for the Measurement Setup; ISO/PAS 5672:2023, 7.4)

Contact phase	Relative standard deviation for	[%]	Threshold	Measurement Setup
Quasi-static	Force [N]	N/A	5	N/A
	Pressure [N/cm2]	N/A	10	N/A
Transient	Force [N]	0.42	5	OK
	Pressure [N/cm2]	N/A	10	N/A

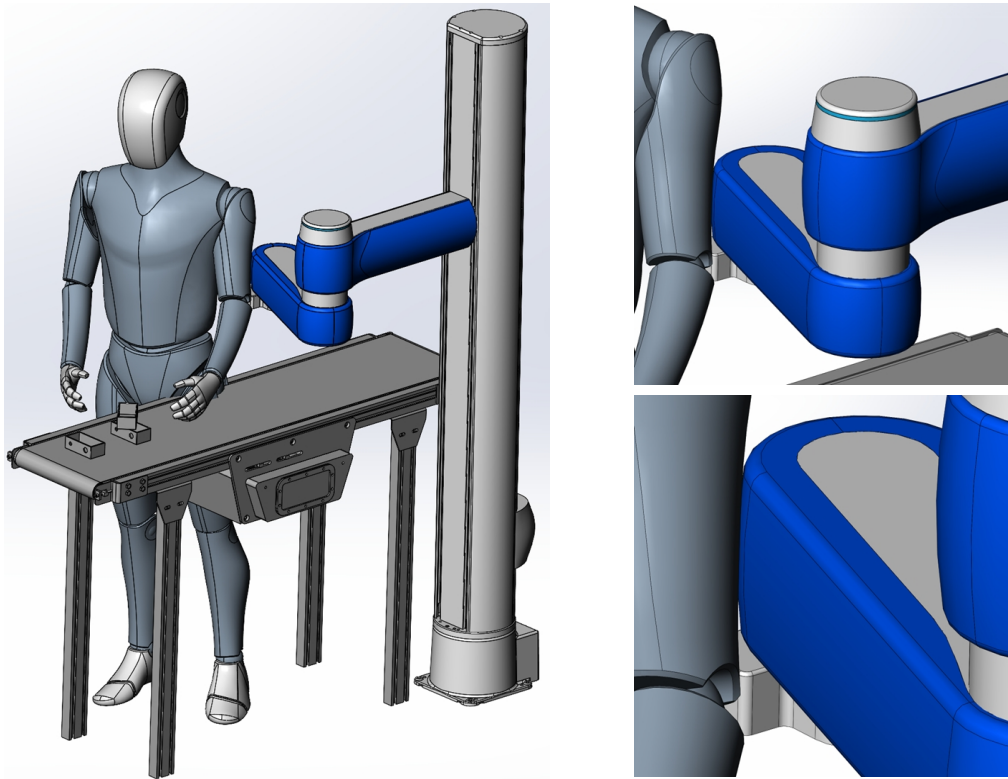## Criteria 2 (Comparison of Sample Mean with the Biomechanical Limit for the Body Location Tested; ISO/PAS 5672:2023, 7.4)

Contact phase	Mean for	Units Measured (N)	Limit	Test
Quasi-static	Force [N]	N/A	N/A	N/A
	Pressure [N/cm2]	N/A	…	N/A
Transient	Force [N]	113.33	280/300/420	Passed
	Pressure [N/cm2]	N/A	…	N/A

Measurement Results from Test of Body Location ID (1,2,3) – Y Axis Cartesian Motion

Speed	100% (600 mm/sec)
Payload	4 kg
Notes	Y Axis Cartesian motion / Default settings

Start Position	XYZ (235,-150,950,-110,90,-180)
End Position	XYZ (235,-550,950,-110,90,-180)
Impact Position	XYZ (235,-600,950,-110,90,-180)
Distance after Impact	50 mm
Motion Profile	Accel/Decel: 100%/100% RampUp/RampDown: 0.15 InRange: 10 System Speed: 100%

Criteria 1 (Quality Indicator for the Measurement Setup; ISO/PAS 5672:2023, 7.4)

Contact Phase	Relative Standard Deviation for	[%]	Threshold	Measurement Setup
Quasi-Static	Force [N]	N/A	5	N/A
	Pressure [N/cm2]	N/A	10	N/A
Transient	Force [N]	0.72	5	OK
	Pressure [N/cm2]	N/A	10	N/A

Criteria 2 (Comparison of Sample Mean with the Biomechanical Limit for the Body Location Tested; ISO/PAS 5672:2023, 7.4)

Contact Phase	Mean for	Units Measured (N)	Limit	Test
Quasi-static	Force [N]	N/A	N/A	N/A
	Pressure [N/cm2]	N/A	…	N/A
Transient	Force [N]	113	280/300/420	Passed
	Pressure [N/cm2]	N/A	…	N/A

NOTE: Weight of the pressure-force measurement devices (PFMD) used for the impact force testing is 1.9 kg.

Appendices

Appendix I: c8A - Test Methods for Meas-
uring Forces and Pressures in Human-
Robot Contact

PreciseFlex c10-c8A User Manual

Part Number: 629013 Rev. C

Appendix I: c8A - Test Methods for Measuring Forces and Pressures in Human-Robot Contact

Testing in this report is based on the publicly available specification ISO/PAS 5672:2023 *Robotics — Collaborative applications — Test methods for measuring forces and pressures in human-robot contacts*. This document is modeled on the Reporting Template of that ISO specification, Annex E.

Application

This Pick and place application includes a robot shown in the figure below. The robot's task is to pick up workpieces from the conveyor and transfer them to a target station.

Contact Hazards and Measuring Points: Contact Hazard 1

Pinch of the Hand When Robot Approaches Workpiece on the Station

If a misaligned workpiece on the station is about to disturb the process, a human operator can try to correct the position of the workpiece by hand as the robot approaches it. This event of foreseeable misuse can lead to unintended contact with human. Since the robot approaches the workpiece slowly and the station constitutes an obstacle that hinders movement of the human body, the type of contact constitutes a pinch (load profile = quasi-static; spatial config = constrained).

Body regions that can be affected by the impact are lower arms and wrist joints and hands and fingers. Measurement method is a force sensor.

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Possibly Endangered Body Locations

ID	Body Location	Force [N]		Contact type		
		QS	TR	Pinch	Impact	Crush
1	Lower arms and wrist joints	160 N	N /A	X	N/A	N/A
2	Hands and fingers	140 N	N/A	X	N/A	N/A

Measurement Results from Test of Body Location ID (1,2) – Height Detection Enabled.

Speed	Auto adjusted by Z-Height detect functionality
Payload	4 kg
Notes	Default settings / Z-Height detection enabled
Start position	XYZ(428,-200,1200,70, 180,-145)
End position	XYZ(428,-200,1106,70, 180,-145)
Impact Position	XYZ(428,-200,1086,70, 180,-145)
Distance after impact	20 mm
Motion profile	Auto adjusted by Z-Height detect functionality

Criteria 1 (quality indicator for the measurement setup; ISO/PAS 5672:2023, 7.4)

Contact Phase	Relative Standard Deviation For	~ [%]	Threshold	Measurement Setup
Quasi-static	Force [N]	1.43	5	OK
	Pressure [N/cm2]	N/A	10	N/A
Transient	Force [N]	0.361	5	OK
	Pressure [N/cm2]	N/A	10	N/A

Criteria 2 (Comparison of Sample Mean with the Biomechanical Limit for the Body Location Tested; ISO/PAS 5672:2023, 7.4)

Contact phase	Mean for	Units Measured (N)	Limit	Test
Quasi-static	Force [N]	118.33	140/160	Passed
	Pressure [N/cm2]	N/A	…	N/A
Transient	Force [N]	130.34	280/320	Passed
	Pressure [N/cm2]	N/A	…	N/A

Measurement Results from Test of Body Location ID (1,2) – Adjusted Negative Output Limit

Speed	10% (60 mm/sec)
Payload	4 kg
Notes	Adjusted negative output level for Z axis
Start Position	XYZ(428,-200,1200,70, 180,-145)
End Position	XYZ(428,-200,1106,70, 180,-145)
Impact Position	XYZ(428,-200,1086,70, 180,-145)
Distance After Impact	20 mm
Motion Profile	Accel/Decel: 100%/50% RampUp/RampDown: 0.15 InRange: 10 System Speed: 100%

Criteria 1 (Quality Indicator for the Measurement Setup; ISO/PAS 5672:2023, 7.4)

Contact Phase	Relative Standard Deviation for	~ [%]	Threshold	Measurement Setup
Quasi-static	Force [N]	0.70	5	OK
	Pressure [N/cm2]	N/A	10	N/A
Transient	Force [N]	N/A	5	N/A
	Pressure [N/cm2]	N/A	10	N/A

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Criteria 2 (Comparison of Sample Mean with the Biomechanical Limit for the Body Location Tested; ISO/PAS 5672:2023, 7.4)

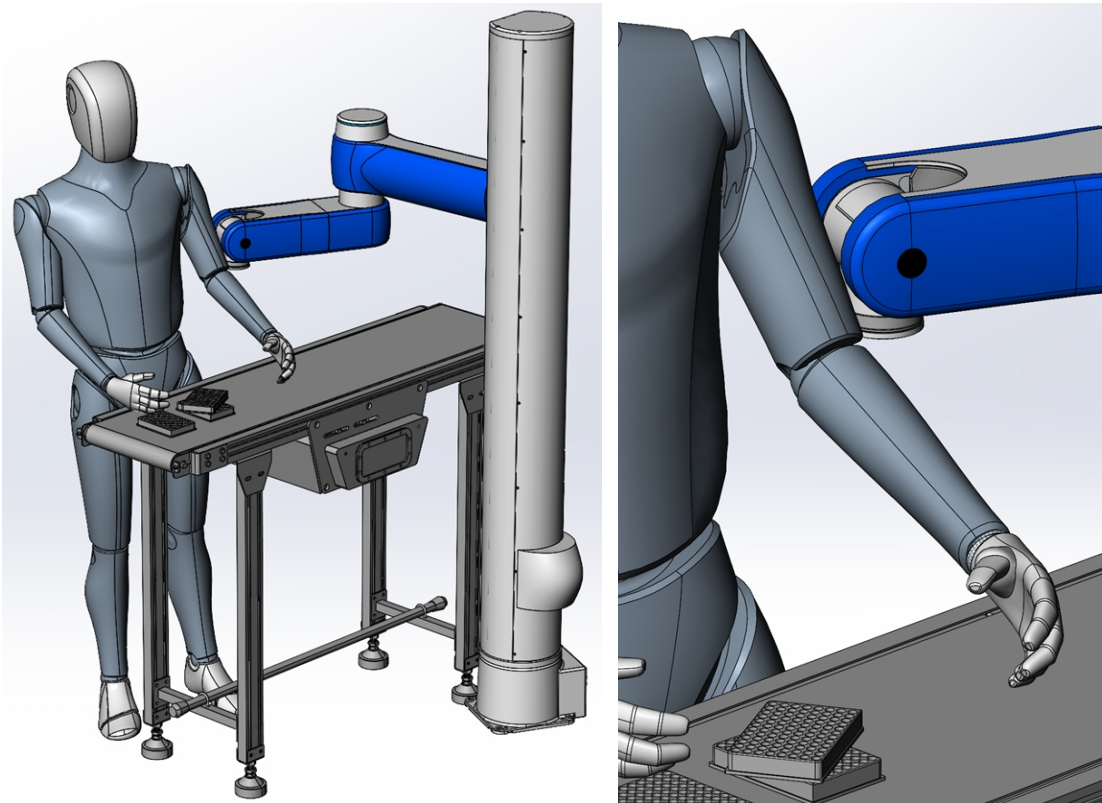| Contact Phase	Mean for	Units Measured (N)	Limit	Test
Quasi-static	Force [N]	133.34	140/160	Passed
	Pressure [N/cm2]	N/A	…	N/A
Transient	Force [N]	N/A	N/A	N/A
	Pressure [N/cm2]	N/A	…	N/A

Contact Hazards and Measuring Points: Contact Hazard 2

Impact with Upper Body Extremity When Robot Approaches Station Where Operator Task is Being Performed

A robot or operator drops a workpiece at the assembly/inspection station. The operator tries to remove it while the robot approaches the station with another part, leading to unintended contact with the operator's shoulder, back, or upper arms. Since the human body can move freely (no obstacles near the station), the type of contact will constitute an impact (load profile = dynamic; special config = unconstrained).

Body locations that can be affected by the impact are back, shoulders, chest, upper arms, and elbow joints. The cell must be designed with a spatial configuration resulting in the human body being able to recoil at impact and being unconstrained. Robot lateral motion shall be at or below the shoulder level. Pinch and crush contact types are not considered for this contact hazard. Measurement method is a force sensor.

Possibly Endangered Body Locations

An X in one of the last three columns indicates the contact type that affects the associated body location.

ID	Body Location	Force [N]		Contact Type		
		QS	TR	Pinch	Impact	Crush
1	Back & shoulder	N/A	$F_T = 210 \times 2$	N/A	**X**	N/A
2	Chest	N/A	$F_T = 140 \times 2$	N/A	**X**	N/A
3	Upper arms & elbow joints	N/A	$F_T = 150 \times 2$	N/A	**X**	N/A

Measurement Results from Test of Body Location ID (1,2,3) – X Axis Cartesian Motion – Wrist Impact.

Speed	100% (600 mm/sec)
Payload	4 kg
Notes	X Axis Cartesian motion / Default settings
Start position	XYZ(400,-360,1024,-115,90,-50)
End position	XYZ.(660,-360,1024,-115,90,-50)
Impact Position	XYZ(610,-360,1024,-115,90,-50)
Distance after impact	50 mm
Motion profile	Accel/Decel: 100%/100% RampUp/RampDown: 0.15 InRange: 10 System Speed: 100%
Image	

Criteria 1 (Quality Indicator for the Measurement Setup; ISO/PAS 5672:2023, 7.4)

Contact phase	Relative standard deviation for	[%]	Threshold	Measurement Setup
Quasi-static	Force [N]	N/A	5	N/A
	Pressure [N/cm2]	N/A	10	N/A
Transient	Force [N]	0.65	5	OK
	Pressure [N/cm2]	N/A	10	N/A

Criteria 2 (Comparison of Sample Mean with the Biomechanical Limit for the Body Location Tested; ISO/PAS 5672:2023, 7.4)

Contact phase	Mean for	Units Measured (N)	Limit	Test
Quasi-static	Force [N]	N/A	N/A	N/A
	Pressure [N/cm2]	N/A	…	N/A
Transient	Force [N]	125	280/300/420	Passed
	Pressure [N/cm2]	N/A	…	N/A

Measurement Results from Test of Body Location ID (1,2,3) – X Axis Cartesian Motion – Cover Edge Impact.

Speed	100% (600 mm/sec)
Payload	4 kg
Notes	Y Axis Cartesian motion / Default settings
Start Position	XYZ(250,-250,1115,0,0,-70)
End Position	XYZ(730,-250,1115,0,0,-70)
Impact Position	XYZ(680,-250,1115,0,0,-70)
Distance after Impact	50 mm
Motion Profile	Accel/Decel: 100%/100% RampUp/RampDown: 0.15 InRange: 10 System Speed: 100%

Image

Criteria 1 (Quality Indicator for the Measurement Setup; ISO/PAS 5672:2023, 7.4)

Contact Phase	Relative Standard Deviation for	[%]	Threshold	Measurement Setup
Quasi-Static	Force [N]	N/A	5	N/A
	Pressure [N/cm2]	N/A	10	N/A
Transient	Force [N]	1.1	5	OK
	Pressure [N/cm2]	N/A	10	N/A

Criteria 2 (Comparison of Sample Mean with the Biomechanical Limit for the Body Location Tested; ISO/PAS 5672:2023, 7.4)

Contact Phase	Mean for	Units Measured (N)	Limit	Test
Quasi-static	Force [N]	N/A	N/A	N/A
	Pressure [N/cm2]	N/A	…	N/A
Transient	Force [N]	113.33	280/300/420	Passed
	Pressure [N/cm2]	N/A	…	N/A

Measurement Results from Test of Body Location ID (1,2,3) – Y Axis Cartesian Motion – Wrist Impact.

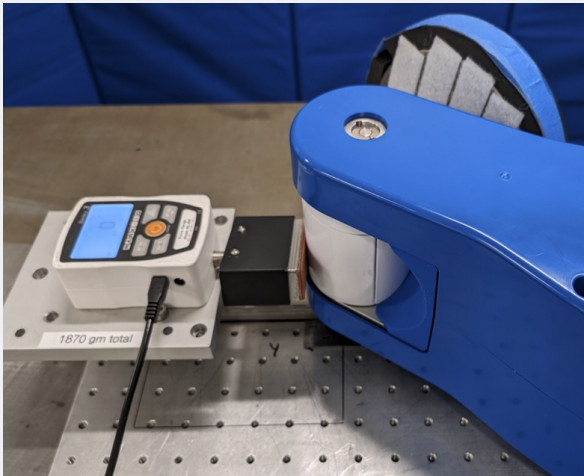|	
Speed	100% (600mm/sec)
Payload	4 kg
Notes	Y Axis Cartesian motion / Default settings
Start position	XYZ(140,-180,1025,135,90,-170)
End position	XYZ(140,-600,1025,135,90,-170)
Impact Position	XYZ(140,-550,1025,135,90,-170)
Distance after impact	50 mm
Motion profile	Accel/Decel: 100%/100% RampUp/RampDown: 0.15 InRange: 10 System Speed: 100%
Image	

Criteria 1 (Quality Indicator for the Measurement Setup; ISO/PAS 5672:2023, 7.4)

Contact phase	Relative standard deviation for	[%]	Threshold	Measurement Setup
Quasi-static	Force [N]	N/A	5	N/A
	Pressure [N/cm2]	N/A	10	N/A
Transient	Force [N]	**0**	**5**	**OK**
	Pressure [N/cm2]	N/A	10	N/A

Criteria 2 (Comparison of Sample Mean with the Biomechanical Limit for the Body Location Tested; ISO/PAS 5672:2023, 7.4)

Contact Phase	Mean for	Units Measured (N)	Limit	Test
Quasi-static	Force [N]	N/A	N/A	N/A
	Pressure [N/cm2]	N/A	…	N/A
Transient	Force [N]	122	280/300/420	Passed
	Pressure [N/cm2]	N/A	…	N/A

Measurement Results from Test of Body Location ID (1,2,3) – Y Axis Cartesian Motion – Cover Edge Impact.

Speed	100% (600 mm/sec)
Payload	4 kg
Notes	Y Axis Cartesian motion / Default settings
Start position	XYZ(215,-180,1115,40,0,-70)
End position	XYZ(215,-600,1115,40,0,-70)
Impact Position	XYZ(215,-550,1115,40,0,-70)
Distance after impact	50 mm

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uring Forces and Pressures in Human-
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Motion profile	
	Accel/Decel: 100%/100% RampUp/RampDown: 0.15 InRange: 10 System Speed: 100%
Image	

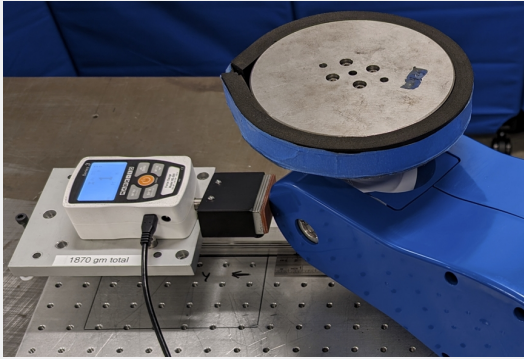## Criteria 1 (Quality Indicator for the Measurement Setup; ISO/PAS 5672:2023, 7.4)

Contact Phase	Relative Standard Deviation for	[%]	Threshold	Measurement Setup
Quasi-static	Force [N]	N/A	5	N/A
	Pressure [N/cm2]	N/A	10	N/A
Transient	Force [N]	0.40	5	OK
	Pressure [N/cm2]	N/A	10	N/A

Criteria 2 (Comparison of Sample Mean with the Biomechanical Limit for the Body Location Tested; ISO/PAS 5672:2023, 7.4)

Contact Phase	Mean for	Units Measured (N)	Limit	Test
Quasi-static	Force [N]	N/A	N/A	N/A
	Pressure [N/cm2]	N/A	…	N/A
Transient	Force [N]	117.67	280/300/420	Passed
	Pressure [N/cm2]	N/A	…	N/A

NOTE: Weight of the pressure-force measurement devices (PFMD) used for the impact force testing is 1.9kg