Brooks

PreciseFlex™ 3400 Robots

Service Manual

Part Number 628699, Revision B

Brooks Automation

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Revision History

Revision	ECO	Date	Action	Author
A	---	2/1/2024	Released manual at Rev. A to follow standard Brooks technical publication styles..	M. Ashenfelder
B	EC154083	4/19/2024	Split manual into two: User Manual and Service Manual	M. Ashenfelder
C	EC158651	11/12/2024	Updated content for introduction of PreciseFlex 3400 with new generation electronics. Changed G1400 A/B controller references.	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.

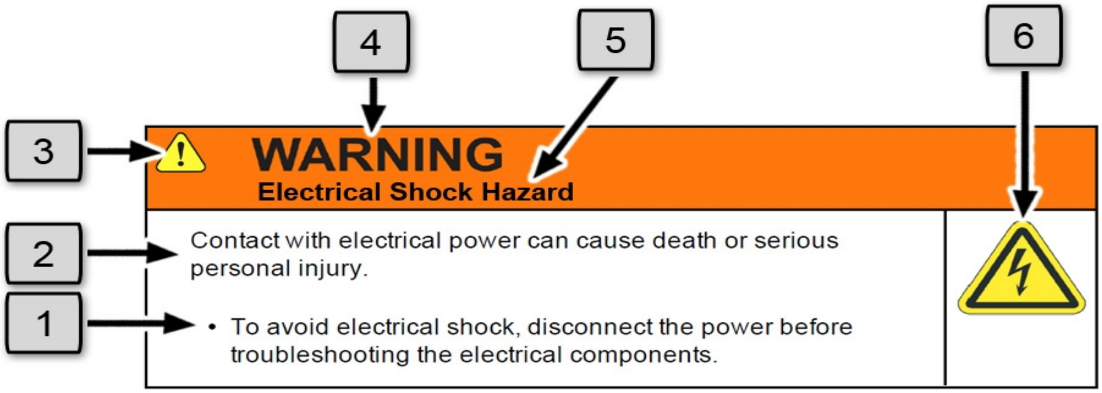
Signal Words and Color

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.

CAUTION

Seismic Restraint

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

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

Mechanical Hazards

CAUTION

Pinch Point

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

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

WARNING

Automatic Movement

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

- Follow safe practices for working with energized products per the facility requirements.
- Do not rely on the system software or process technology to prevent unexpected product motion.
- Do not operate the product without its protective covers in place.
- While the collaborative robotics system is designed to be safe around personnel, gravity and other factors may present hazards and should be considered.

CAUTION

Vibration Hazard

As with any servo-based device, the robot can enter a vibratory state resulting in mechanical and audible hazards. Vibration indicates a serious problem. Immediately remove power.

- Before energizing, ensure the robot is bolted to a rigid metal chamber or stand.

Electrical Hazards

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

DANGER

Electrical Shock Hazard

Contact with electrical power can cause personal harm and serious injury.

- To avoid electrical shock, disconnect the power before troubleshooting the electrical components.
- Check the unit's specifications for the actual system power requirements and use appropriate precautions.
- Never operate this product without its protection covers on.

WARNING

Electrical Burn

Improper electrical connection or connection to an improper electrical supply can result in electrical burns resulting in equipment damage, serious injury, or death.

- Always provide the robot with the proper power supply connectors and ground that are compliant with appropriate electrical codes.

WARNING

Electrical Fire Hazard

All energized electrical equipment poses the risk of fire, which may result in severe injury or death. Fires in wiring, fuse boxes, energized electrical equipment, computers, and other electrical sources require a Class C extinguisher.

- Use a fire extinguisher designed for electrical fires (Class C in the US and Class E in Asia).
- It is the facility's responsibility to determine if any other fire extinguishers are needed for the system that the robot is in.

NOTICE

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

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

Ergonomic Hazards

CAUTION

Heavy Lift Hazard

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

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

CAUTION

Tipover Hazard

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

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

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

Emergency Stop Circuit (E-Stop)

The integrator of the robot must provide an 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. Service Procedures

Recommended Tools

The following tools are recommended for these service procedures:

1. Gates Sonic Belt Tension Meter, Model 507C for checking timing belt tension.
2. A set of metric “stubby” hex L-keys, for example McMaster Carr PN 6112A21 with 1.5, 2.0, 2.5, 3.0, 4, 5, and 6 mm L Keys.
3. A set of metric hex drivers including 1.27, 1.5, 2.0, 2.5 and 3.0 mm driver, for example McMaster Carr PN 52975A21.
4. A pair of tweezers or needle nose pliers.
5. A pair of side angle cutters.
6. Small flat bladed screw driver, with 1.5 mm wide blade typical.
7. M5 socket driver or M5 open end wrench or pliers.

Troubleshooting

PreciseFlex robots and controllers have an extensive list of error messages. Refer to the *PreciseFlex Library* to search for a specific error message and cause. Listed below are errors that may be generated by hardware failures.

Symptom	Recommended Action
System error message generated	
“E-Stop not Enabled”	Check both Phoenix plug and 9 pin Dsub for E-stop jumpers.
“Encoder Battery Low”	Replace absolute encoder battery in base of robot
“Encoder Battery Down”	If encoder cable has been disconnected, recalibrate robot. If battery voltage has dropped below 2.5 V replace encoder battery and recalibrate robot.

Symptom	Recommended Action
“Encoder Operation Error”	Joint rotated too quickly with power off. See Procedure below.
“Encoder Data, Accel/decel Limit Error”	Check that the FPGA code is dated Jan 25, 2012 or later. Upgrade FPGA if necessary. Encoder cable may be damaged and encoder is getting intermittent communication, causing apparent jumps in position. Check encoder connectors on flat ribbon cable. Replace cable. Replace motor.
“Encoder Communication Error”	Check that the FPGA code is dated Jan 25, 2012 or later. Check encoder connectors on flat ribbon cable. Replace encoder cable or motor/encoder.
"Encoder quadrature error"	Replace slip ring. Replace motor/encoder (only Gripper motor). See the *IntelliGuide Grippers* user manual.
"Missing zero index"	See "Encoder quadrature error"
“Motor duty cycle exceeded”	Reduce speed or acceleration of robot. Check for instability.
“Amplifier under voltage”	Motor power supply has reached current limit and shutdown. Slow down robot. Check Energy Dump PCA. Replace 48 V supply.
“Amplifier Fault”	Check harness and motor for shorts.
“Amplifier Over Voltage”	Replace energy dump board. Check harness for shorts.
“Soft Envelope Error”	Make sure robot not pressing against surface. If this occurs on the gripper repeatedly, replace slip ring. See the *IntelliGuide Grippers* user manual.
“Hard Envelope Error”	Typically means robot has crashed into something.
Pneumatic Gripper Sensor not working	Check continuity of cable through wrist. Check green lights on sensor to see if sensor is triggering. See the *IntelliGuide Grippers* user manual.
“Time Out Nulling Error”	Check that joint is free to move with brake off. Check that joint is not vibrating or unstable. If unstable check belt tension. If Gripper, replace slip ring after checking that brake releases.
“Joint Out of Range”	The joint actual or commanded position may be beyond the software limit stop. Move joint back into range while monitoring virtual pendant or check program for commanded position.
“PAC Files Corrupted”	See recovering from corrupted PAC Files
Physical or audible problem	
Brown streaks on linear bearing	Clean with alcohol and add grease to bearing blocks. This should not be required sooner than 20,000 hours of run time. Grease is Alvania Grease EP2 from Shell.

Symptom	Recommended Action
Mechanical noise from any joint	Check joint bearings for failure. Re-tension belt.
Loud buzzing or vibration from any joint	Re-tension timing belts. If timing belt will not hold tension, replace.
Squeaking from Z belt	Apply thick grease to front and rear edges of belt, (Mobile 222 XP). Belt can get stiff over time and squeak against pulley flanges.

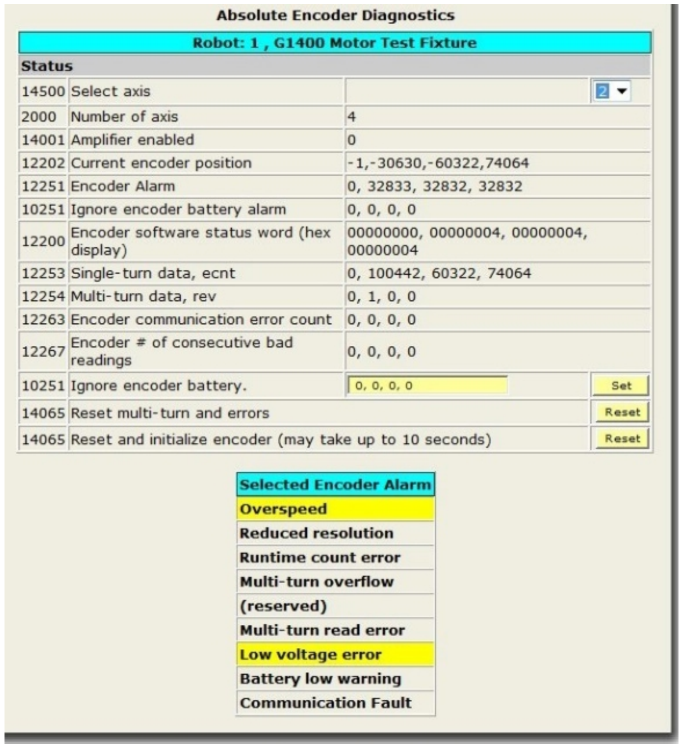
Encoder Operation Error

The PreciseFlex 3400 robot is equipped with absolute encoders that keep track of the robot position even when AC power to the robot is disconnected. There is a battery in the base of the robot that provides standby power to the encoders. In standby mode, there is a limit on how quickly the motor can turn and still have the standby counter operate properly. The limits are 6,000 rpm and 4000 rad/s^2. Even at 100% speeds the robot joints normally do not move faster than about 2,000 rpm and 1300 rad/s^2. However, if the robot is shocked during shipping, it is possible the standby operation acceleration error limit may be exceeded. This can generate an encoder operation error that will prevent the robot from homing after power up.

This error will be displayed in the Operator Window of the Web Interface as “Encoder Operation Error” Robot 1: <axis number>.

Assuming the robot has not been damaged by the shipping process, this error can be reset by the following procedure:

Step	Action
1.	Open the browser interface to the robot with either “Maintenance” or “Administrator” privileges.

Step	Action
2.	In the **Setup** menu, select **System Setup** > **Hardware Tuning and Diagnostics** > **Absolute Encoder**. 
3.	In the drop-down menu at the top right of the screen, select the robot axis that was associated with the error and check to see if the Overspeed panel is yellow. This indicates an overspeed error during encoder standby mode due to shock or vibration. This error can be reset by selecting the reset button next to **Reset and initialize encoder**. This button resets error flags, but does not reset the encoder counters. The robot can then be homed normally.
4.	For cases where the encoder operation error was triggered by shipping vibration, IN MOST CASES the encoder will not have lost any position data. However after homing the robot it is a good idea to move the robot to the calibration position (using the calibration pins if desired-see Calibrating the Robot), or another known position, and check the joint angles in the Virtual Pendant in the Web Operator Interface. The joint angles in the Calibration Position are: • Z-axis: -1 mm (-2 mm for Beta robots) • J2 or Shoulder: -90 • J3 or Elbow: 179.99 • J4 or Wrist: -180

If the robot joints after this procedure followed by homing are different from the above, then the robot needs to be re-calibrated.

Replacing the Encoder Battery

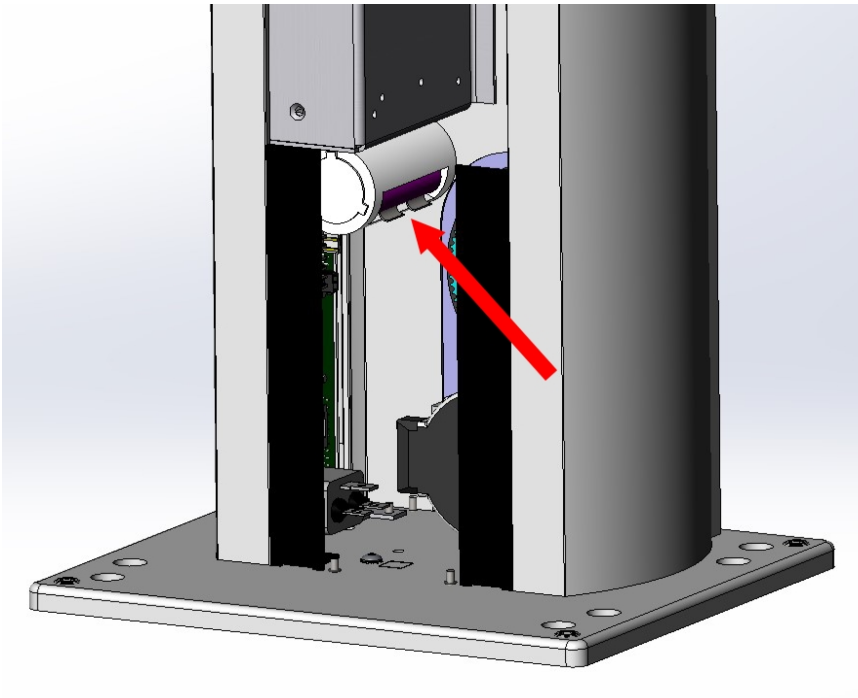
DANGER

Electrical Shock

Before replacing the encoder battery, the AC power should be disconnected. Removing the front cover allows access to the AC power terminals.

The Encoder Battery is designed to last for several years with robot power turned off. With robot power turned on, there is no drain on the battery. The battery voltage is monitored by the system. The nominal battery voltage is 3.6 Volts. If the battery voltage drops to 3.3 Volts an error message "Encoder Battery Low" is generated. At this level the absolute encoder backup function will still work, however the Battery should be replaced. If the voltage drops to 2.5 Volts, an error message "Absolute Encoder Down" is generated. At this point, the absolute encoder backup function will not work.

If any motor/encoder is disconnected from the encoder battery by disconnecting the encoder cable, the "Encoder Battery Low" or "Encoder Battery Down" message will be generated. However, in this case, the encoder battery does not need to be replaced. It is only necessary to re-calibrate the robot.



Encoder Battery Pack

Tools Required:

- 3.0 mm hex driver or hex L wrench

Parts Required:

- New Encoder Battery
- 6 in long by 125 wide tie wrap

To replace the Encoder Battery, perform the following procedure:

Step	Action
1.	Turn off power to the robot and remove the AC power plug.
2.	Remove the top plate of the robot by removing the (4) M5 low socket head screws from the top plate of the robot that attach the top plate to the Z column. Lift up the top plate.
3.	Remove the Front Cover by lifting it out vertically.
4.	The Encoder Battery pack is located at the base of the electronics bracket behind the Z column front cover. Disconnect the connector from J1 at the FFC board, insert the battery pack into the clips, and reconnect the connector at J1.
5.	Replace the front cover and top plate.

If the instructions are followed to turn off the robot and remove the battery, the error message "Encoder Battery Down" will display. This procedure will require robot recalibration after changing the battery.

Calibrating the Robot: Setting the Encoder Zero Positions

Cal_PP is a service program that must be run to set the zero positions of the absolute encoders on each motor. The zero positions must be re-established if any of the motors are replaced, their cables disconnected for a long duration, or the encoder backup battery has been disconnected.

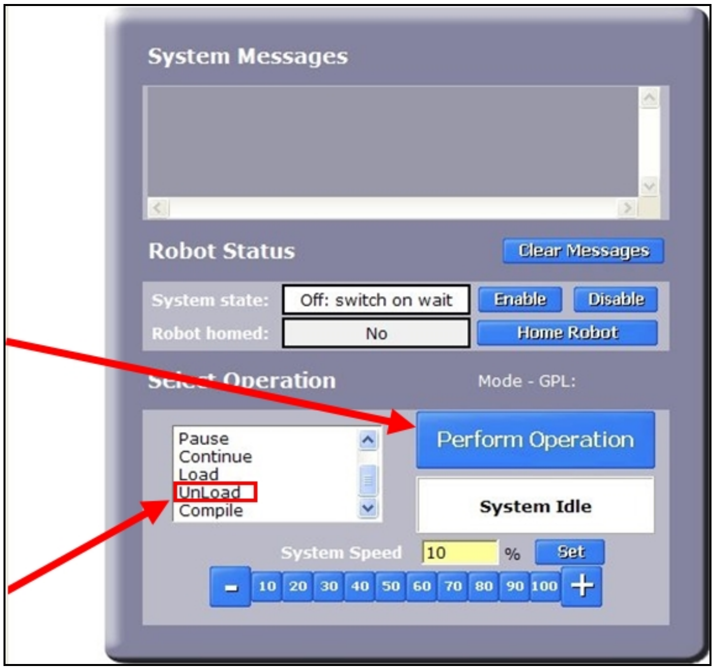
To run Cal_PP, the controller must be configured to run GPL programs and Cal_PP must be loaded into the controller's memory (See Preventative Maintenance).

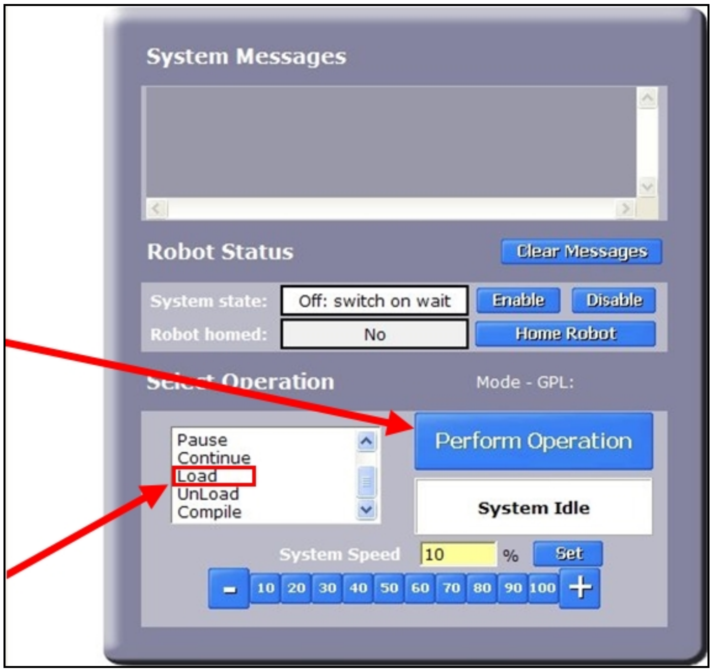
Tools Required:

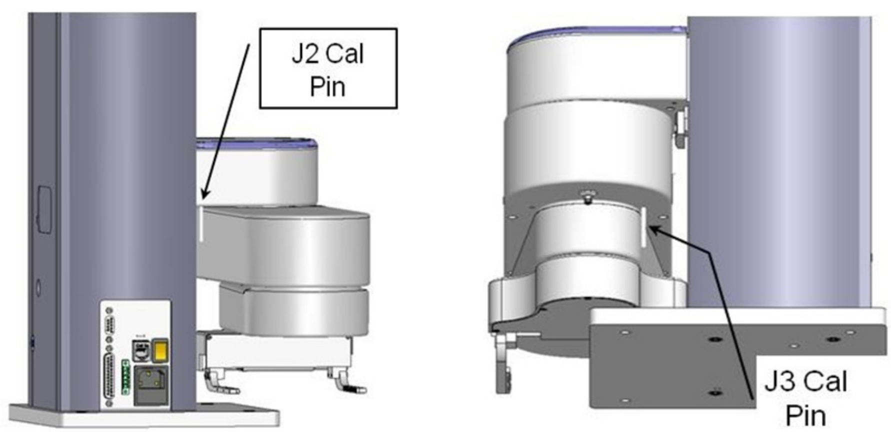
- 2.5 mm and 3.0 mm hex drivers or hex L wrenches
- Set of (3) Calibration Dowel Pins, located in plastic bag inside the hollow slot in the front cover

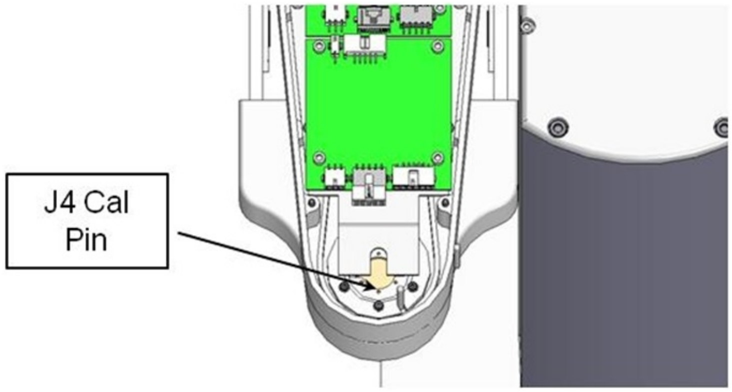
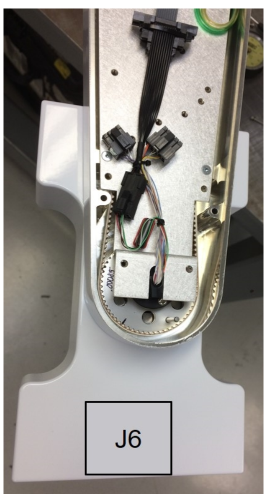
The following procedure describes the steps for defining the zero positions of the PF400 robot axes using Cal_PP.

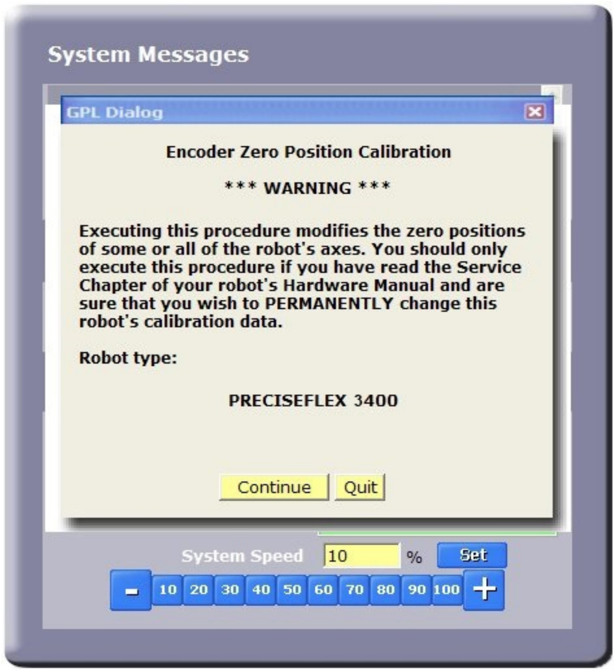
Step	Action
1.	Enable power to the robot's controller, but do not turn on power to the motors. (This procedure should be executed with the motor power off. The robot does not move).

Step	Action
2.	The CALPP program is typically installed at the factory and should be loaded into flash memory. Using the browser-based *Operator Control Panel*, first unload any currently loaded programs. Select the **UnLoad** item in the left scrolling window and click **Perform Operation**. This ensures that no GPL project is currently selected for execution. 

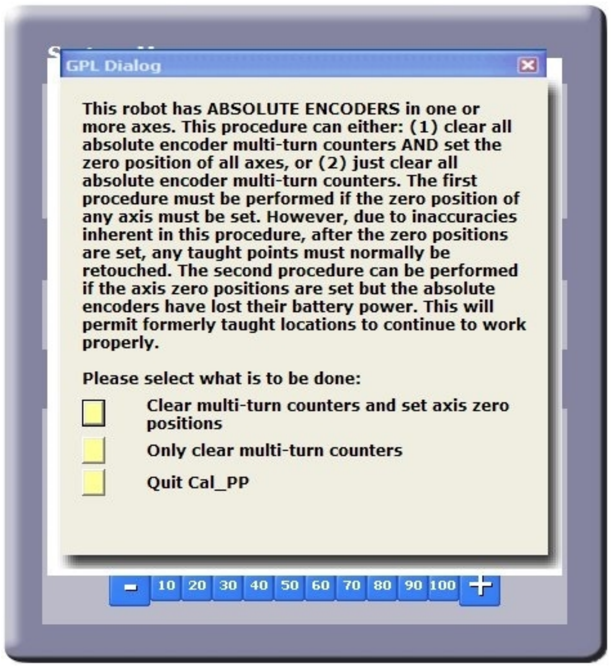
Step	Action
3.	Select the **Load** item and click **Perform Operation**. This displays a pop-up list of Projects that are in the flash disk and available for execution. 
4.	In the window, click **CALPP_RevXX** and click **Select**. To execute the Project, select **Start application** and click **Perform Operation**. If CALPP is not loaded in the robot, first Load Cal_PP into the controller's memory from a PC, using the browser interface.
5.	Manually move the robot into the configuration shown in Step 10. The top cover of the outer link will need to be removed by removing the (4) M3 X 20 SHCS that are located in counter bores under the outer link. ***NOTE:*** *If the optional Linear Axis is installed, move the Linear Axis carriage to the hard stop near the connector end cap. For the Linear Axis calibration, be sure to use CALPP Revision 21 or later.*
6.	Ensure that the Z-axis is resting on the lower hard stop by releasing the Z-axis brake by pushing on the brake release button under the shoulder while supporting the robot arm, and lowering the robot arm gently until it rests on the lower hard stop.

Step	Action
7.	If the Calibration Pins have not already been removed from the robot, it may be necessary to remove the top cover of the robot by removing the (4) M5 Low Head screws with a 3.0 mm hex driver and then removing the front cover to access the bag with the Calibration Pins which are inside the front cover extrusion at the bottom.
8.	Insert an M3 X 30 mm Calibration Dowel Pin into the J4 (wrist) pulley with the gripper positioned under the outer link and rotate the gripper back and forth until the pin drops into a slot in the outer link, locating the gripper under the center of the outer link.
9.	Insert a tapered 0.5 in Calibration Dowel Pin into the hole in the bottom of the shoulder. Rotate the inner link counter-clockwise until it rests against this pin as shown in Step 10.
10.	Insert a tapered 0.5 in Calibration Dowel Pin into the hole on the inner link. 

Step	Action
11.	Rotate the outer link clockwise until it rests against the dowel pin. If the robot is installed on a linear rail, push the rail carriage all the way to the hard stop at the linear rail connector end cap. 
12.	For the Dual Gripper, J6 will be in the outwards orientation in the CALPP position. 

Step	Action
13.	With the CALPP application loaded, select **Start Application** and then click **Perform Operation**. The application should start and prompt the user to confirm the correct robot position for calibration. 

<table>
<tr><th>Step</th><th>Action</th></tr>
<tr><td>14.</td><td>The CALPP application takes about 1 minute to run.


</td></tr>
<tr><td>15.</td><td>After calibration is complete, use the brake release button and move the Z-axis up from the hard stop. Failing to do this will produce an error as the robot is outside of the soft stop limits.</td></tr>
<tr><td>16.</td><td>Ensure that the pins are removed.</td></tr>
<tr><td>17.</td><td>Enable power and home the robot. Calibration does not take effect until the robot is homed.</td></tr>
</table>

Manual Calibration of PCR Robots

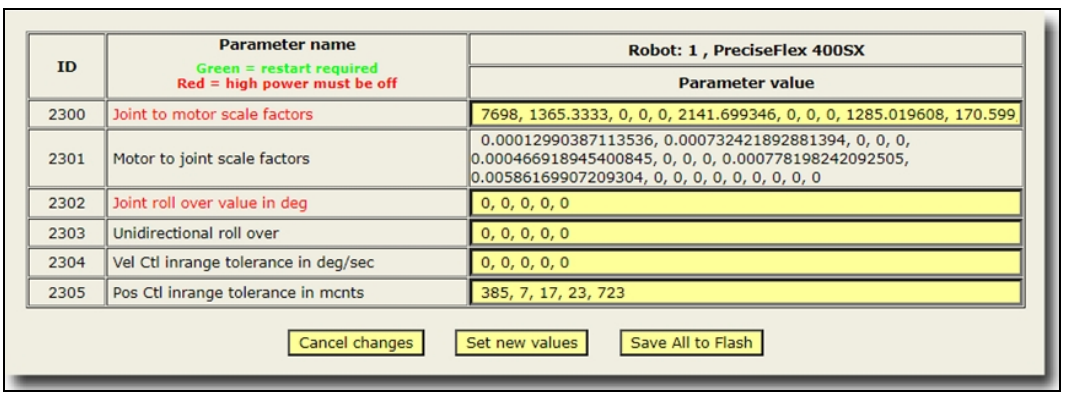
The standard calibration procedure for the PreciseFlex 400 and PreciseFlex 3400 is listed in "Calibrating the Robot: Setting the Encoder Zero Positions." However, there may be situations where the robot cannot be placed in the standard calibration position, for example when mounted in a work cell where equipment may be in the way. In this case, the calibration can be performed manually according to the following steps.

<table>
<tr><th>Step</th><th>Action</th></tr>
<tr><td>1.</td><td>
(Recommended, but optional) If possible, the robot should be moved to the top of the Z axis travel where it may be clear of equipment, and J2, J3, and J4 placed in the standard calibration position shown below. Connect to the robot via the browser, and from the home page, go to Setup > Parameter Database > Robot > Joint/Cartesian Control > Joint/Motor Factors. Then Cal_PP may be fully executed.
<table>
<tr><th rowspan="2">ID</th><th rowspan="2">Parameter name
Green = restart required
Red = high power must be off</th><th>Robot: 1 , PreciseFlex 400SX</th></tr>
<tr><th>Parameter value</th></tr>
<tr><td>2300</td><td>Joint to motor scale factors</td><td>7698, 1365.3333, 0, 0, 0, 2141.699346, 0, 0, 0, 1285.019608, 170.599</td></tr>
<tr><td>2301</td><td>Motor to joint scale factors</td><td>0.00012990387113536, 0.000732421892881394, 0, 0, 0, 0.000466918945400845, 0, 0, 0, 0.000778198242092505, 0.00586169907209304, 0, 0, 0, 0, 0, 0, 0, 0, 0</td></tr>
<tr><td>2302</td><td>Joint roll over value in deg</td><td>0, 0, 0, 0, 0</td></tr>
<tr><td>2303</td><td>Unidirectional roll over</td><td>0, 0, 0, 0, 0</td></tr>
<tr><td>2304</td><td>Vel Ctl inrange tolerance in deg/sec</td><td>0, 0, 0, 0, 0</td></tr>
<tr><td>2305</td><td>Pos Ctl inrange tolerance in mcnts</td><td>385, 7, 17, 23, 723</td></tr>
</table>
Cancel changes | Set new values | Save All to Flash
This will calibrate J2, J3 and J4 correctly, leaving only J1 that needs adjustment. The Z axis calibration will be set to -2 mm at the top of the travel, so it will be off by 400 mm, 750 mm, or 1160 mm depending on the Z axis stroke of the robot. If you perform this step, 400, 750, or 1160 will be the offset change value used in step 2.
</td></tr>
</table>

<table>
<tr><th>Step</th><th>Action</th></tr>
<tr><td>2.</td><td>
Determine the value in position 1 of parameter 2300 (Joint to Motor Scale Factors). See the graphic below. For the PreciseFlex 400 and 3400, the positions contain in order:

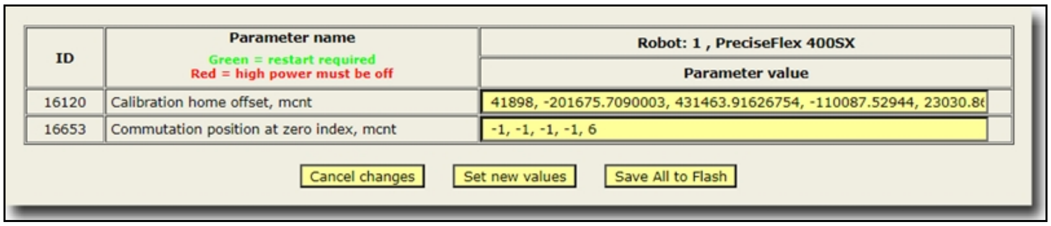
Z in encoder counts per mm, J2 in encoder counts per degree
N/A
NA
NA
J3 in encoder counts per degree
NA
NA
NA
J4 in encoder counts per degree
Gripper in encoder counts per mm

For the PreciseFlex 400 and 3400 the correct value in position 1 should be 7698 encoder counts per mm. Multiply the amount you need to change the Z offset by this value. For example, if Z is reading as 400 mm too high, the computed value will be 400 X 7698 = 3,079,200 encoder counts too high. Make note of this value for the next step.



ID	Parameter name Green = restart required Red = high power must be off	Robot: 1 , PreciseFlex 400SX Parameter value
2300	Joint to motor scale factors	7698, 1365.3333, 0, 0, 0, 2141.699346, 0, 0, 0, 1285.019608, 170.599
2301	Motor to joint scale factors	0.00012990387113536, 0.000732421892881394, 0, 0, 0, 0.000466918945400845, 0, 0, 0, 0.000778198242092505, 0.00586169907209304, 0, 0, 0, 0, 0, 0, 0, 0, 0
2302	Joint roll over value in deg	0, 0, 0, 0, 0
2303	Unidirectional roll over	0, 0, 0, 0, 0
2304	Vel Ctl inrange tolerance in deg/sec	0, 0, 0, 0, 0
2305	Pos Ctl inrange tolerance in mcnts	385, 7, 17, 23, 723

Cancel changes | Set new values | Save All to Flash
</td></tr>
</table>

Step	Action
3.	Navigate to **Parameter Database > Robot > Calibration Parameters > Servo Settings** and identify the value of parameter 16120 (Calibration home offset, mcnt) as shown below. This contains the Z axis offset in encoder counts set by Cal_PP, which will need to be corrected for the new calibration. These values are in the order of the axes, Z, J2, J3, J4, Gripper. Take the value in position 1 and subtract the correction value computed above in step 2. ***NOTE:*** *Note it is OK if the resulting value is negative. Then, enter this new value into position 1 and press "Set new values," followed by "Save all to Flash."* 
4.	After setting the new offset, click the **Home** button on the Virtual Pendant, and check the Z value for J1. It should now read the correct Z height. 
5.	If step 1 was not possible, repeat step 2 through 4 for all axes 2 through 4, substituting the values of ID 2300 from step 2 and 16120 from step 3 with the correct axis' value.

Replacing Belts and Motors

The timing belts and motors are designed to last the life of the robot. It is not expected that they will need to be replaced in the field. In most cases, if a belt or a motor needs to be replaced, the robot should be returned to the factory. While there are procedures at the end of this manual for replacing belts and motors, only experienced service technicians should attempt these procedures.

General Belt Tensioning

The PreciseFlex 3400 has been designed to make belt tensioning very simple. See "Belt Tensions, Gates Tension Meter" for belt tension specifications.

Tensioning the J1 (Z Column) Belts

Tensioning the 1st Stage Belt

DANGER

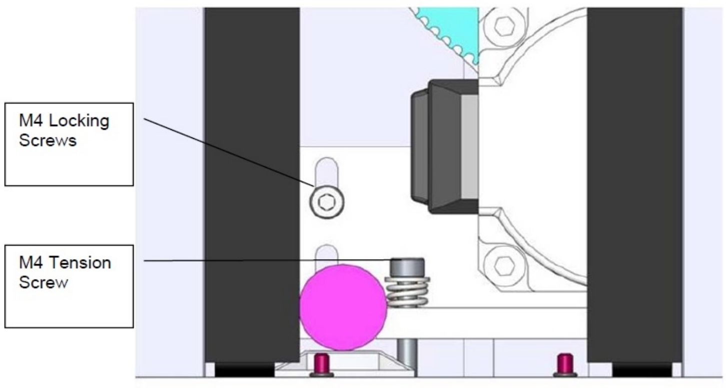
Electrical Shock

Before tensioning the timing belts or replacing any motors, the AC power should be disconnected. Removing the front cover allows access to the AC power terminals.

Tools Required:

- 3.0 mm hex driver or hex L wrench

Step	Action
1.	Turn off robot power and remove the AC power cord.
2.	Remove the Top Plate of the robot by removing the (4) M5 socket head screws from the top plate of the robot that attach the top plate to the Z column. Lift up the Top Plate.
3.	Remove the Front Cover by lifting it out vertically.

Step	Action
4.	Loosen the (2) M4 locking screws on the J1 Motor Mount Bracket to allow the Mount Bracket to slide up and down.
5.	Adjust the M4 Tension Screw compressing the spring assembly. The tension spring should be compressed until the spring length is 5.5 mm under the washer.
6.	After adjusting the Tension Screw, the M4 locking screws should be tightened to lock the assembly in place and the Front Cover and Top Plate should be replaced. 

Tensioning the 2nd Stage Belt

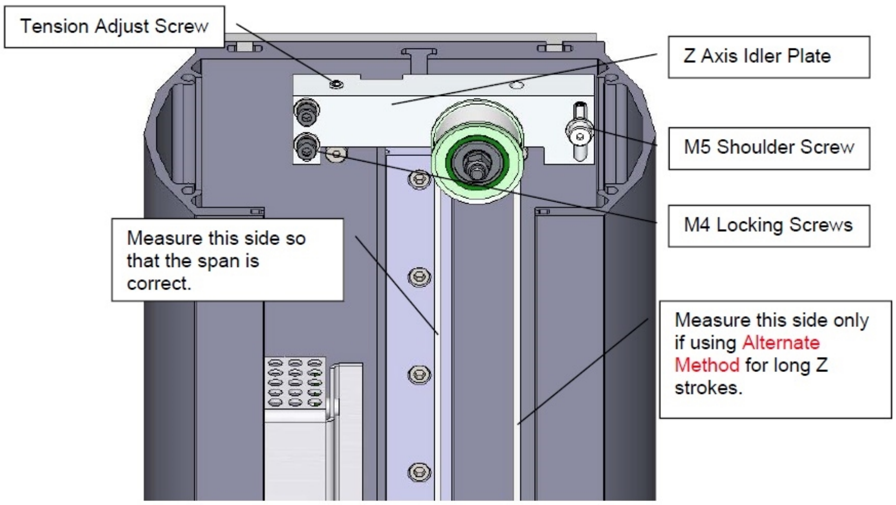
DANGER

Electrical Shock

Before tensioning the timing belts or replacing any motors, the AC power should be disconnected. Removing the front cover allows access to the AC power terminals.

Tools Required:

- Gates Sonic Belt Tension Meter, Model 507C
- 3.0 mm hex driver or hex L wrench
- 2.5 mm hex driver or hex L wrench

Step	Action
1.	Turn off the robot power and remove the AC power cord.
2.	Remove the Top Plate of the robot by removing the (4) M5 socket head screws from the top plate of the robot that attach the top plate to the Z column. Lift up the Top Plate.
3.	Remove the Front Cover by lifting it out vertically.
4.	Loosen the (2) M4 locking screws and the M5 shoulder screw on the Z idler plate. 
5.	The tension is set to the value in "Belt Tensions, Gates Tension Meter" by adjusting the M5 set screw which pushes on a spring in the Z Axis Idler Plate. Re-tighten the 3 screws and replace the Front Cover and Top Plate. **Alternate Method**: For the 750 mm and 1160 mm Z travel robots, it can sometimes be difficult to get a good tension reading for the spans for these long belts, which are 880 mm and 1290 mm respectively and as a result have low vibration frequencies. In this case it may be easier to position the Z carriage so that the span from the top idler pulley to the Z carriage is 530 mm, which is the span for the 400 mm Z stroke when measured on the left hand side of the belt as shown above. With the carriage at this location with a span of 530 mm, for these longer travel Z strokes, a user can then measure the tension on the right hand side of the belt, and use the values for tension and frequency for the 400 mm Z stroke.

Tensioning the J2 Belt

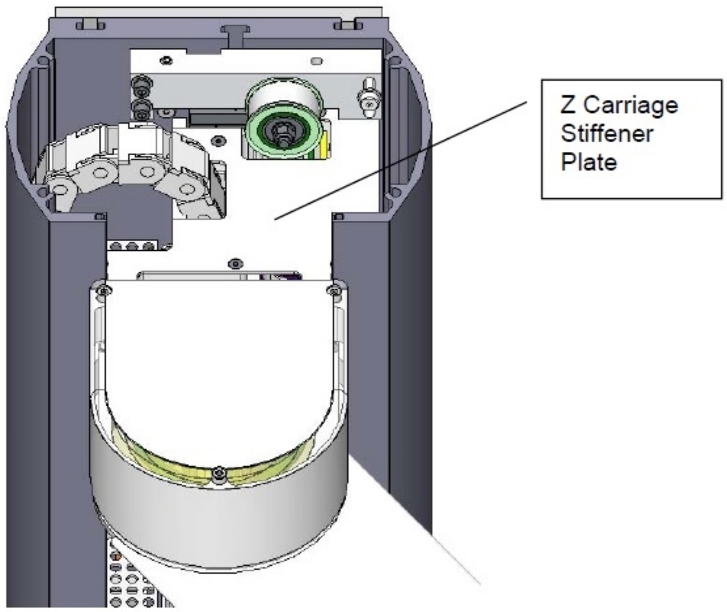
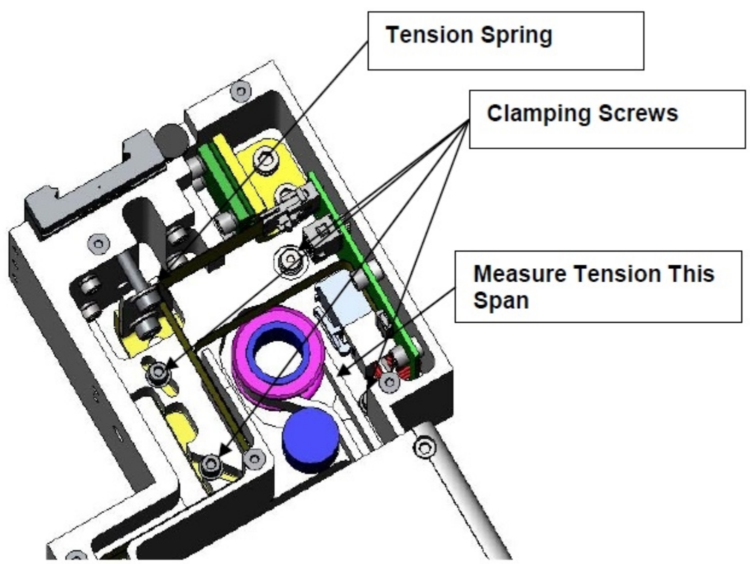
DANGER Electrical Shock	
Before tensioning the timing belts, the AC power should be disconnected. Removing the front cover allows access to the AC power terminals.	

Tools Required:

- Gates Sonic Belt Tension Meter, Model 507C
- 3.0 mm hex driver or hex L wrench
- 2.5 mm hex driver or hex L wrench
- 2.0 mm hex ball driver or hex L wrench

In order to re-tension the J2 (shoulder) Timing Belt, perform the following steps:

Step	Action
1.	Move the robot arm to the top of the Z Column travel.
2.	Turn off the robot power and remove the AC power cord.
3.	Remove the Top Plate of the robot by removing the (4) M5 socket head screws from the top plate of the robot that attach the top plate to the Z column. Lift up the Top Plate.

Step	Action
4.	Remove the Front Cover by lifting it out vertically. 
5.	Remove the Z Carriage Stiffener Plate by removing the M3 X 6 FHCS attaching it to the Z Carriage (shoulder). 

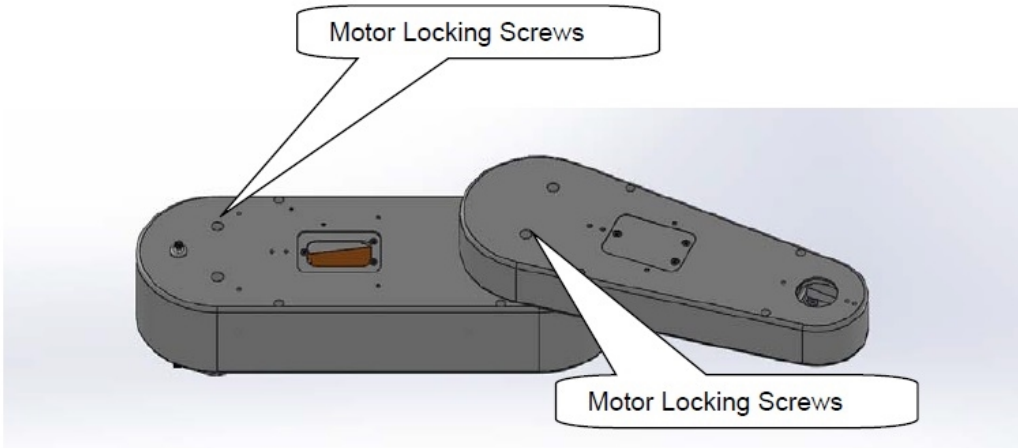
Step	Action
6.	Loosen the (3) M3 SHCS and (1) M4 Shoulder screw clamping the J2 Motor Mount Plate to the Z Carriage. It may be necessary to remove the tie wrap securing the J2 Motor cables to the Z carriage in order to access the clamping screw under these cables. It is best to measure the belt tension with a tension meter as described in "Belt Tensions, Gates Tension Meter." If a belt tension meter is not available, the Tension Leaf Spring will automatically reset the belt tension. It is helpful to jiggle the motor a little bit to be sure any friction is overcome. The motor can be easily grasped by reaching under the Z carriage (shoulder). Then re-tighten the clamping screws. Replace the tie wrap if it was removed.
7.	Replace the Z Carriage Stiffener Plate.
8.	Replace the Front Cover.
9.	Replace the Top Plate.

Tensioning the J3 and J4 Belts

Once the hatch cover is removed, loosen the appropriate motor locking screws one turn to unclamp the motor.

NOTE: Do not loosen these screws more than one or two turns or the retaining nuts can fall off inside the link.

To tension the J3 and J4 belts , perform the following procedure:

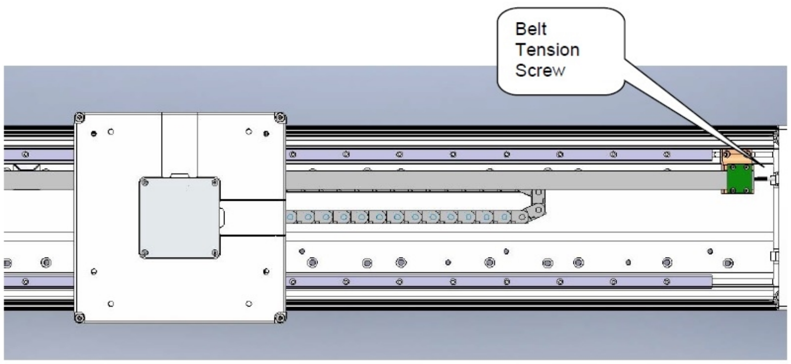
Step	Action
1.	Insert the microphone from the belt tension meter near the belt to measure belt tension and adjust the M4 SHCS to adjust belt tension. Be sure to measure the belt tension eight times, at 45 increments of the pulley in the axis rotation and set the tension at the position that has the lowest tension. 
2.	

Tensioning the Belt on the Optional Linear Axis

Tools Required:

- Gates Sonic Belt Tension Meter, Model 507C
- 3.0 mm hex driver or hex L wrench

To tension the Linear Axis Belt:, perform the following procedure:

Step	Action
1.	Remove the linear axis cover by sliding the carriage to one end of travel, remove the (4) M4 X 30 mm SHCS from the end caps retaining the cover. It may also be necessary to loosen the connector end cap by loosening the screws attaching the connector end cap to the Linear Axis Extrusion, so that the cover can be lifted up and removed.
2.	Slide the carriage so that there is a 500 mm span of the belt between the belt tension clamp block and the idler roller on the carriage.
3.	Loosen the (2) clamping screws on the belt tension clamp block slightly. Adjust the belt tension screw to adjust the belt tension to the values in "Belt Tensions, Gates Tension Meter." Tighten the clamping screws.
4.	Move the carriage back and forth the full length of travel and check the belt tension again.
5.	Replace the cover. 

Replacing the Power Supplies, Energy Dump PCA, or J1 Stage Two (Output) Timing Belt

DANGER

Electrical Shock

Before replacing the power supplies, the AC power should be removed.

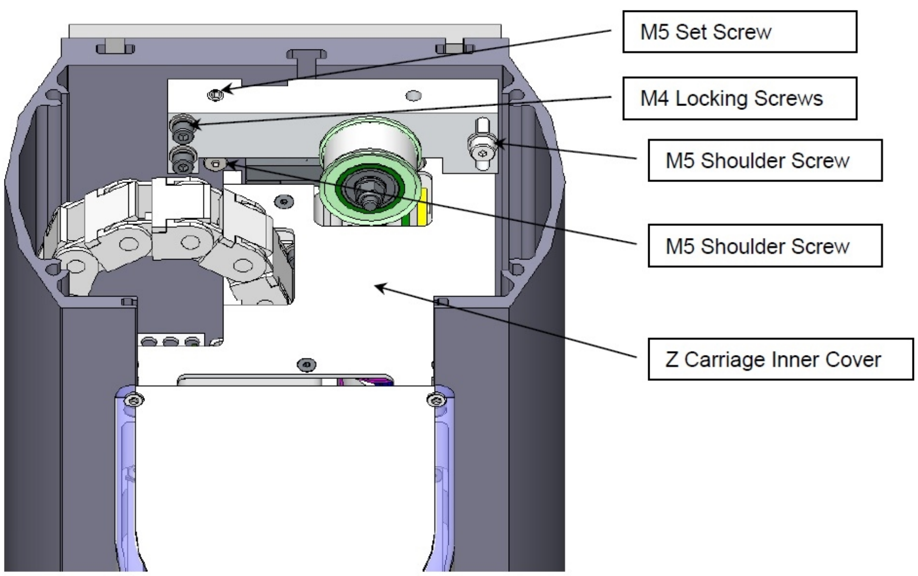
Tools Required:

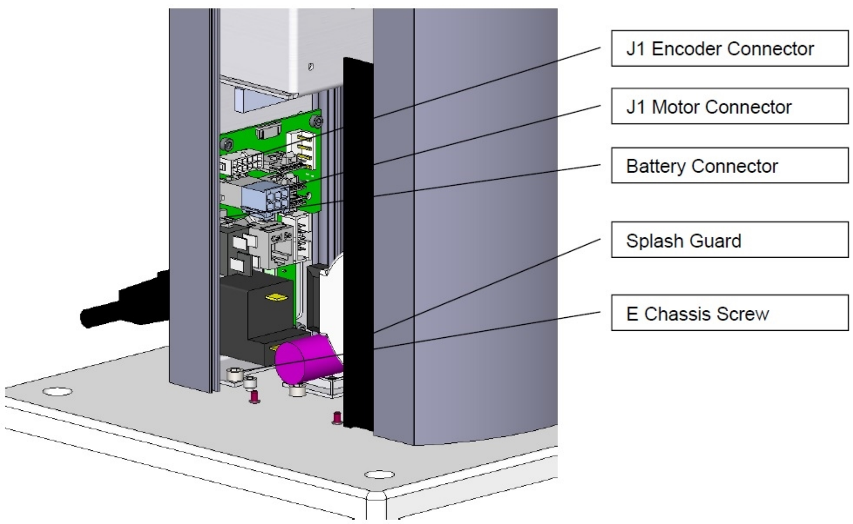
- 3.0 mm hex driver or hex L wrench
- 2.5 mm hex driver or hex L wrench

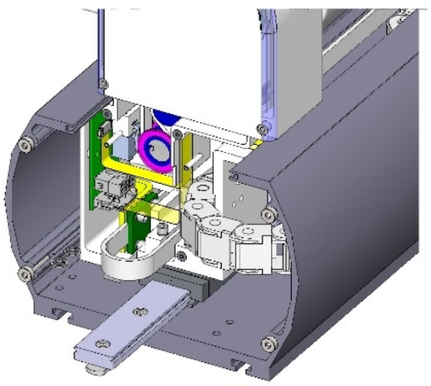
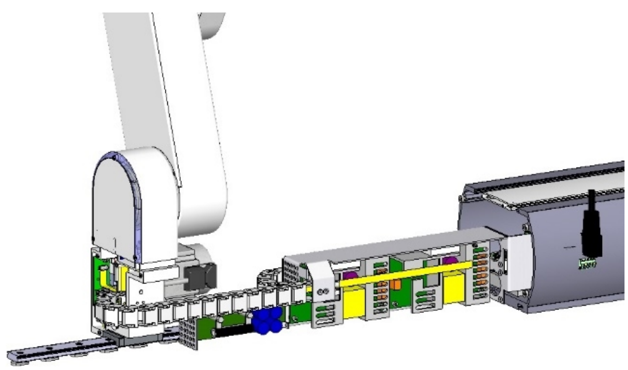
Spare Parts Required:

- 24 VDC power supply, PS10-EP-24150 or
- 48 VDC power supply, PS10-EP-48500 or
- J1 Stage Two Belt, PN PF00-MC-X0022. (400 mm) or PF00-MC-X0023 (750 mm)

To replace the power supplies, Energy Dump PCA, or J1 Stage Two (Output) timing belt, perform the following procedure:

Step	Action
1.	Move the robot arm to the top of the Z Column travel.
2.	Turn off the robot power and remove the AC power cord.
3.	Remove the Top Plate of the robot by removing the (4) M5 socket head screws from the top plate of the robot that attach the top plate to the Z column. Lift up the Top Plate.
4.	Remove the Front Cover by lifting it out vertically. 
5.	Lay the robot down on its back side on a table where there is room to work.
6.	Remove the Idler Plate Assembly by removing the M5 set screw that compresses the Idler Plate Spring, the (2) M4 SHCS that clamp the Idler Plate, and the M5 Shoulder Screw that forms the Idler Plate pivot. Be careful not to drop the pressure washer and tension spring that are inside the Idler Plate assembly. The tension spring presses against an M5 shoulder screw to tension the Z-axis Stage 2 belt.
7.	Remove the remaining M5 shoulder screw.

Step	Action
8.	Disengage the Z Carriage Timing Belt from the lower Drive Pulley. If it is necessary to replace the Z Carriage 2nd Stage Timing Belt, remove the Z Carriage Inner Cover and then the Timing Belt Clamp from the Z carriage by removing the (2) M4 X 12 mm SHCS and lock washers and replace the belt.
9.	Remove the left splash guard by removing the M3 X 8 mm SHCS on the retaining bracket.
10.	Remove the (4) screws that hold the Electronic Chassis to the Z Extrusion and the (2) screws that attach the Electronic Chassis and ground wire to the Base Plate. 
11.	Remove the J1 motor and encoder connectors that plug into the J1 Motor Interface Board.
12.	Remove the Battery connector that plugs into the J1 Motor Interface Board.
13.	Loosen the M4 SHCS screws attaching the Z bearing rail to the Z Extrusion.
14.	Slide the Z Rail and Z Carriage with the robot arm still attached partially out the top of the robot, far enough to expose the power supplies. It may be more convenient to slide the carriage and Z rail all the way out of the Z extrusion. Take care the bearing block does not slide off the Z rail. It may be helpful to wrap some tape around the rail to prevent this. If the bearing block slides off the rail, the bearing balls may be lost, damaging the bearing. Simultaneously slide the Electronic Chassis out of the Z Extrusion and lay both assemblies on the table.
15.	Unplug the cables from the failed power supply.

Step	Action
16.	Remove the (4) M3 X 8 mm SHCS and lock washers to replace the power supply or energy dump PCA. Be careful not to pull the J1 FFC encoder cable (white 14 mm wide flat cable) out of the FFC connector on the J1 Motor Interface PCA. If this cable is pulled out, carefully release the clamping lid on the FFC cable connector on the J1 Motor Interface PCA by inserting a small flat bladed screwdriver in the notch in the clamping lid and very gently prying the lid out of the connector. This lid is a cam-lock type of lid, which when inserted, clamps the flat white J1 encoder ribbon cable. Re-insert the J1 flat white encoder ribbon cable into this connector and carefully press the clamping lid back into the connector. If the J1 encoder cable is disconnected during this procedure, it will be necessary to re-calibrate the robot as the absolute encoder backup power will be interrupted to the J1 absolute encoder.
17.	Re-attach the power supply cables and re-assemble the robot. Ensure that the bearing rail reference edge is tightly pressed against the reference boss in the Z extrusion. The top of the bearing rail should be about 35 mm below the top of the extrusion and the bottom of the rail should clear the stage one Z timing belt on the large diameter pulley.
18.	Recalibrate the robot.  

Replacing the Robot Controller

DANGER Electrical Shock	
Before replacing the Robot Controller, the AC power should be removed.	

Tools Required:

- 2.5 mm hex driver or hex L wrench
- 2.0 mm hex driver or hex L wrench
- Small flat bladed screw driver, with 1.5 mm wide blade type
- M5 socket driver or M5 open end wrench or pliers

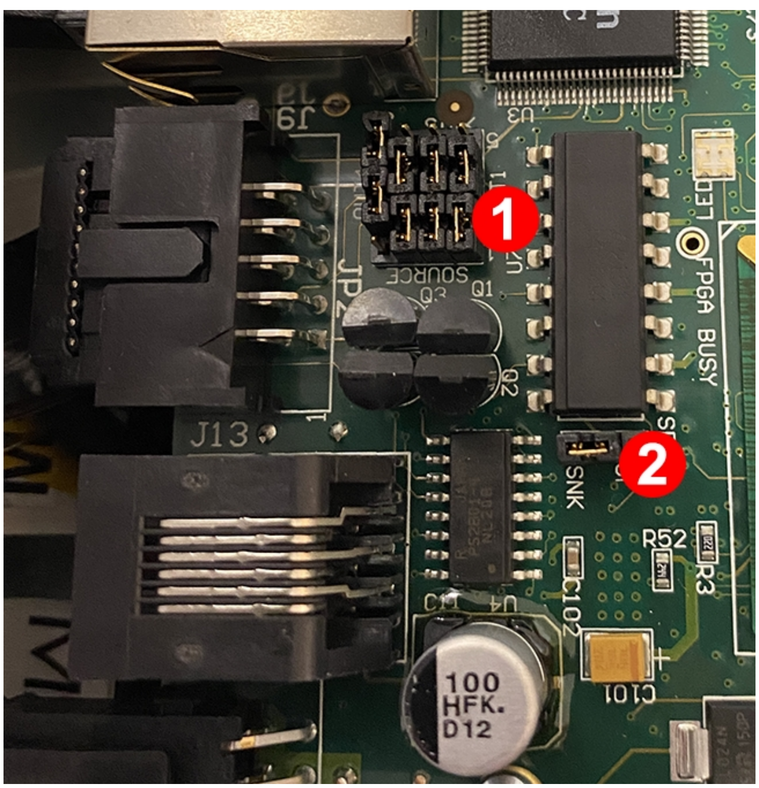
Spare Parts Required:

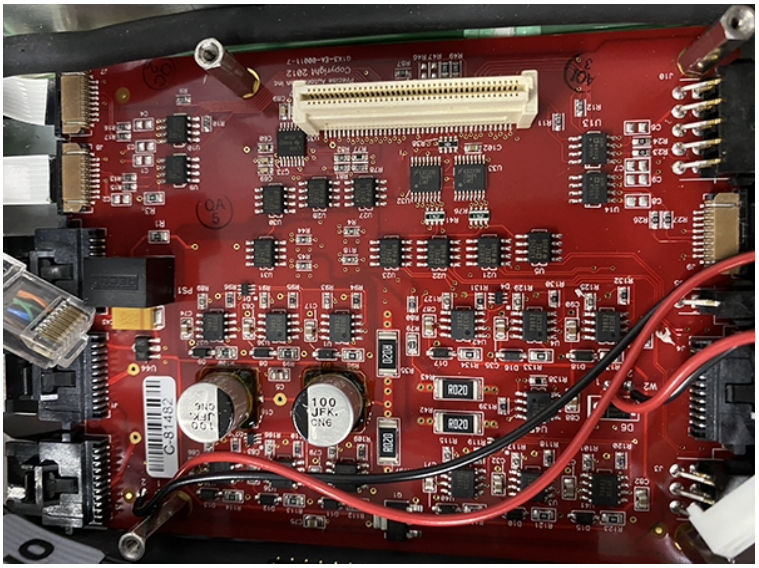
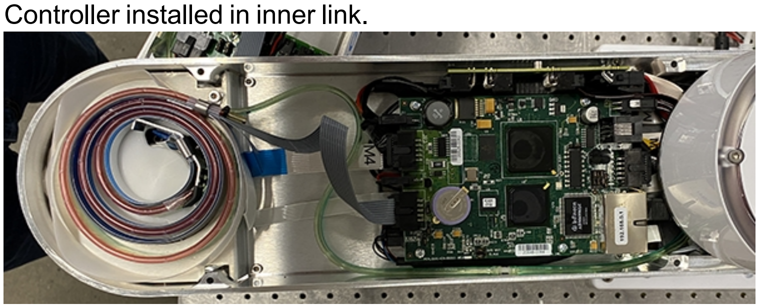
- Guidance Controller G5X0-EA-C5400

NOTE: Before replacing the controller, save copies of the robot PAC files and any project files to a PC, using a procedure similar to that described in the *PreciseFlex 3400 User Manual* in the "Software" section, titled "Loading a Project (Program) or Updating PAC Files."

To replace the Robot Controller, perform the following procedure:

Step	Action
1.	Turn off the robot power and remove the AC power cord.
2.	Remove the Inner Link Cover by removing the (4) M3 X 20 mm SHCS that attach the cover.
3.	Remove the upper circuit board by removing the (4) M2.5 X 6 mm screws.
4.	Unplug the cables from upper circuit board.
5.	Remove the lower circuit board by removing the (4) M2.5 X 16 mm standoffs with an M5 socket driver.

Step	Action
6.	Unplug the cables from the lower circuit board. Use a small flat bladed screwdriver to gently release the 3 zero-insertion-force (ZIF) flat flexible cable (FFC) connector compression lids.
7.	Check the jumpers on the replacement CPU board (top board) per the photo in Step 13.
8.	Re-attach the harness and replace the circuit boards. Refer to the schematics section above for connector labeling on the circuit boards. Be careful that the 2-pin plug from the brake release switch plugs into the lower board and the 2-pin plug on the pigtail from the lower board plugs into the upper board. Be careful to gently press in the compression latch on the FFC encoder connectors with your finger, not a sharp object.
9.	Make sure the Ethernet cable folds back along the under the upper circuit board but does not obstruct the board to board connector.
10.	Make sure no cables will be pinched by the Inner Link Cover and replace the Cover.
11.	After replacing the Robot Controller the robot must be re-calibrated. See "Calibrating the Robot: Setting the Encoder Zero Positions."
12.	After replacing the Robot Controller, install the PAC files on the controller.
13.	Move jumpers as shown below in 1 and 2. 

Step	Action
14.	Power amplifier installed in inner link. 
15.	Controller installed in inner link. 

Replacing the Linear Axis Controller

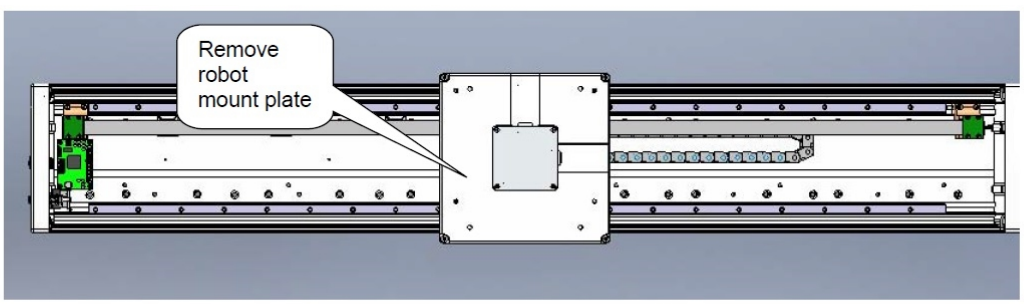
Tools Required:

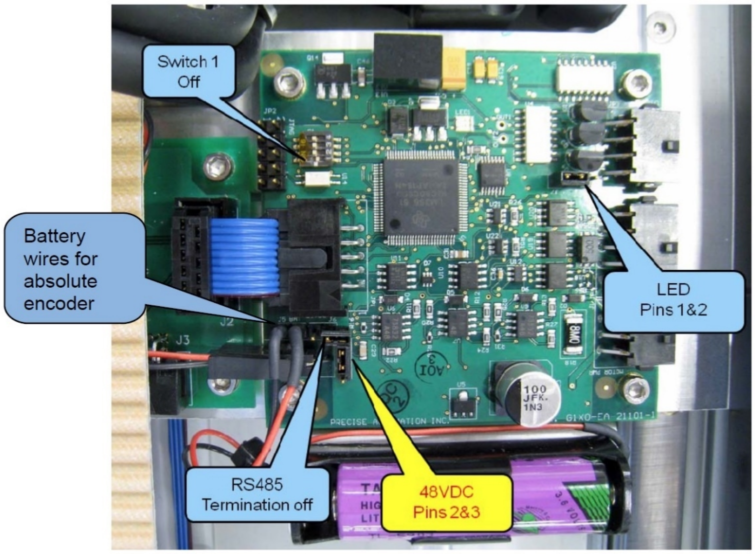
- 2.5 mm hex driver or hex L wrench
- 2.0 mm hex driver

Spare Parts Required:

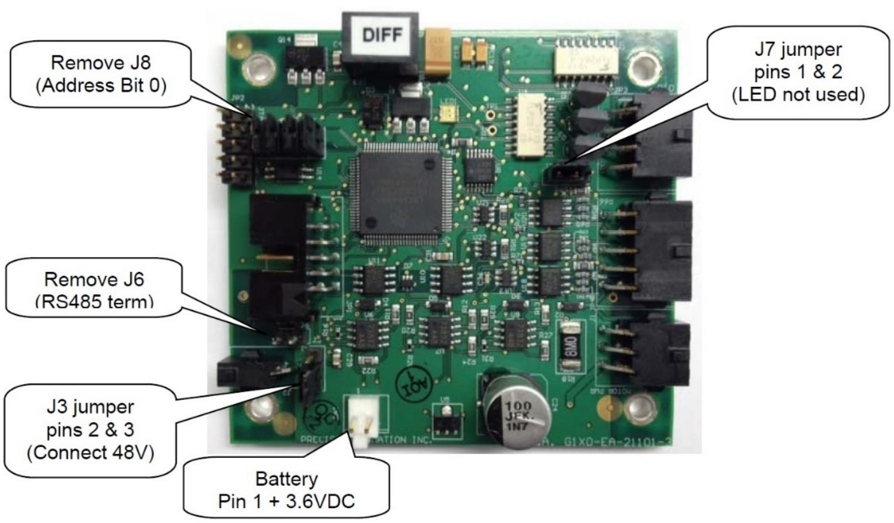
- G1100T Slave Controller (“GSB3-DIFF”) see “Spare Parts List." Note this part has differential encoder inputs and is not the same part as the GSB3-SE for the gripper (See the *IntelliGuide Grippers* user manual), which has single ended encoder inputs.

To replace the Linear Axis Controller, perform the following procedure:

Step	Action
1.	Remove the linear axis cover by sliding the carriage to one end of travel, remove the (4) M4 X 30 mm SHCS from the end caps retaining the cover. It may also be necessary to loosen the connector end cap by loosening the bottom (2) screws that attach the connector end cap to the Linear Axis Extrusion, so that the cover can be lifted up and removed.
2.	Remove the cable covers on the robot mount plate, and remove the robot mount plate.
3.	Replace the Linear Axis Controller Board. Ensure that all jumpers are set as shown below and that the battery wires are re-connected as shown. It will be necessary to recalibrate the robot if this board is replaced and the absolute encoder battery wires are disconnected. 



Linear Axis Controller (GSB Revision 2)



Linear Axis Controller Rev2 (GSB Revision 3)

Replacing the GIO Board

The PreciseFlex 3400 robot has a GIO board integrated into the FFC board in its base with 8 inputs and 8 outputs as a standard feature.

A GIO board may also be installed in the Linear Axis extrusion for robots with the Linear Axis option. GIO boards communicate over the same RS485 network as the GSBs. Add them to the controller (network node parameter) in the same fashion.

NOTE: Do not access the IO at the base of the robot when moving on a linear rail.

This board is provided with a 150 mm pigtail harness to a 25-pin Dsub connector. The board is attached with (4) M3 X 10 mm SHCS and the 25-pin Dsub is attached with standard D-sub 4-40 mounting standoffs.

This board is typically installed at the factory, but can be installed in the field for robots shipped after July 2012 which have the appropriate mounting holes.

Tools Required:

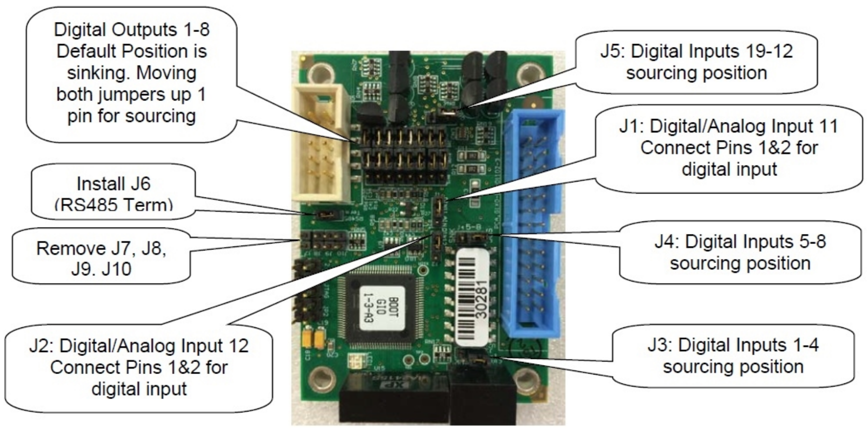
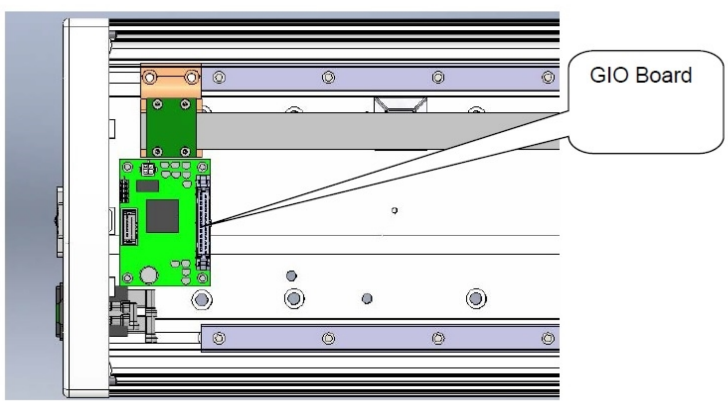
- 3 mm hex driver or hex L wrench
- 2.5 mm hex driver
- M5 socket driver
- M5 open end wrench

Spare Parts Required:

- GIO Digital IO Board see “Spare Parts List”

To install the GIO Board in a robot with a Linear Axis, perform the following procedure:

Step	Action
1.	Slide the carriage of the Linear Axis to one end of travel.
2.	Remove the top cover from the Linear Axis by removing the (4) M4 X 30 mm SHCS from the end caps. It may be necessary to loosen the (2) bottom screws on the connector end cap to provide clearance to remove the cover.

Step	Action
3.	Remove all (4) address jumpers on the GIO board J7-J10, as shown. 
4.	Install the GIO Board in the linear axis using the (4) M3 X 10 mm SHCS and lockwashers. 
5.	Remove the termination resistor from the 10-pin connector plug attached by (4) wires to the 9-pin Dsub Pendant connector and plug the 10-pin connector into the GIO board.
6.	Install the GIO output pigtail by plugging the 26-pin connector into to the GIO board and attaching the 25-pin Dsub connector to the end cap with the 4-40 standoffs provided. Make an accordion fold with the extra ribbon cable and tie wrap to hold the fold down over the GIO board.
7.	Replace the covers.
8.	Set value 8 in Data ID 151 to “GIO_8”, so that this ID reads “<Controller Serial No>”, “GSB_1”, “”,“”,“”,”“”,“”,GIO_8” This parameter may be found in Setup/Parameter Database/Controller/System ID.

Step	Action
9.	GIO signals may then be checked under Control Panels/Remote IO/Servo Node 8.

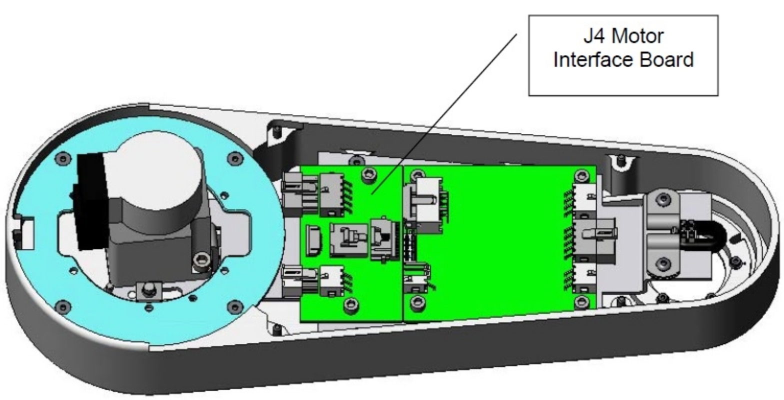
Replacing the Main Harness

Replacement of the Main Robot Harness is typically only performed at the factory. The Main Robot Harness is intended to last for the life of the robot.

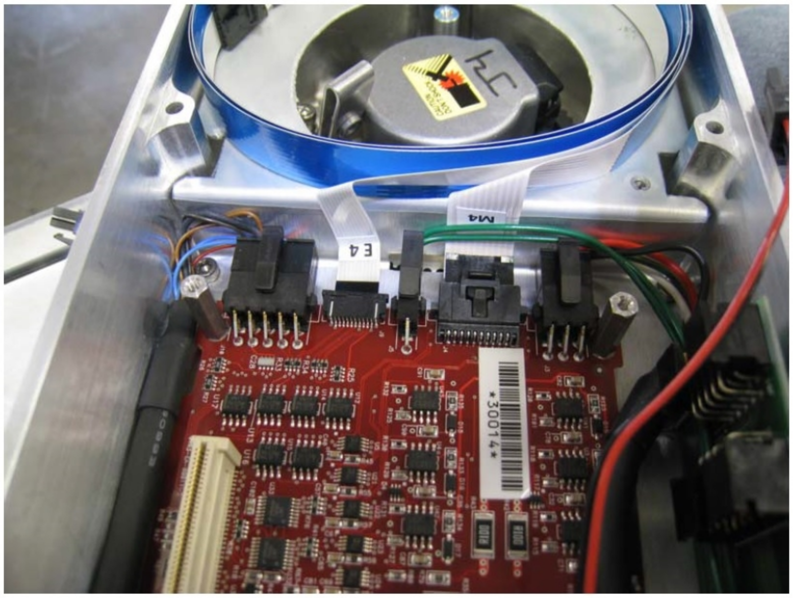
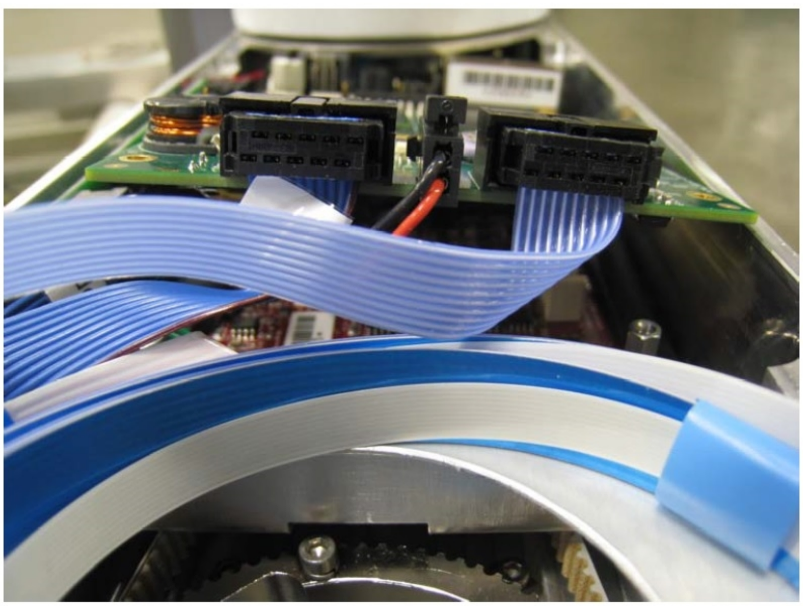
Replacing the Outer Link Harness

The Outer Link Harness is composed of three cables: Harness, FFC, J4 Motor, (PF0H-MA-00002-02), Harness, FFC, J4 Encoder (PF0H-MA-00020-2), and Harness, Gripper Controller (PF0H-MA-00036). See the *IntelliGuide Grippers* user manual.

Replacing the Outer Link Harness does not require unmounting the robot from its surface. To replace the Outer Link Harness, perform the following procedure:

Step	Action
1.	Remove the Inner Link Cover.
2.	Remove the Outer Link Cover.
3.	Unwind the Outer Link in counterclockwise direction, looking down from above the J3 axis until it reaches the hard stop.
4.	Release the J4 Motor Interface circuit board by removing the (2) M3 X 10 mm SHCS. 

Step	Action
5.	Disconnect the Outer Link Harness from the J4 Motor Interface PCA and the Guidance 1100C Slave Controller in the Outer Link.
6.	Remove the upper circuit board in the Robot Controller by removing the (4) M2.5 X 6 mm screws and disconnect the harness.
7.	Remove the Harness Retaining Clip from the Robot Controller Mount Plate to release the controller end of the harness.
8.	Remove the (4) M2.5 X 16 mm standoffs attaching the lower circuit board in the Robot Controller. Gently tip the lower circuit board upwards and disconnect the motor and encoder cables from the lower circuit board.
9.	Release the Harness Retaining Clip from the J3 Output Pulley by loosening the M3 X 25 mm SHCS attaching the clip to the pulley. Pull the clip upwards and remove the M3 X 4 mm BHCS that clamps the harness to release the harness from the clip.
10.	Replicate the folds on the controller end of the replacement harness.

Step	Action
11.	Insert the replacement harness into the Robot Controller circuit boards and reattach the Robot Controller circuit boards.  
12.	Attach the Harness Retaining Clip near the Robot Controller to retain the Robot Controller end of the Harness.
13.	Coil the replacement harness into (3) loops.
14.	Fold the ends of the harness down at a right angle to replicate the replaced harness.

Step	Action
15.	Insert the connectors down thru the Elbow into the Outer Link.
16.	Attach the J3 Harness Retaining Clip with the M3 X 4 mm BHCS and the 1/32 in thick Neoprene rubber strain relief pad around the harness to protect it along with the bent stainless steel retaining clip that protects the harness fold. 
17.	Attach the J3 Harness Retaining Clip to the J3 Output Pulley.
18.	Attach the connectors to the circuit boards in the Outer Link.
19.	Attach the J4 Motor Interface circuit board.
20.	Replace the covers.
21.	After replacing the harness the robot must be re-calibrated. See "Calibrating the Robot: Setting the Encoder Zero Positions."

Replacing the Z-axis Motor Assembly

DANGER

Electrical Shock

Before replacing the Z-axis Motor, the AC power should be removed.

Tools Required:

- 5.0 mm hex driver or hex L wrench
- 4.0 mm hex driver or hex L wrench
- 3.0 mm hex driver or hex L wrench
- 2.5 mm hex driver or hex L wrench
- Loctite 243

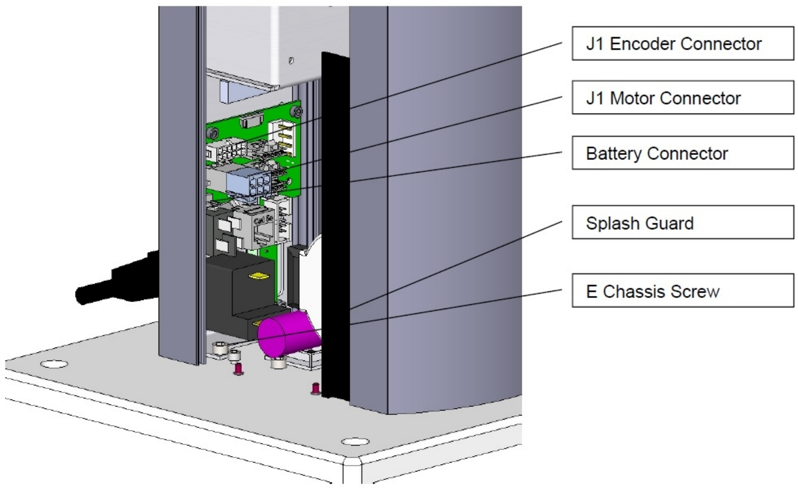
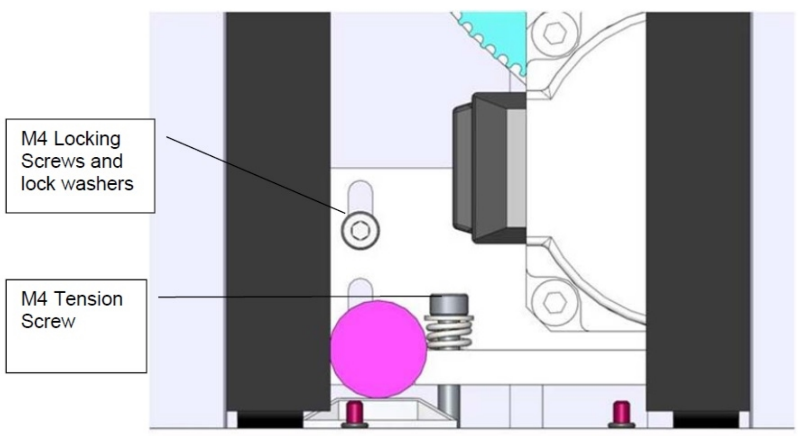
Spare Parts Required:

- J1 Motor Assembly PN PF00-MA-00071

The J1 Motor Assembly is composed of the J1 motor, connectors and a timing belt pulley.

To replace the Z -axis motor assembly, perform the following procedure:

Step	Action
1.	Remove AC power and connectors from the base of the robot.
2.	Unfasten the robot from its mounting surface by removing the (4) M6 SHCS.
3.	Lay the robot on its back, being careful the robot links do not fall over and damage the paint. It is a good idea to wrap the links with a protective cover first, such as a sheet of foam.
4.	Remove the top cover by removing the (4) M5 Low Head Cap Screws.
5.	Remove the Front Cover by sliding it out.
6.	Remove the left splash guard by removing the M3 X 8 mm SHCS and M3 star washer.
7.	Remove the screws attaching the Electronics Chassis and ground lug to the Bottom Mounting Plate.

Step	Action
8.	Unplug the Battery from the J1 Motor Interface Board. 
9.	Remove the screw compressing the J1 Motor Tension Spring and spring. 
10.	Remove the Base Mounting Plate by removing the (4) M5 SHCS. The right splash guard is attached to the base mounting plate.
11.	Remove the M4 Locking Screws that attach the J1 Motor Mount Bracket to the Z Column.
12.	Slide the J1 Stage 1 timing belt off the large idler pulley.
13.	Slide the J1 Motor and Motor Mount Bracket assembly out the bottom of the Z Column.
14.	Remove the J1 Motor Assembly from the J1 Motor Mount Bracket and replace with the new motor, using Loctite 243.
15.	Replace the components in reverse order.

Step	Action
16.	Compress the tension spring to 5.5 mm under the washer with the M4 Motor Bracket Locking screws slightly loose, then tighten the screws. Use Loctite 222 or 243 on the Base Plate and Top Plate screws.
17.	Before replacing the Front Cover and Top Plate, the Cal Pins should be removed from inside the Front Cover and the robot should be re-calibrated following the Calibration Procedure in "Calibrating the Robot: Setting the Encoder Zero Positions."

Replacing the J2 (Shoulder) Axis Motor or Timing Belt

DANGER
Electrical Shock

Before replacing the J2 Motor, the AC power should be removed.

Tools Required:

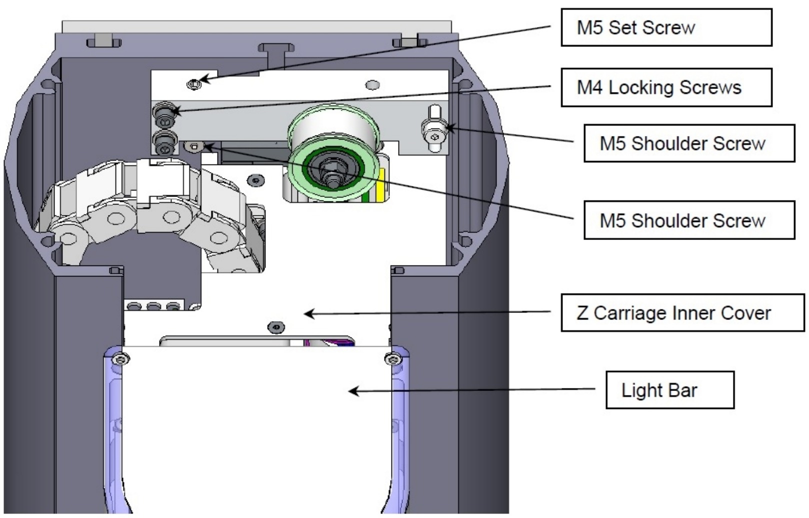
- 5.0 mm hex driver or hex L wrench
- 4.0 mm hex driver or hex L wrench
- 3.0 mm hex driver or hex L wrench
- 2.5 mm hex driver or hex L wrench
- 2.0 mm hex driver or hex L wrench
- Fine point tweezers
- 0.06 in flat blade screwdriver

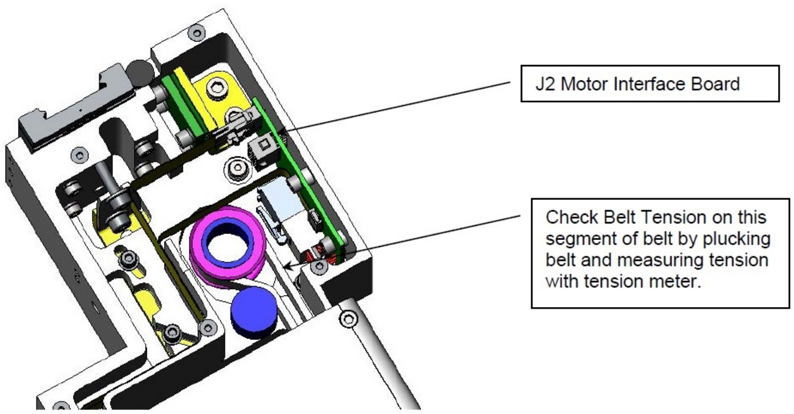
Spare Parts Required:

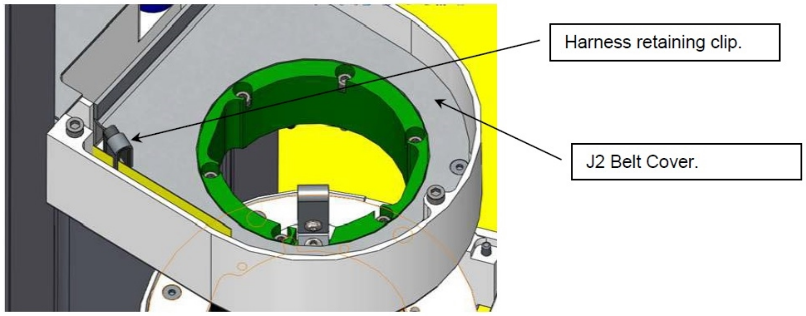
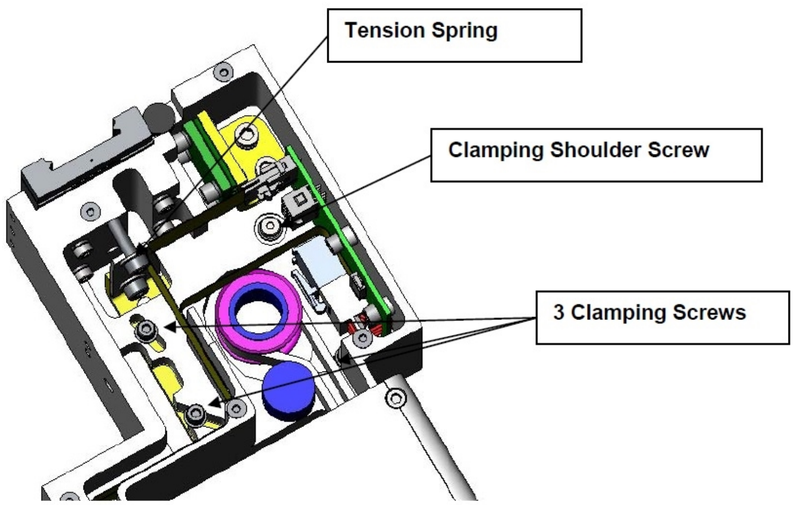
- J2 Motor Assembly (PF02-MA-00020) or J2 Timing Belt (PF00-MC-X0005 or PF00-MC-X0099)
- 2 1/8th by 8 in tie wraps
- Loctite 243

The J2 Motor Assembly is composed of the J2 motor, connectors, and a timing belt pulley. To replace the J2 (shoulder) axis motor or timing belt, perform the following procedure:

Step	Action
1.	Unbolt the robot from its mounting surface and set it vertically on the floor or a low surface.
2.	Move the robot arm to about 2 inches below the top of the Z Column travel.

Step	Action
3.	Turn off the robot power and remove the AC power cord.
4.	Remove the Top Plate of the robot by removing the (4) M5 socket head screws from the top plate of the robot that attach the top plate to the Z column.
5.	Remove the Front Cover by lifting it out horizontally.
6.	Remove the Z carriage inner cover by removing the (5) M3 X 10 mm FHCS. 
7.	Remove the Light Bar by removing the (3) M3 X 8 mm SHCS and unplugging the connector from the J2 Motor Interface PCA.
8.	Remove the tie wrap securing the harness loop to the Z carriage.
9.	Remove the M2 and E2 Flat Ribbon Cables from the J2 motor interface board. The E2 connector Cam lid must be VERY gently pried open with a .06 in flat bladed screwdriver.

Step	Action
10.	Remove the J2 Motor Interface PCA by removing the (2) M3 X 8 mm SHCS. Cut the tie wrap securing the J2 motor cables to the Z Carriage. Unplug the J2 motor and encoder cable from the J2 Motor Interface PCA. 
11.	Disconnect the harness retaining clip from the Z carriage, but do not remove the clips that attach the harness to the J2 pulley.
12.	Uncoil the harness. One end will remain connected to the E-Chain and the other end will be connected to the J2 Pulley.
13.	Remove the J2 Belt Cover by removing the (3) M3 X 10 mm FHCS, and pull it partially up the uncoiled harness to expose the J2 timing belt.

Step	Action
14.	Unsnap (3) or (4) of the E-Chain harness retaining segments, working up from the carriage, and fold the E-chain and harness back over the power supply side of the robot to get it out of the way.  
15.	Loosen the (3) M3 SHCS and (1) M4 shoulder screw that attach the J2 motor bracket.
16.	Measure and record the distance from the back of the Tension Spring to the carriage, then remove the M4 X 20 mm SHCD and washer that compress the Tension Spring.
17.	Pull the timing belt up over the idler cam follower closest to the large J2 pulley to release belt tension and provide enough slack to remove the motor.
18.	If it is necessary to replace the J2 timing belt, replace the belt and reassemble the robot. Otherwise, skip this step and continue on to Step 19.
19.	Loosen the (4) screws and washers that attach the motor mount plate to the Z carriage while supporting the motor. It may be easiest to leave these screws in the carriage during this process.
20.	Drop the motor assembly downwards while threading the motor cables through the access hole in the bottom of the Z carriage, and pulling the timing belt up over the pulley flange.

Step	Action
21.	Remove the motor from the Motor Mount Bracket by removing the (4) M5 X 12 mm SHCS. Attach the new motor to the Motor Mount Bracket using Loctite 243.
22.	Re-install motor, threading cables through the Z carriage first, and pulling timing belt over pulley flange. Attach motor with (4) clamping screws. Do not tighten clamping screws all the way.
23.	Re-install the M4 X 20 mm Tension Bolt and compress the Tension Spring to the previous value. Tighten the M4 Jam nut to lock the bolt and Tension Spring. This will cause motor assembly to pivot on the shoulder screw and will apply tension to the timing belt. Before tightening the clamping screws, rotate the J2 output pulley back and forth to ensure that the timing belt is running true on the output pulley.
24.	Tighten the clamping screws. If a Tension Meter is available check the belt tension for a minimum tension of 150N. See "Belt Tensions, Gates Tension Meter."
25.	Re-assemble the robot except for the front cover and top cover.
26.	Remove the Calibration Pins from the inside of the front cover extrusion and re-calibrate the robot following the Calibration Procedure in "Calibrating the Robot: Setting the Encoder Zero Positions."

Replacing the J3 (Elbow) Axis Motor or Timing Belt

DANGER

Electrical Shock

Before replacing this motor, the AC power should be removed.

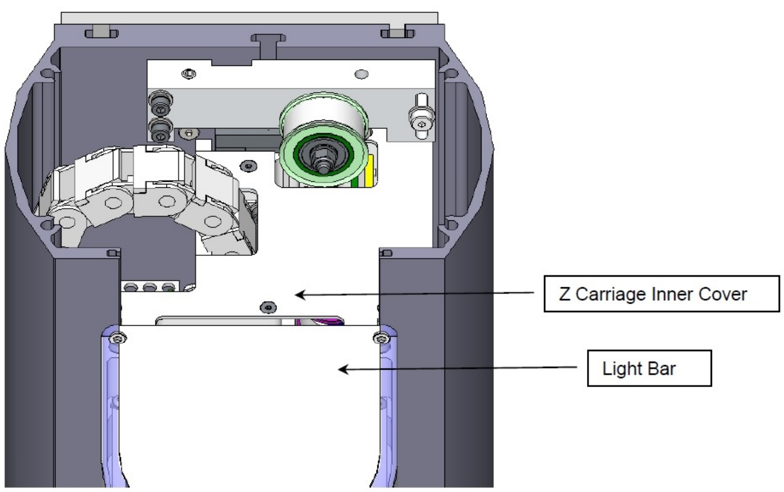
Tools Required:

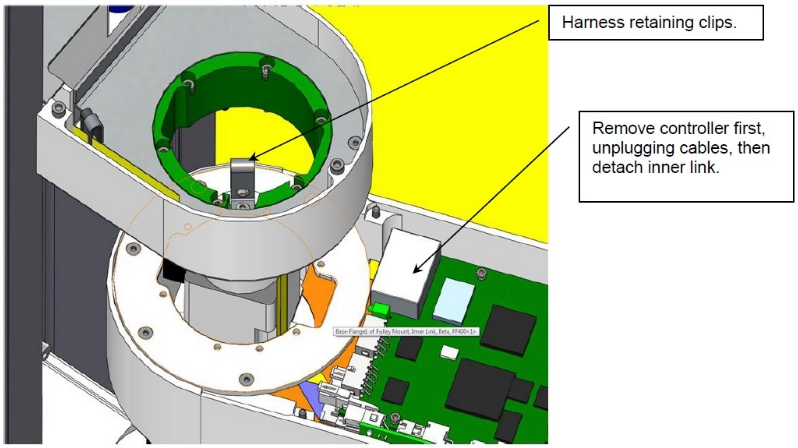
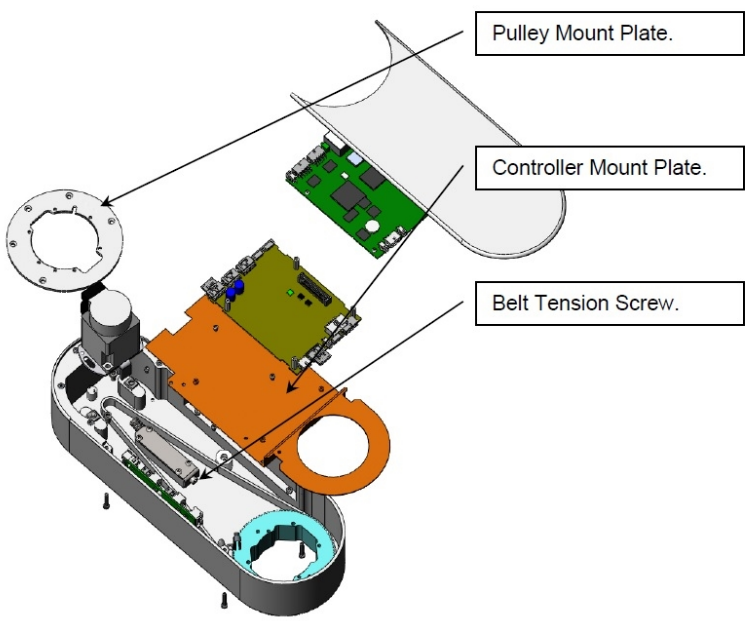
- 3.0 mm hex driver or hex L wrench
- 2.5 mm hex driver or hex L wrench
- 2.0 mm hex driver or hex L wrench
- Fine point tweezers
- 0.06 in flat blade screwdriver

Spare Parts Required:

- J3 Motor Assembly (PF00-MA-00030) or J3 Timing Belt (PF00-MC-X0066)
- 2 1/8th by 8 in tie wraps
- Loctite 222 and 243

The J3 Motor Assembly is composed of the J3 motor, connectors, and a timing belt pulley. To replace the J3 (elbow) axis motor or timing belt, perform the following procedure:

Step	Action
1.	Unbolt the robot from its mounting surface and set it vertically on the floor or a low surface.
2.	Move the robot arm to about 2 inches below the top of the Z Column travel.
3.	Turn off the robot power and remove the AC power cord.
4.	Remove the Top Plate of the robot by removing the (4) M5 socket head screws from the top plate of the robot that attach the top plate to the Z column.
5.	Remove the Front Cover by lifting it out horizontally.
6.	Remove the Z carriage inner cover by removing the (5) M3 X 10 mm FHCS. 
7.	Remove the Light Bar by removing the (3) M3 X 8 mm SHCS and unplugging the connector from the J2 Motor Interface PCA.
8.	Remove the controller from inner link.

Step	Action
9.	Detach the inner link from the Z carriage by removing the (6) M3 X 35 mm SHCS and lock washers. 
10.	Remove round Pulley Mount Plate from the Inner Link by removing the (5) M3 FHCS.
11.	Remove the J3 Controller Mount Plate from the Inner link by removing the (4) M3 X 5 mm SHCS. 
12.	Remove the J3 motor by removing the (2) M4 screws that attach the motor to the motor mount plate, and rotate the motor up and out of the motor mount plate. This procedure will preserve the belt tension and avoid having to use a tension meter to reset the belt tension, as it preserves the position of the motor mount plate.

Step	Action
13.	Replace the J3 motor, using Loctite 243, or optionally, replace the J3 timing belt if necessary. Since the motor mount plate has not been removed, the belt tension should not need to be adjusted.
14.	If a Belt Tension Meter is available, check the belt tension per "Belt Tensions, Gates Tension Meter." Check the belt tension every 10 degrees of rotation of the J3 output pulley and set the belt tension at its lowest point to the minimum value in "Belt Tensions, Gates Tension Meter."
15.	Replace the pulley mount plate using Loctite 222 and re-assemble the robot.
16.	Re-calibrate the robot.

Replacing the J4 (Wrist) Axis Motor or Timing Belt

DANGER

Electrical Shock

Before replacing this motor, the AC power should be removed.

Tools Required:

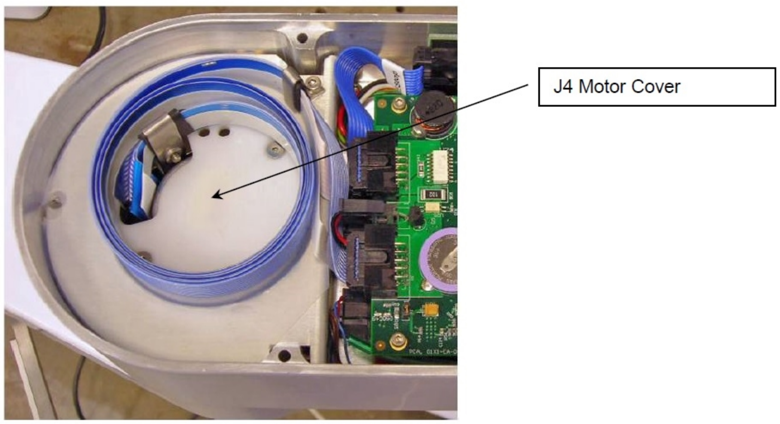
- 3.0 mm hex driver or hex L wrench
- 2.5 mm hex driver or hex L wrench
- 2.0 mm hex driver or hex L wrench
- Fine point tweezers
- 0.06 in flat blade screwdriver

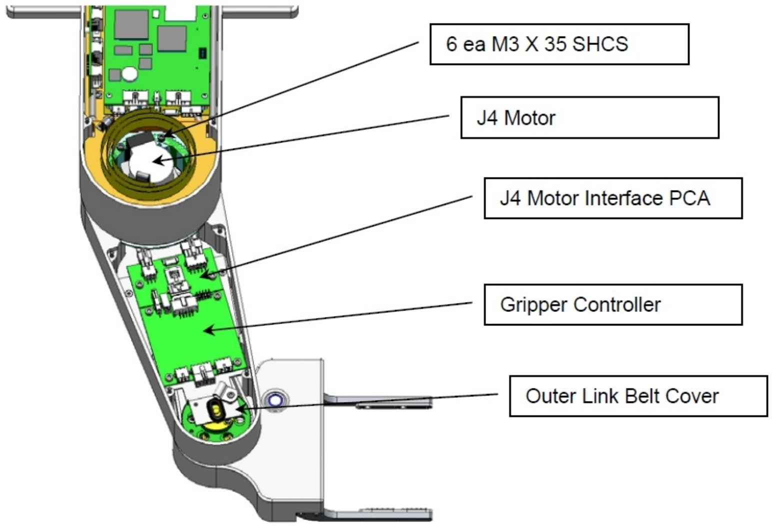
Spare Parts Required:

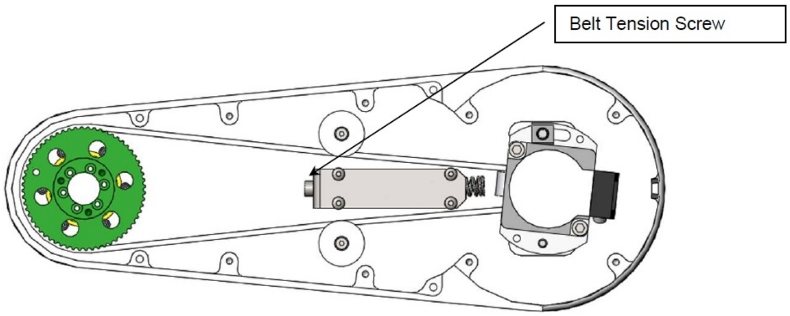
- J4 Motor Assembly (PF04-MA-00023) or J4 Timing Belt (PF00-MC-X0065)
- Loctite 222 and 243

The J4 Motor Assembly is composed of the J4 motor, connectors, and a timing belt pulley. To replace the J4 (Wrist) Axis Motor or Timing Belt, perform the following procedure:

Step	Action
1.	Move the robot arm to a convenient height on the Z column for removing the outer link.

Step	Action
2.	Turn off the robot power and remove the AC power cord.
3.	Remove the inner link cover by removing the (4) M3 X 20 mm SHCS and lock washers.
4.	Remove the outer link cover by removing (4) M3 X 20 mm SHCS and lock washers.
5.	Remove the J4 Motor Cover in the Elbow by removing the (2) M3 X 10 mm FHCS. 
6.	Rotate the Outer Link clockwise (viewing from above) until it hits the hard stop. This will expand the harness coil and the link will be position as shown below, about 10 degrees from straight out.
7.	Remove the J4 Motor Interface Board in the Outer Link and unplug the cables.
8.	Remove the Outer Link by removing the (6) M3 X 35 mm SHCS in the J3 Output Pulley that attach the Outer Link.
9.	Remove the Gripper Controller by unplugging the Gripper harness and removing the (4) M3 X 8 mm SHCS. See the *IntelliGuide Grippers* user manual.

Step	Action
10.	Remove the Outer Link Belt Cover by removing the (4) M3 X 10 mm SHCS. 
11.	Remove the J4 motor by removing the (2) M4 screws attaching the motor to the motor mount plate, and rotate the motor up and out of the motor mount plate. This procedure will preserve the belt tension and avoid having to use a tension meter to reset the belt tension, as it preserves the position of the motor mount plate.
12.	Replace the J4 motor, using Loctite 243, or optionally, replace the J4 timing belt if necessary. Since the motor mount plate has not been removed, the belt tension should not need to be adjusted.
13.	If a Belt Tension Meter is available, check the belt tension per "Belt Tensions, Gates Tension Meter." Check the belt tension every 10 degrees of rotation of the J4 output pulley and set the belt tension at its lowest point to the minimum value in "Belt Tensions, Gates Tension Meter."
14.	Replace the pulley mount plate using Loctite 222 and re-assemble the robot, with the outer link positioned as shown in Step 10 so that the link is correctly oriented with respect to the hard stop.

Step	Action
15.	Re-calibrate the robot. 

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: Product Specifications

General Specification	Range
Performance	
Payload	3 kg
Max Speed at TCP	1500 mm/sec (horizontal) 500 mm/sec2 (vertical)
Max Joint Speed	J1 - 500 mm/sec J2 - 360°/sec J3 - 720°/sec J4 - 720°/sec
Max Acceleration	1000 mm/sec2 with 0.5 kg payload
Repeatability	±0.090 mm at tool flange center
Range of Motion	
Joint 1 (Z) Axis	400, 750, 1160 mm
Joint 2	±93°
Joint 3 (Elbow)	±168°
Joint 4	+100° to +470° (±960° with servo gripper)
Horizontal Reach	588 mm (666 mm with servo gripper)
Communications	
General	100 Mb Ethernet, TCP/IP Modbus/TCP RS232, at end-of-arm
E-stop	Dual-channel E-stop
Operator Interface	Web-based operator interface
Digital I/O	8 inputs, 8 outputs at base of robot Optically isolated, 24V @ 100 mA 2 in, 4 out for end-of-arm-tooling Remote I/O available
Facilities	
Power	90 to 132 VAC and 180 to 264 VAC Auto selecting, 50-60 Hz 100-250 watts typical operation DC power option available
Pneumatics	Two 3.2 mm OD (1.7 mm ID) airlines provided for end-of-arm-tooling. 4.9 bar max (71 PSI)
Operating Temp	0-50°C (32-122°F)
Relative Humidity	90% non-condensing
Controller Mounting	Embedded into robot base

General Specification	Range
Air Lines	Two, 3.2 mm OD, 1.6 mm ID Max pressure 500 kba (75 PSI)
Weight	25 kg (400 mm Z-axis) 30 kg (750 mm Z-axis) 35 kg (1160 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 (standard) Horizontal Compensation Z-Height Detection
Peripherals and Accessories	
General	IntelliGuide s23 IntelliGuide s60 IntelliGuide s23D (Dial Gripper) Remote I/O (RIO)
Linear Rail	1.0, 1.5, and 2.0 M travel
Vision	IntelliGuide v23 Vision IntelliGuide v60 Vision

Appendix C: Environmental Specifications

NOTE: PreciseFlex robots are powered by 24 VDC and 48 VDC low-voltage DC power supplies with built-in overcurrent protection. For this reason, the PreciseFlex robots do not have a Short-Circuit Current Rating (SCCR).

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

Table 2-1: Environmental Specifications

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

Appendix D: Spare Parts List

Some equipment has changed between current robot hardware and previous (revision 9x or older) robot hardware as noted by the two right-most columns in the table below. In general, use the numbers in the “Part Number” column. If the part that is being ordered is for a hardware revision 9x or older robot, if there is an entry in the “Specific to Revision 9x or Older” column for the part in question, use that number. Refer to Explanation of the Product Label section of this manual to determine the revision of the robot. If the Part Number entry is blank, that part is discontinued or no longer needed.

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

Description	Part Number	Specific to Revision 9x or Older
Absolute Encoder Battery Assembly	612747-0001	
J1 Motor Assembly - 3 kg, PF3400	PF00-MA-00071	
J1 Stage 1 Belt	PF00-MC-X0119	
J1 Stage 2 Belt 400 mm	PF00-MC-X0023-4	
J1 Stage 2 Belt 750 mm	PF00-MC-X0023-5	
J1 Stage 2 Belt 1160 mm	PF00-MA-X0023-6	
J2 400 W Motor Assembly 20 mm Pulley (PreciseFlex 3400)	PF02-MA-00020	
J2 Belt 20 mm PreciseFlex 3400	PF00-MC-X0099	
Assembly, 20 mm belt roller, PreciseFlex 3400	PF00-MA-00078	
J3 Motor Assembly	PF00-MA-00030	
J3 Belt, Extended Reach	PF00-MC-X0066	
J4 50 W Motor Assembly (PreciseFlex 3400)	PF04-MA-00023	
J4 Belt - LR 3 MM PITCH GT2,TRUMOTION,232G	PF00-MC-X0065	
23 N Servo Gripper	PF0-MA-00059-1	
23 N Servo Gripper Fingers	PF0S-MA-00010	
60 N Servo Gripper	PF00-MA-00093	
Dual Gripper	PF00-MA-00094	
23 N Gripper with Vision	397209	
60 N Gripper with Vision	601388	
Ethernet Cable Assembly, Gripper with Vision		398058-0001
Guidance Controller with advanced kinematics license	G5X0-EA-C5400	G1X0-EA-C1400-13
Guidance 1100T Slave (GSB) for Single Gripper	389629-0005	G1X0-EA-T1101-4
Guidance 1100T Slave (GSB) for Dual Gripper/Rail	389629-0005	G1X0-EA-T1101-4D

Description	Part Number	Specific to Revision 9x or Older
24 VDC Supply	PS10-EP-24150	
48 VDC Motor Supply	605889	PS10-EP-48500
Slip Ring Harness Assembly, 23 N Dual/Single Servo Gripper	397515	
Slip Ring Harness Assembly, 23 N Single Servo Gripper w/Vision	398215	600186
Slip Ring Harness Assembly, 60 N Spring Gripper	PF04-MA-00030-E2	
Slip Ring Harness Assembly, 60 N Spring Gripper w/Vision	600186	
Harness, FFC, J4 Motor	PF0H-MA-00002-2	
Harness, FFC, J4 Encoder	PF0H-MA-00002-2	
Harness, Gripper Controller	PF0H-MA-00036	
J1 Motor Interface PCA	602414-0011	PF00-EA-00031
J2 Motor Interface PCA	602414-0021	PF00-EA-00030
MIDS Interface PCA	602414-0031	PF00-EA-00032
J4 Motor Interface PCA	602414-0041	PF00-EA-00033

Appendix E: Preventative Maintenance

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

Preventative Maintenance, Checklist & Procedures

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

PreciseFlex 3400 PM Schedule

Component	Expected Life	Action
Slip ring	3-5 years	Replace component
J2 timing belt	5 years heavy use	Replace component
Ethernet cable	2-4 years	Replace component

Linear Axis PM Schedule

Component	Expected Life	Action
Ethernet cable	2-4 years	Replace component
Tape seals	2-4 years	Replace component
Tape seal rollers	2-4 years	Replace component
Timing belt	6,000 hours/duty cycle*	Replace component
E-chain harnessing	20,000 hours	Replace all cables

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

Appendix F: Verification of PreciseFlex 3400 Collision Forces

PAC Files PreciseFlex 3400S

170713

Configuration	J1	J2	J3	J4	J5	Rail	XYZ
10351	4000	12000	14000	9000	0	NA	
10352	-2600	-12000	-14000	-9000	0	0	
Peak current, tcnts	7077	27702	24279	14837	6356	22933	
PID Error (10352) % of peak	37%	43%	58%	61%	100%	100%	
Standard Config for crash tests	50	-52	113	-61	102	-230	
Config for J2 Rotation (max velocity)	44	-1	66	-334	102	NA	
100% Joint Speed	500mm/s	90deg/s	720deg/s	720deg/s	400mm/s	750mm/s	
100% Joint Accel	1800	1100	1200	4000	10000	1000	
100% XYZ Speed							500
100% XYZ Accel							2000

PF400 Collisions at Gripper, 50mm programmed interference										Z deceleration %	
Speed	Manual Control			Free Space Collision			Rigid Surface Collision			100%	40%
	X cart	Y cart	-Z 1kg	X cart	Y cart	-Z 1.0kg	X cart	Y cart	J2 rot	-Z 1.0kg	-Z 1.0kg
100%	20	30	95	85	85	100	105	138	223	234	164
80%	21	29	90	64	82	100	89	114	149	195	139
60%	20	24	88	50	51	100	72	94	116	155	118
40%	19	21	81	34	28	96	50	70	87	121	104
20%	17	20	75	18	24	85	23	41	47	105	92
5%	16	12	72	18	23	93	16	22	19	80	77

Appendix G: Belt Tensions, Gates Tension Meter

In some cases it may be desirable to confirm the belt tension of one of the axes in the robot. This is not normally required, as the robot has been designed with spring tensioners that only require loosening and then re-tightening some clamping screws to reset the belt tensions. However, in the case of the long Z column belts it is possible that after several years of operation, the belt may stretch enough that the tension spring pre-load screw may need to be adjusted. If it appears a belt tension is not being adjusted properly by the pre-load spring, the tension can be checked with a Gates Sonic Tension Meter, Model 507C or 508C.

Figure 2-1: Gates Sonic Tension Meter

To use the tension meter

1. Turn on the power.
2. Click the **Mass** button and enter the belt mass from the table below.
3. Click the **Width** button and enter the belt width from the table below.
4. Click the **Span** button and enter the belt free span from the table below.

5. Click **Select**" to record the data.
6. Click **Measure** to take a tension reading.
7. Place the microphone near the belt, typically within 3 mm or so. Gently pluck the belt so that it vibrates. The tension meter will calculate the belt tension from the acoustic vibrations and display the tension in Newtons. Compare the tension to the table below. Adjust the belt tension preload screws if necessary.

Belt	*Mass (g/m)*	*Width (mm)*	*Span (mm)*	*Tension Min (N)*	*Tension Max (N)*	*Frequency Min Hz*	*Frequency Max Hz*
Z S1	2.8	9	58	50	70	384	454
Z S2 PF3400	4.1	12	575	140	180	46	53
Z S2 PF3400	4.1	12	920	140	180	29	33
Z S2 PF3400	4.1	12	1340	140	180	20	23
J2 PF3400	2.8	20	108	250	350	309	366
J3 PF3400	2.8	12	113	90	120	229	264
J4 PF3400	2.8	9	146	65	80	174	193
Linear Axis	4.1	20	500	135	160	41	44

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

Body region	Specific body area		Quasi-static contact		Transient contact	
			Maximum permissible pressure [a] p_s N/cm²	Maximum permissible force [b] N	Maximum permissible pressure multiplier [c] P_T	Maximum permissible force multiplier [c] F_T
Skull and forehead [d]	*1*	*Middle of forehead*	*130*	*130*	*not applicable*	*not applicable*
	2	*Temple*	*110*		*not applicable*	
Face [d]	*3*	*Masticatory muscle*	*110*	*65*	*not applicable*	*not applicable*
Neck	4	Neck muscle	140	150	2	2
	5	Seventh neck muscle	210		2	
Back and shoulders	6	Shoulder joint	160	210	2	2
	7	Fifth lumbar vertebra	210		2	2
Chest	8	Sternum	120	140	2	2
	9	Pectoral muscle	170		2	
Abdomen	10	Abdominal muscle	140	110	2	2
Pelvis	11	Pelvic bone	210	180	2	2
Upper arms and elbow joints	12	Deltoid muscle	190	150	2	2
	13	Humerus	220		2	
Lower arms and wrist joints	14	Radial bone	190	160	2	2
	15	Forearm muscle	180		2	
	16	Arm nerve	180		2	

[a] These biomechanical values are the result of the study conducted by the University of Mainz on pain onset levels. Although this research was performed using state-of-the-art testing techniques, the values shown here are the result of a single study in a subject area that has not been the basis of extensive research. There is anticipation that additional studies will be conducted in the future that could result in modification of these values. Testing was conducted using 100 healthy adult test subjects on 29 specific body areas, and for each of the body areas, pressure and force limits for quasi-static contact were established evaluating onset of pain thresholds. The maximum permissible pressure values shown here represent the 75th percentile of the range of recorded values for a specific body area. They are defined as the physical quantity corresponding to when pressures applied to the specific body area create a sensation corresponding to the onset of pain. Peak pressures are based on averages with a resolution size of 1 mm². The study results are based on a test apparatus using a flat (1,4 × 1,4) cm (metal) test surface with 2 mm radius on all four edges. There is a possibility that another test apparatus could yield different results. For more details of the study, see Reference [5].

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

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

[d] Critical zone (*italicized*)

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

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

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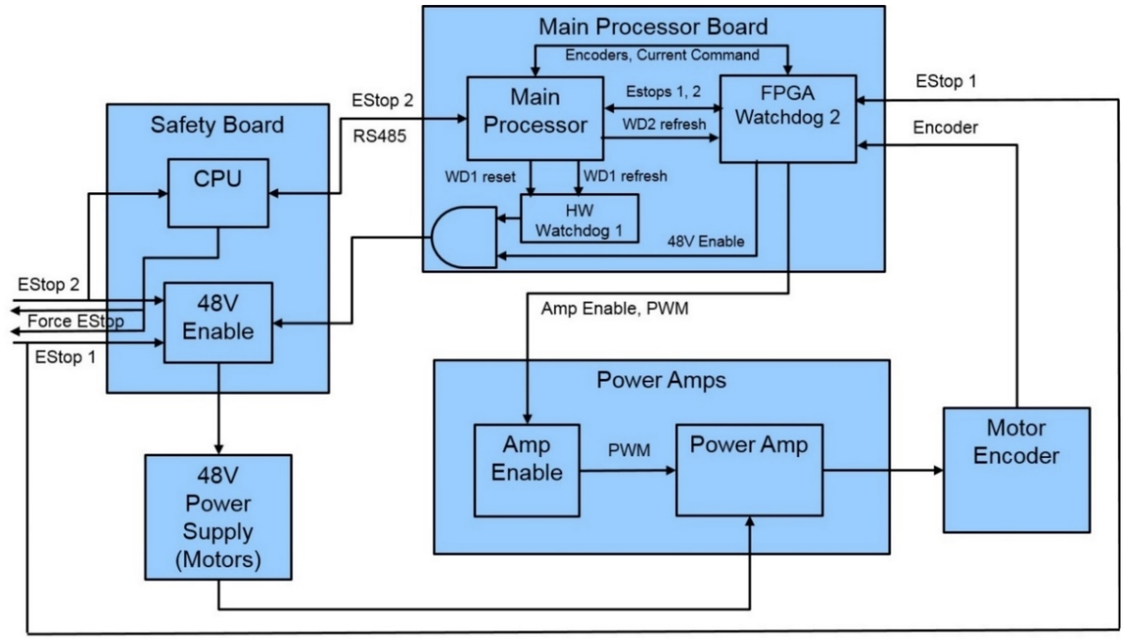
c The multiplier value for transient contact has been derived based on studies which show that transient limit values can be at least twice as great as quasi-static values for force and pressure. For study details, see References [2], [3], [4] and [7].

d Critical zone (*italicized*)

Appendix I: Safety Circuits for PreciseFlex 3400 3 kg Payload

14-Jun-17				PF3400					
Safety Circuit	Start up Test 1	Redundant	Continuous Test	Diagnostic Coverage	MTTFdl, Years	Power Off On Failure	PL	Category Safety	Notes (PF3400t has redundant Estop and 48V power supply enable)
Estop	Yes	Yes	No	99%	100	Yes	d	3	Startup test forces Estop, checks 48V power disable, zero amp current
									Dual Estop circuits tums off amp enable and PWM
									Dual Estop circuits tum5 off 48V power
									Stopping robot with hand turns off amp enable, PWM and 48V
Encoder Feedback	Yes	No	Yes	90%	58	Yes	d	3	Startup test checks encoder communication, prevents mtr power if fault
									Serial update at 8Khz w checksum, comm check, accel check
									Counter embedded in position word to confirm CPU read from FPGA
CPU Monitor	Yes	Yes	Yes	99%	100	Yes	d	3	Startup test forces CPU WD low, checks 48V power disabled
									Independent dual watchdog timers turn off amp enable, PWM and 48V
									Processor on safety board monitors main CPU. Disables 48V if failure.
Position Envelope Error	Yes	Yes	Yes	90%	57	Yes	d	3	Startup test checks encoder communication, prevents mtr power if fault
									Serial update at 8Khz w checksum, comm check, accel check
									SW watchdog in servo loop tums off amp enable, PWM and 48V
									Counter embedded in position word to confirm CPU read from FPGA
Power amp Fault	Yes	Yes	Yes	90%	100	Yes	d	3	Startup test confirms zero current when 48V enabled
									Excess current to ground or phase to phase triggers shutdown in 10 usec
									Saturated PID current command triggers shutdown in .050 sec
									Shorted transistor just locks up brushless motor
Collab Force Limit	Yes	Yes	Yes	90%	SW	Yes	d	3	Tests 2, 3, 4 above test HW. Motor driven against brake to test SW current limit.
									Position envelope error triggers fault, turns off power at amp and 48V
									Current saturation triggers separate fault, turns off power at amp and 48V
									Monitor function with WD turns off power at amp and 48V
									Monitor and CPU WD tested at startup turning off 48V
									Assymetric current limits limit Z force even with gravity load
Velocity Restrict	Yes	Yes	Yes	99%	93	Yes	d	3	Startup test, sets flag to trigger this error, then resets
									Checks velocity limit in FPGA in addition to check in CPU servo software
									1. Cat 2 and Cat 3 require startup test before enabling motor power

Safety Circuits for PreciseFlex 3400 3 kg Payload, Checklist



PreciseFlex 3400 3 kg Safety Circuit

Appendix J: System Diagram and Power Supplies

The robot has a 24 VDC and 48 VDC power supply located in the Z column. The power supplies have both over-current and over-voltage protection and are CSA, UL, and CE certified.

The robot controller and electric gripper are powered by the 24 VDC supply. The four main robot motors are powered by the 48 VDC supply. The 48 VDC supply is protected against over-voltage bus pump up by an energy dump circuit, which connects a 25-Watt dump resistor across the 48 VDC supply output when the voltage reaches 56 Volts and disconnects the dump resistor when the voltage drops to 52 Volts. This protects the power supply during high speed motor deceleration when the motor generates Back EMF voltage that adds to the power supply voltage.

DC power is routed from the power supplies to an interconnect board in the base of the Z column (Z Base Motor Interface Board). From this interconnect board, the power is routed in P1 and P2 flat ribbon cables. The P2 cable contains the 48 VDC motor power and is connected to the power amplifier board in the controller. The P1 cable contains the 24 VDC controller power and is routed to a second interconnect board (the MIDS Power Interface Board), which is mounted on the side wall inside the inner link of the robot. From this board, 24 VDC power is connected to the main robot controller.

Four digital input and four digital output signals from the main robot controller are also connected to the MIDS Power Interface Board through a ten-conductor ribbon cable. One digital input signal, DI3, is routed down to the base of the robot thru the P1 ribbon cable where it is connected to the green Phoenix Estop connector. This provides a digital input for safety interlock purposes. There is a jumper on the MIDS Power Board which jumps this signal to the P1 cable. This jumper must be installed for this connection to work.

The rest of the digital inputs and outputs are daisy chained to a second connector on the MIDS board for use if needed. Some of these signals are used when the pneumatic gripper option is installed.

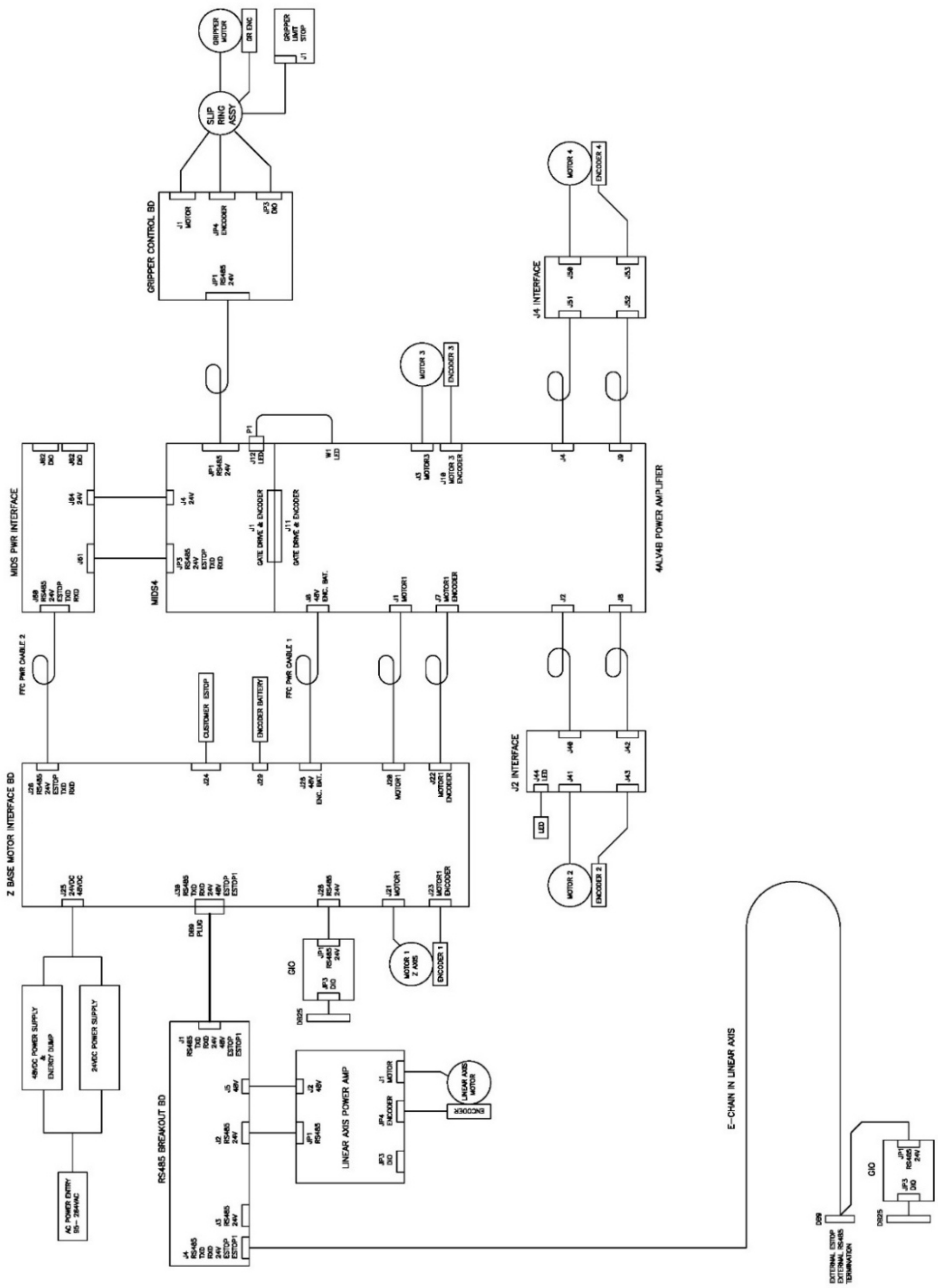
The E-Stop circuit is also connected from the controller to MIDS Power Interface Board and down through the P1 cable to two E-Stop connectors: the green Phoenix connector (J24) and the 9 pin Dsub connector (J30). The E-Stop pins on these connectors are wired in series so that both connectors must have either a jumper or E-Stop switch installed that completes the E-Stop circuit.

The gripper controller is connected to the main controller through an RS-485 cable routed through the elbow along with the power and encoder cables for the J4 motor. The RS-485 cable also supplies power for the gripper controller. See the *IntelliGuide Grippers* manual.

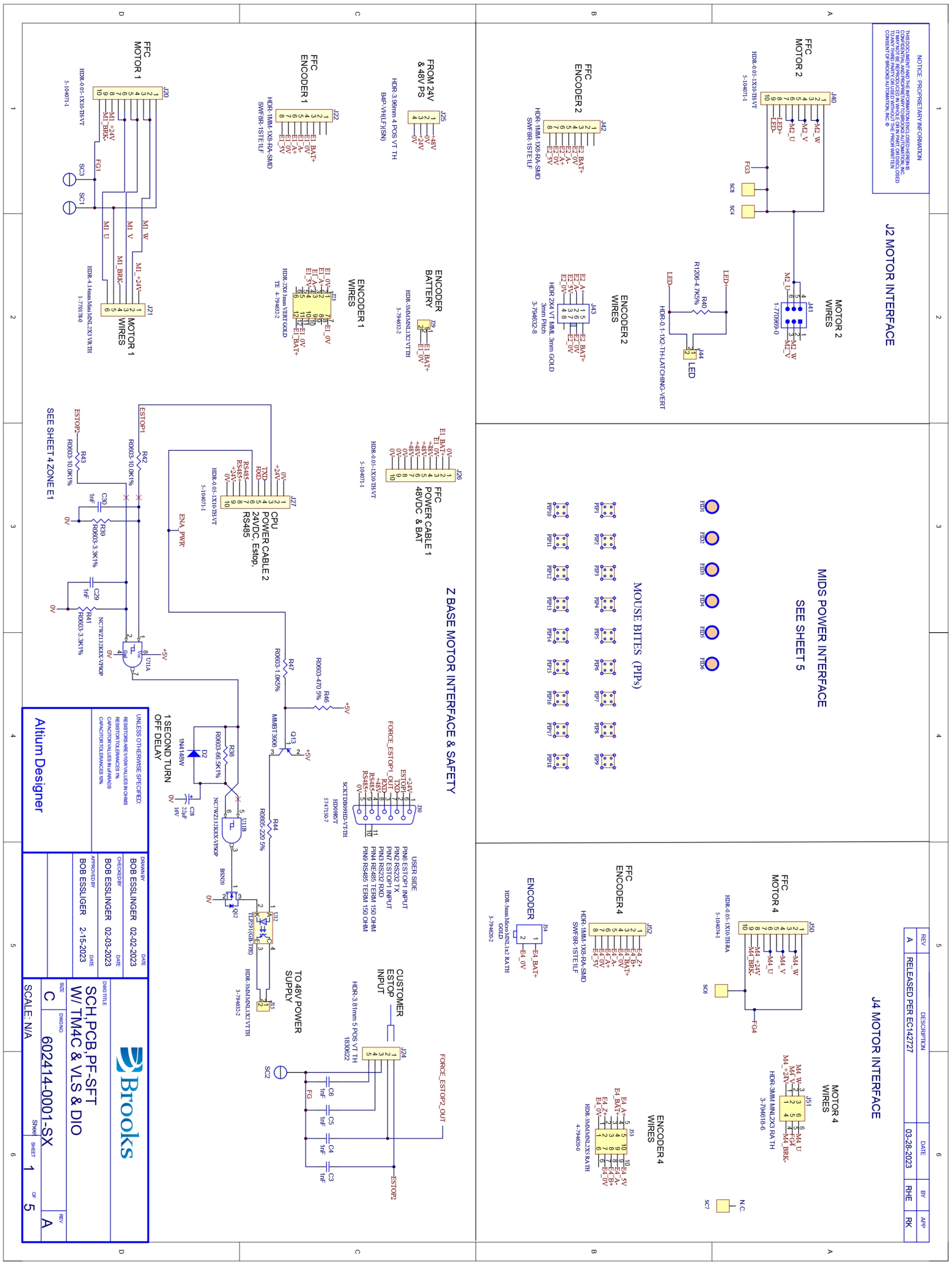
The motors for the Z column, the shoulder, and the wrist all plug into an interconnect board that converts the signals from the motor cables to the flat ribbon cables. The motor for the elbow plugs directly into the controller amplifier board in the inner link.

The cable from the brake release button under the shoulder plugs into the amplifier board in the inner link. This button provides a ground return from the Z column brake to ground bypassing the transistor that performs this function under computer power so that the brake can be released manually without motor power being enabled.

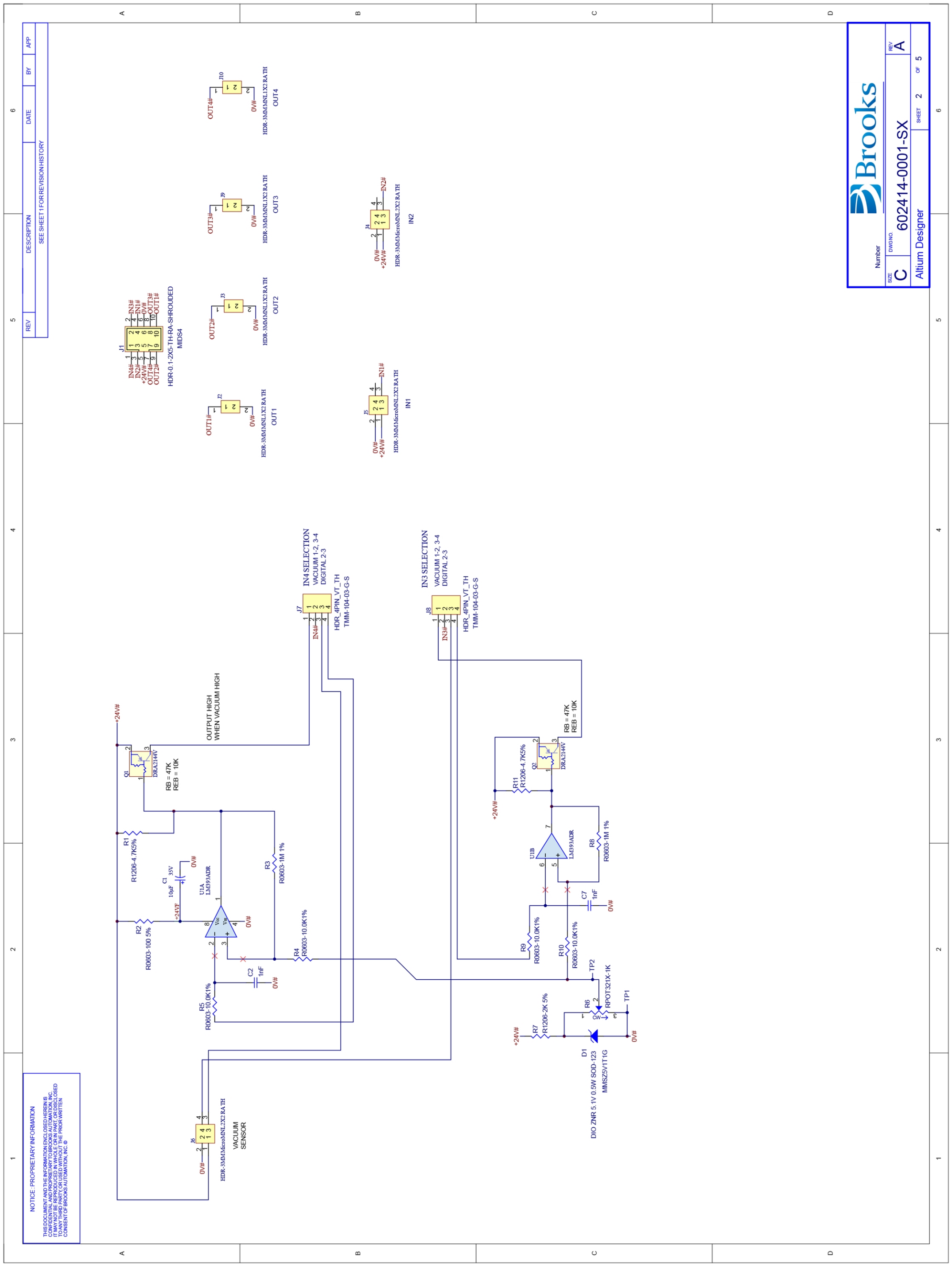
Below are the schematics and diagrams.



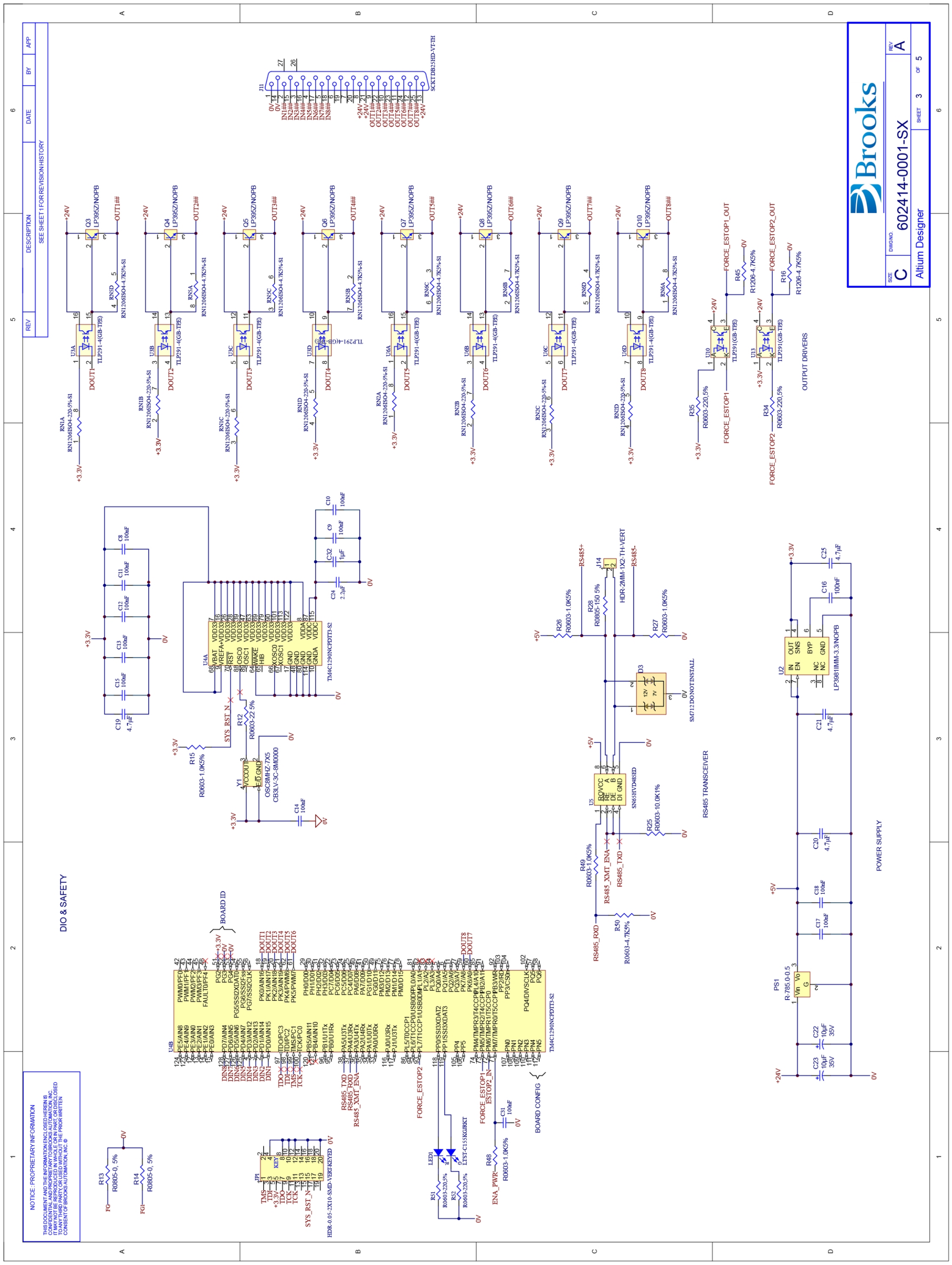
System Overview, PreciseFlex 3400 with Linear Axis



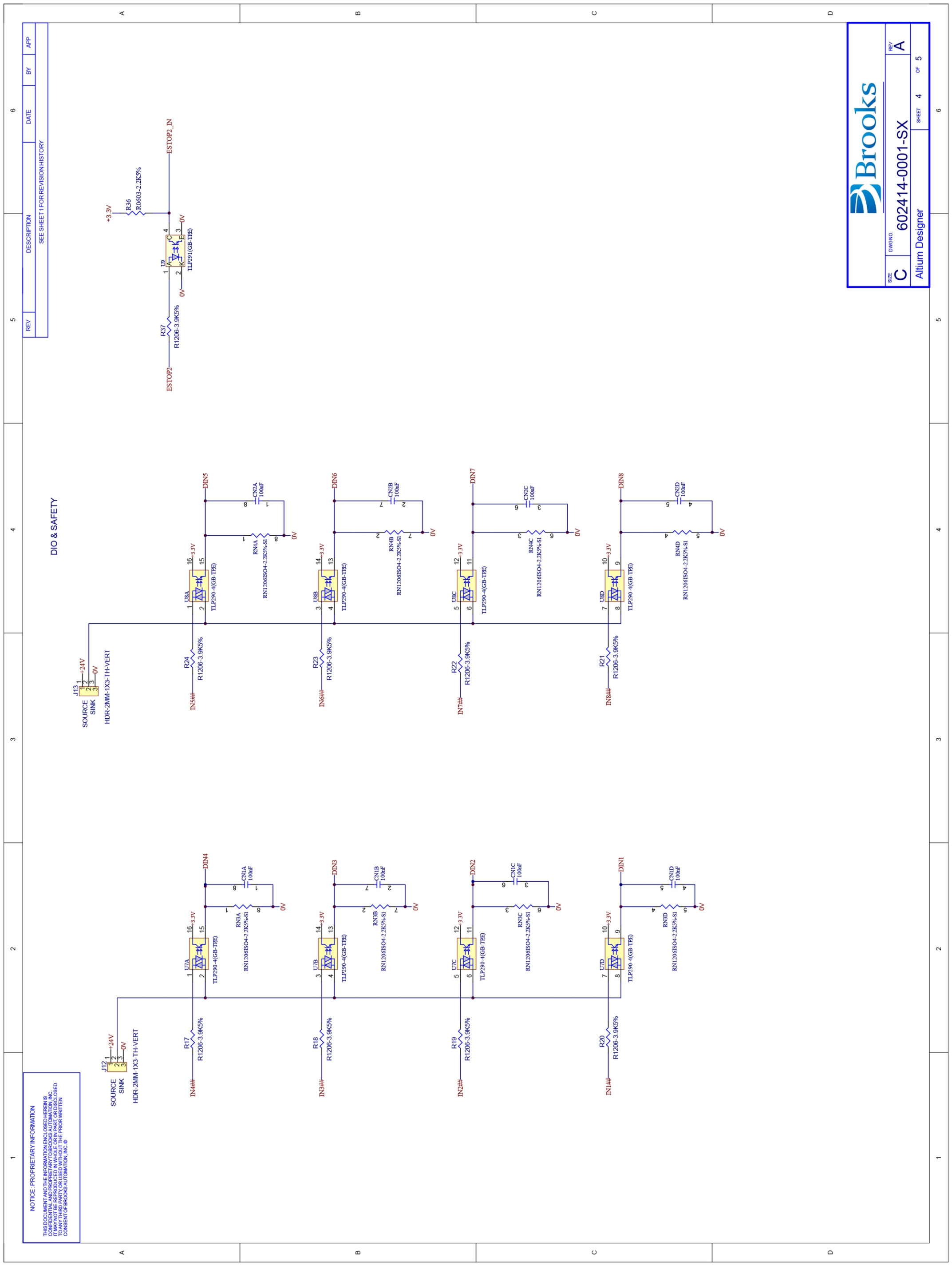
SCH,PCB,PF-SFT W/TM4C & VLS & DIO



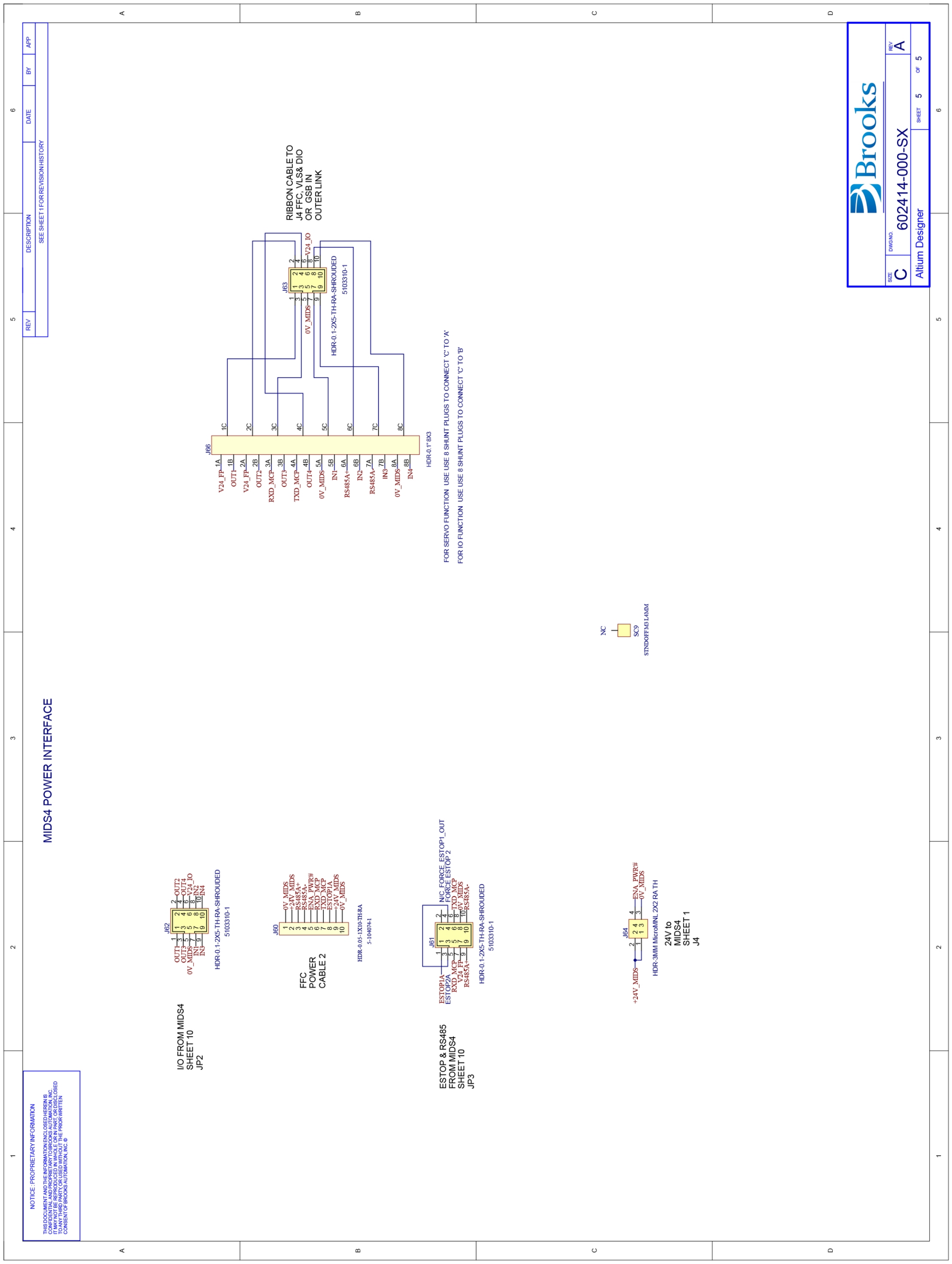
SFT Board, Part 1



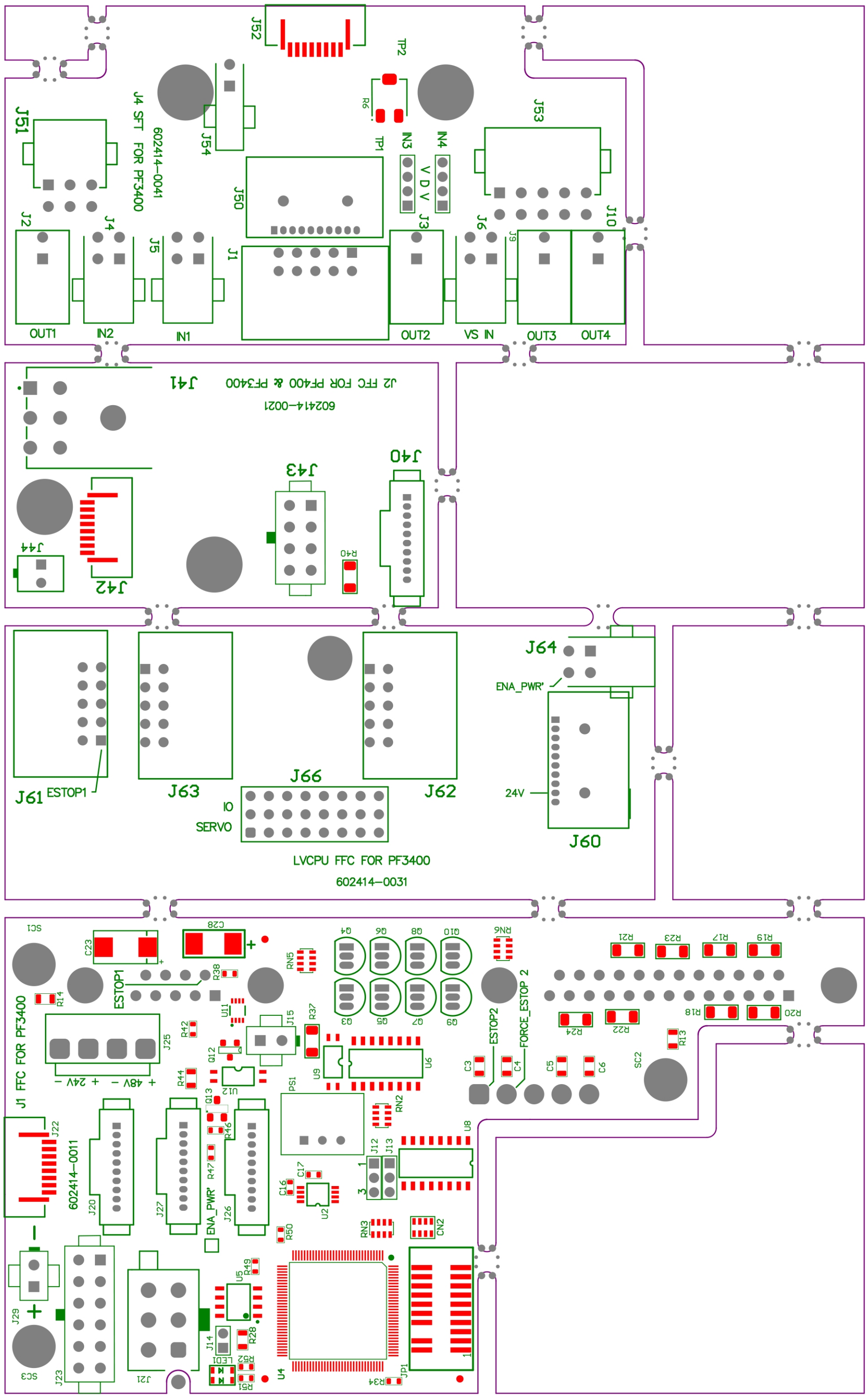
SFT Board, Part 2



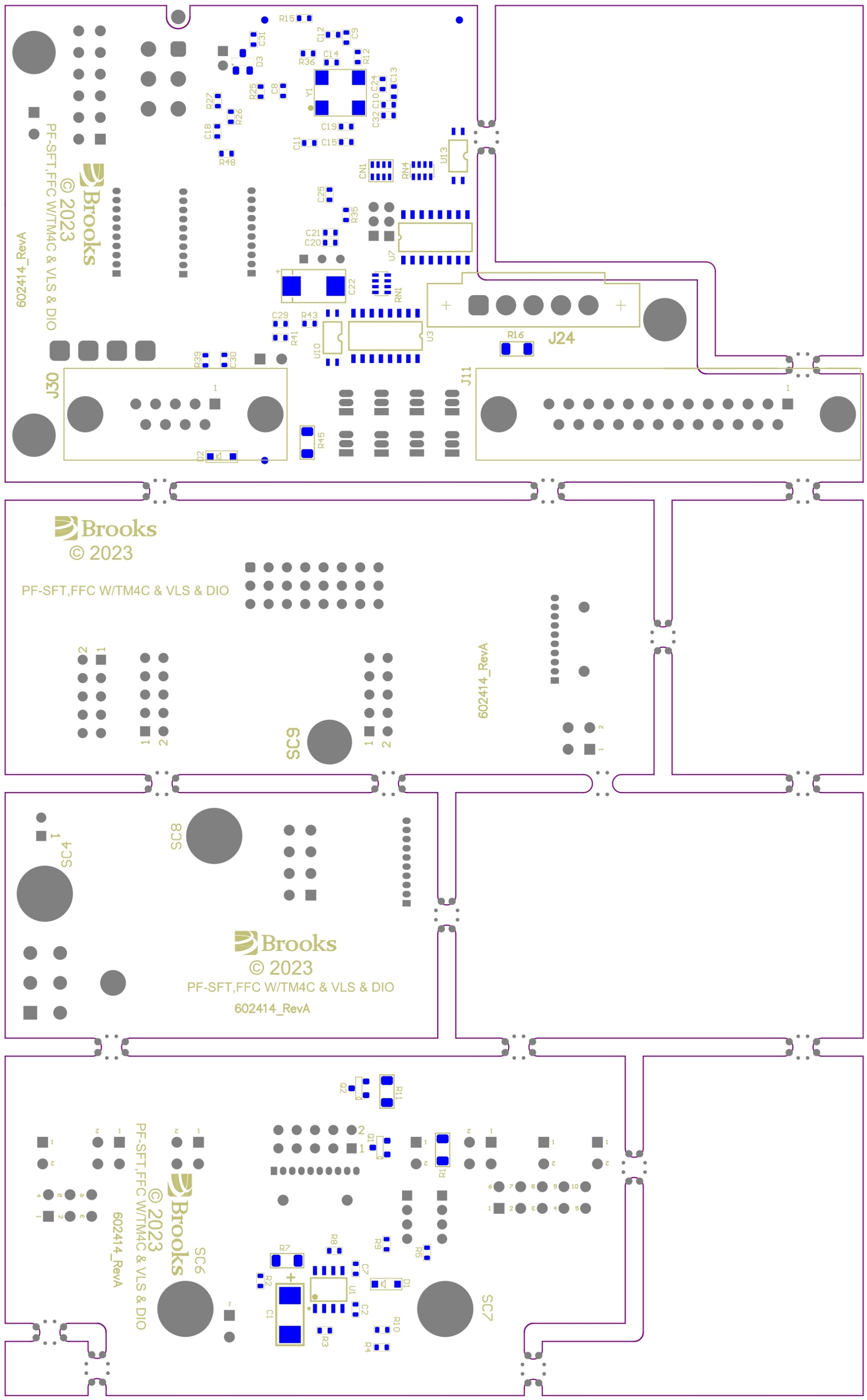
SFT Board, Part 3



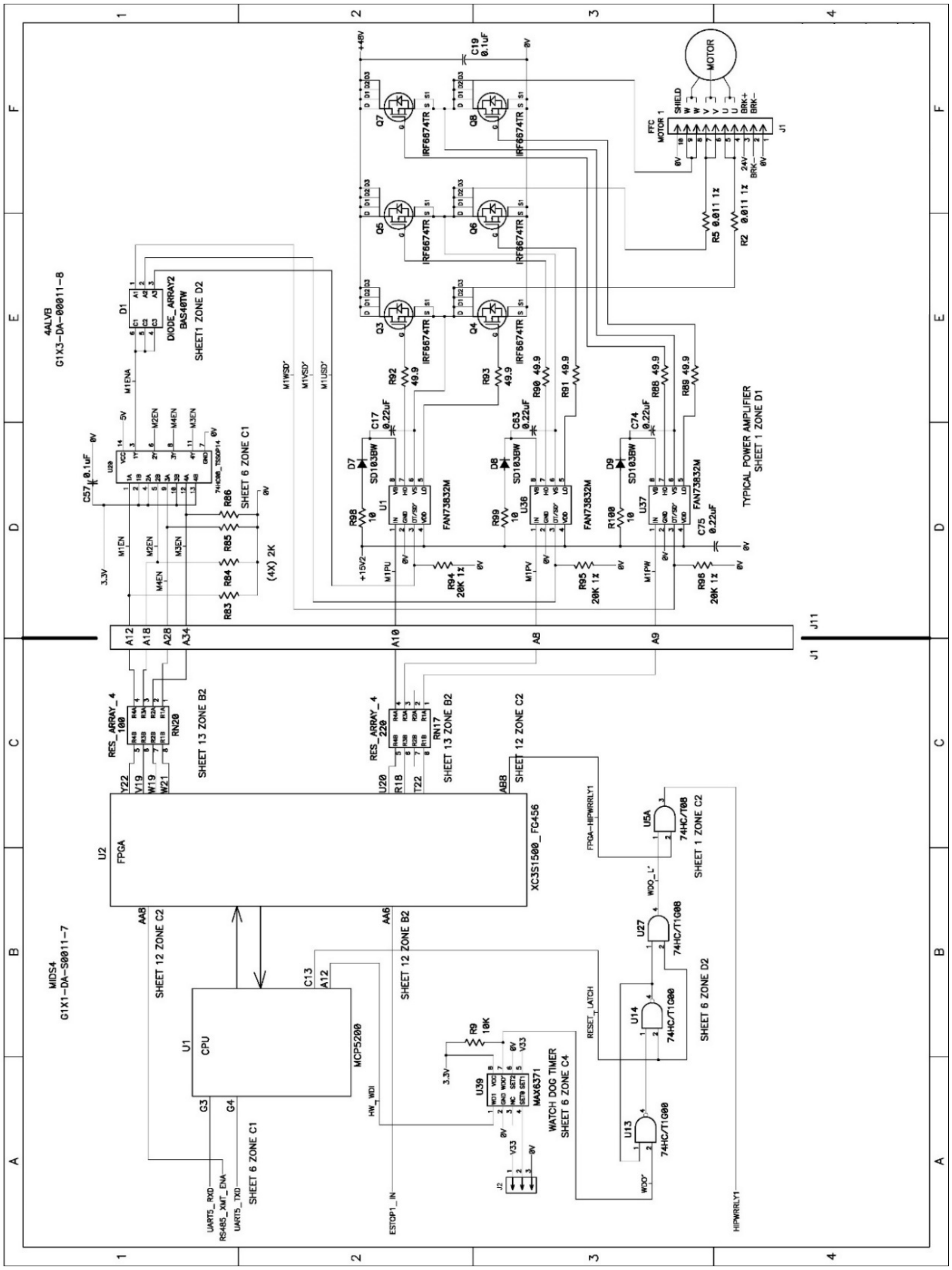
SFT Board, Part 4



SFT Board with CPU



SFT board PCB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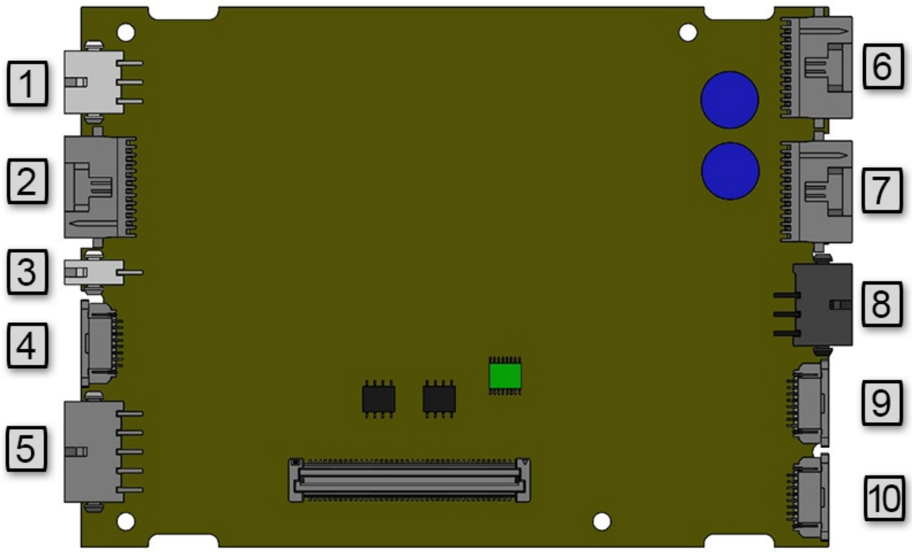
TYPICAL POWER AMPLIFIER
SHEET 1 ZONE D1
FPGA
XC3S1500_FG456
CPU
MCP5200
WATCH DOG TIMER
MAX6371

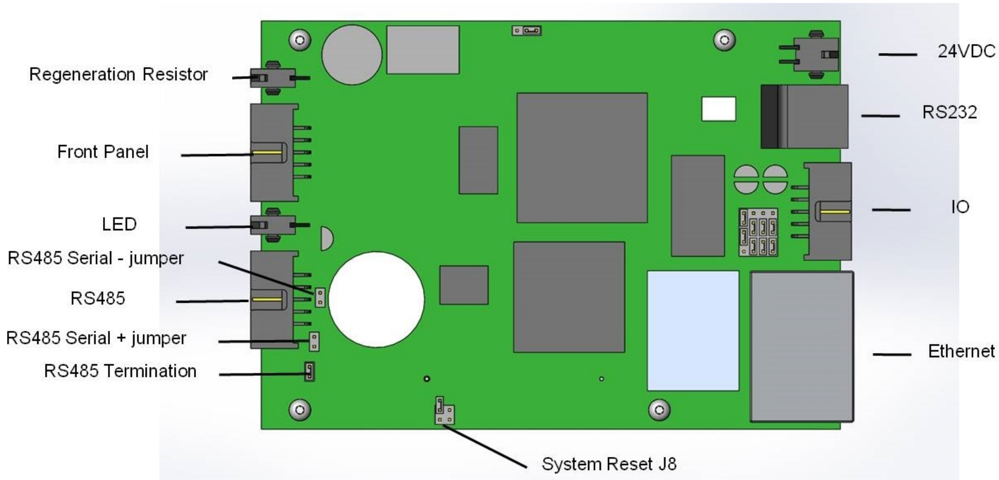
E-Stop Path



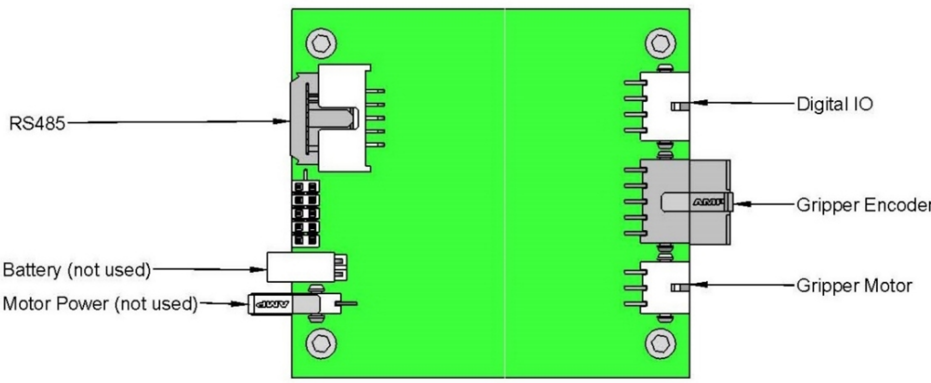
Controller Power Amplifier Connectors

Table 2-2: Controller Power Amplifier Connectors

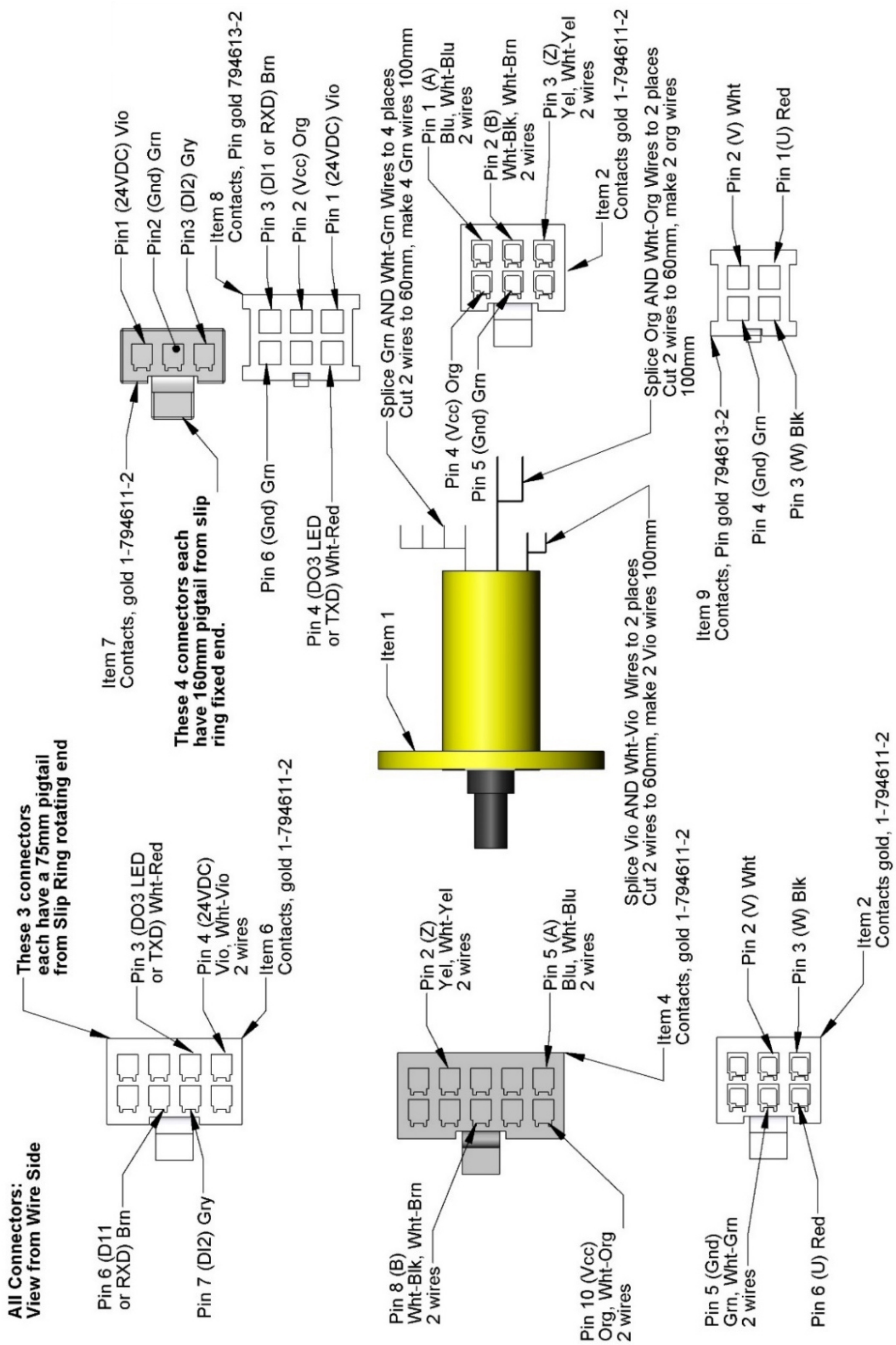
Number	Connector
1.	Motor 3 Cable
2.	Motor 4 FFC
3.	Brake Release Switch
4.	Encoder 4 FFC
5.	Encoder 3 Cable
6.	Motor 2 FFC
7.	Motor 1 FFC
8.	Power 1 FFC
9.	Encoder 2 FFC
10.	Encoder 1 FFC



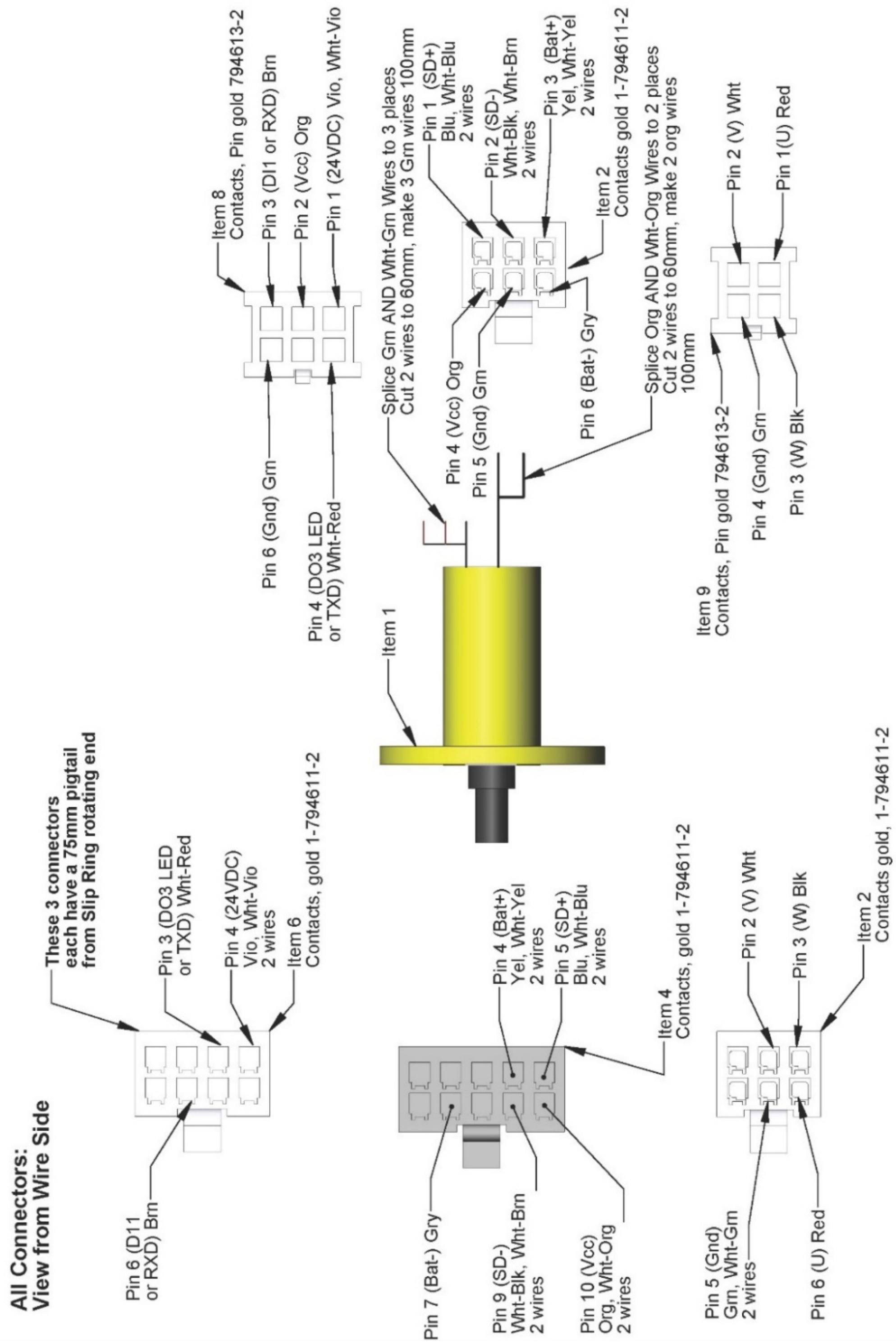
Controller Board Connectors



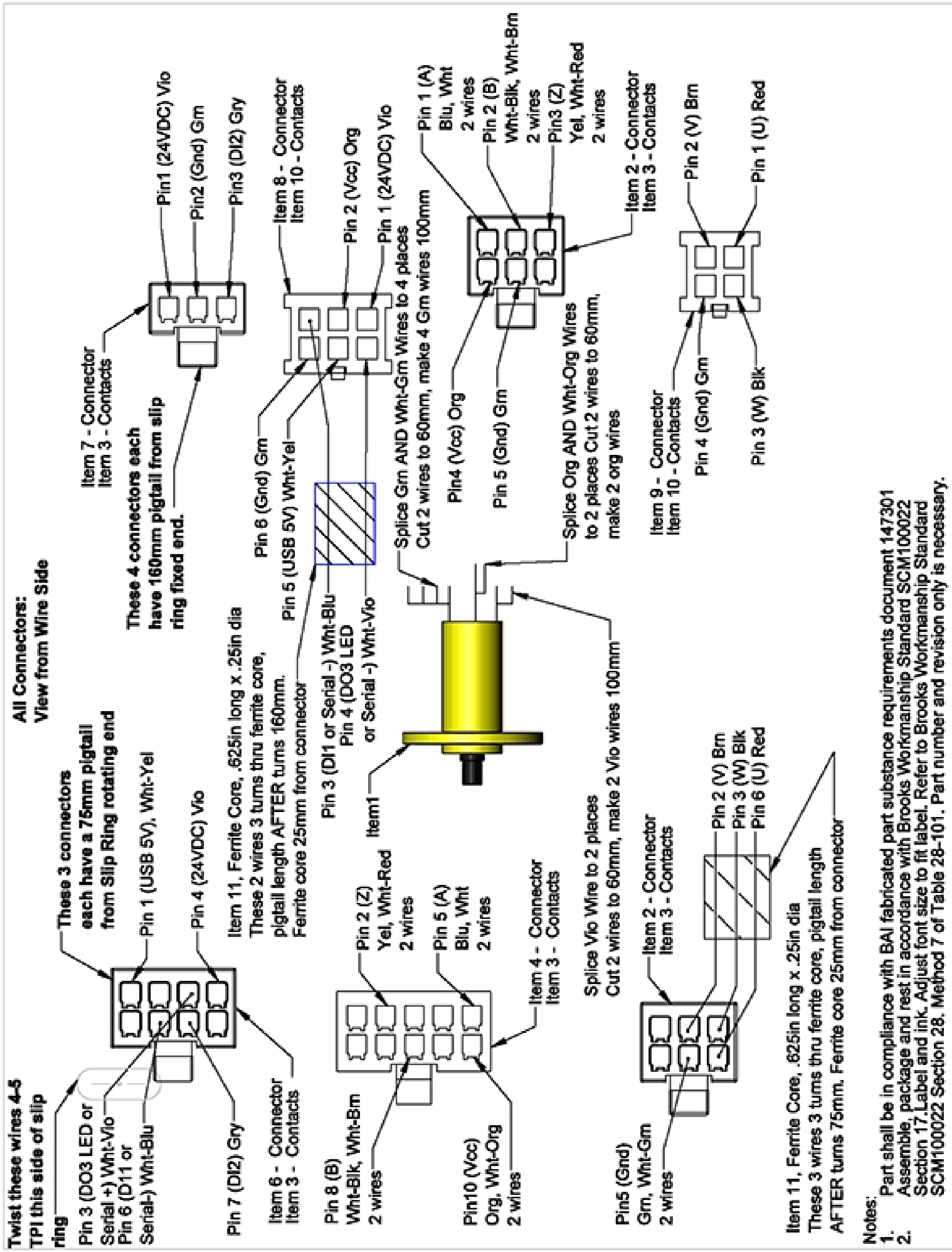
Gripper & Linear Axis Controller Connectors



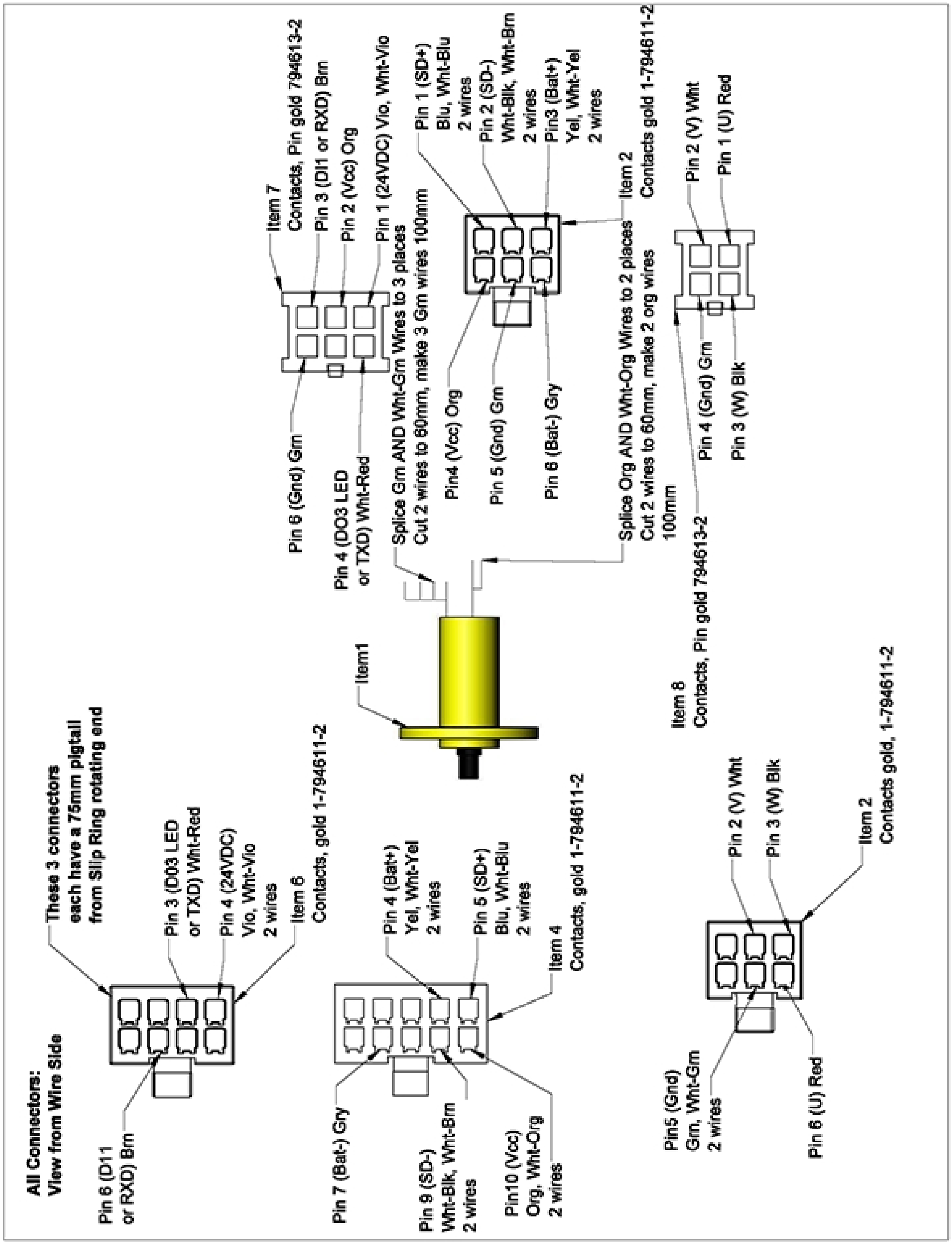
Assembly, Slip Ring Harness with Sensor



Assembly, Slip Ring Harness, 60 N Gripper



Assembly, Harness, Slip Ring, Dual and Single 23 N Gripper



Assembly, Slip Ring Harness, 60 N Gripper, PreciseFlex 400

Appendix K: Low Voltage Option

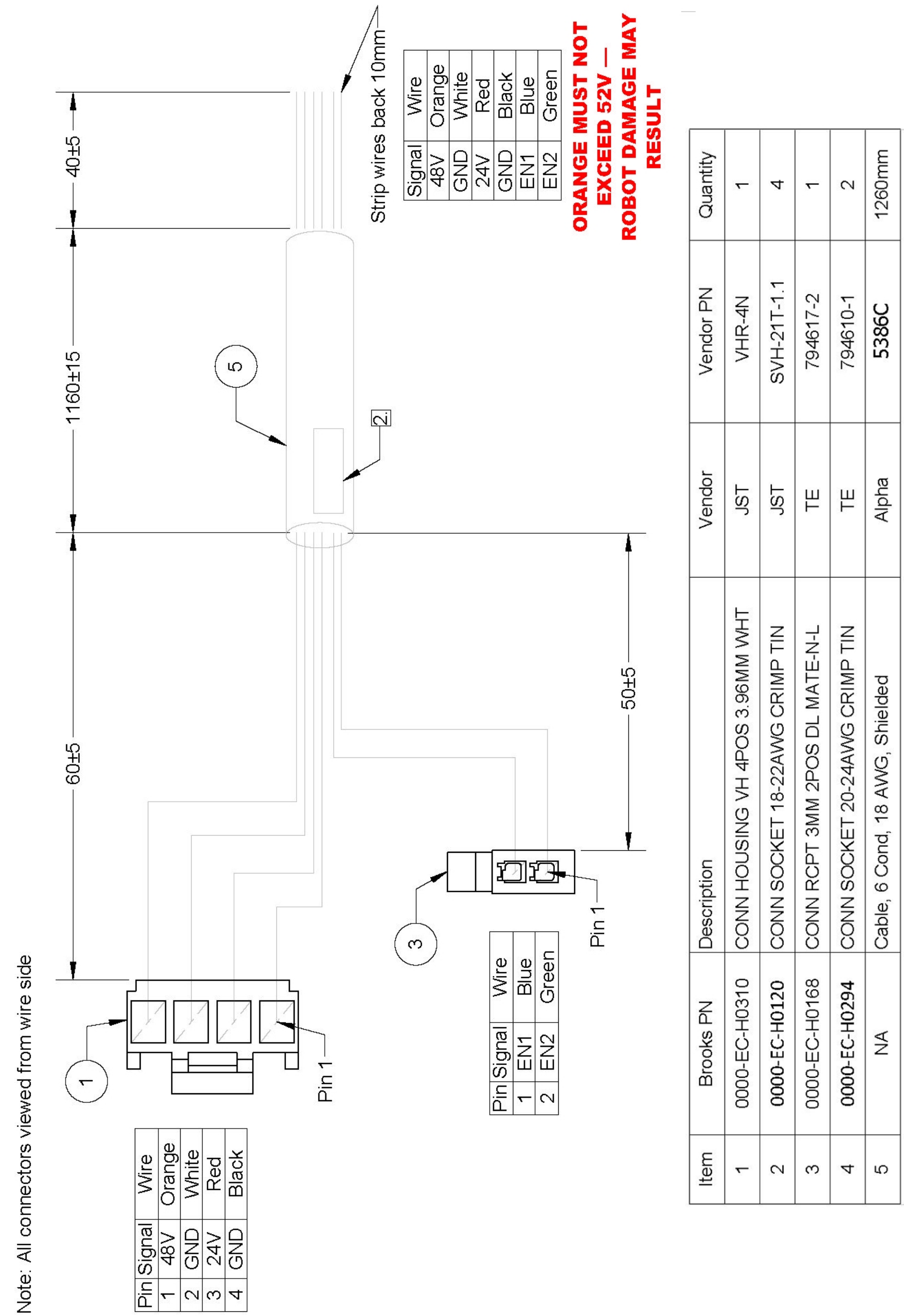
WARNING

Incorrect wiring may result in permanent damage to the robot. The 24 V supply line must never exceed 26 VDC. The 48 V supply line must never exceed 53 VDC.

The PreciseFlex 3400 can be ordered in a low-voltage DC power configuration option. This allows the robot to be run off of the DC power from a mobile robot battery rather than from the AC power from a wall outlet.

When in this configuration, the integrated power supplies are removed, and the standard power plug is removed. Instead, the robot comes with a exposed wire leading from the base of the robot that users can attach to a DC power source. Users will need to provide their own 48 VDC safety power cutoff relay utilizing the Enable (EN) signal. See the "Example Integration" section for information on how this can be wired up. The right side of this cable is what is exposed for user integration.

See the graphic below.



Item	Brooks PN	Description	Vendor	Vendor PN	Quantity
1	0000-EC-H0310	CONN HOUSING VH 4POS 3.96MM WHT	JST	VHR-4N	1
2	0000-EC-H0120	CONN SOCKET 18-22AWG CRIMP TIN	JST	SVH-21T-1.1	4
3	0000-EC-H0168	CONN RCPT 3MM 2POS DL MATE-N-L	TE	794617-2	1
4	0000-EC-H0294	CONN SOCKET 20-24AWG CRIMP TIN	TE	794610-1	2
5	NA	Cable, 6 Cond, 18 AWG, Shielded	Alpha	5386C	1260mm

Harness, Low- Voltage Power, Pigtail

High Power Enable Signal

The High Power Enable signal is used by the robot to enable and disable the 48 V power supply when required to meet ISO 10218 safety standards for E-stop and other safety functions. This feature is available on EN1 and EN2. This safety feature is enabled by default.

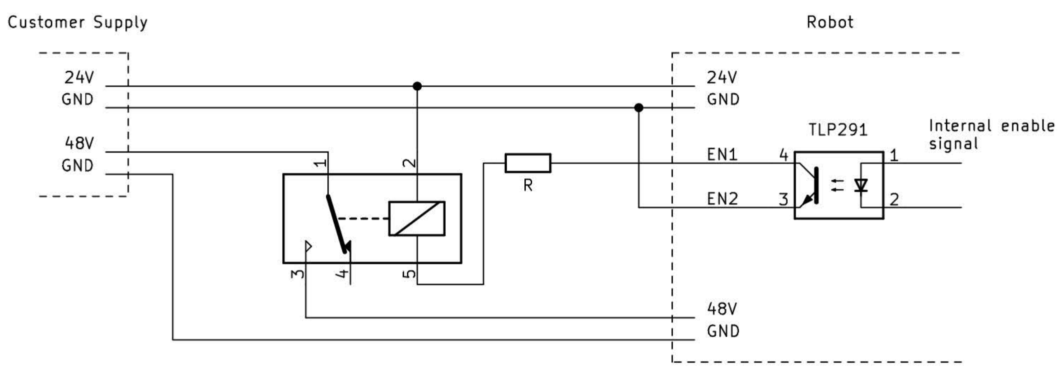
If the feature is enabled and the EN1/EN2 pins are not connected to anything, robot operation will be prevented. This safety feature can be disabled through software configuration if desired. If the feature is disabled, robot operation will not be affected by EN1/EN2

Integrating High Power Enable

EN1 and EN2 act as a current switch. When the robot enables high power, it switches current flow on between EN1 and EN2. When the robot disables high power, it switches current flow off between EN1 and EN2. The internal optocoupler is rated up to 24 V, 100 mA.

Example Integration

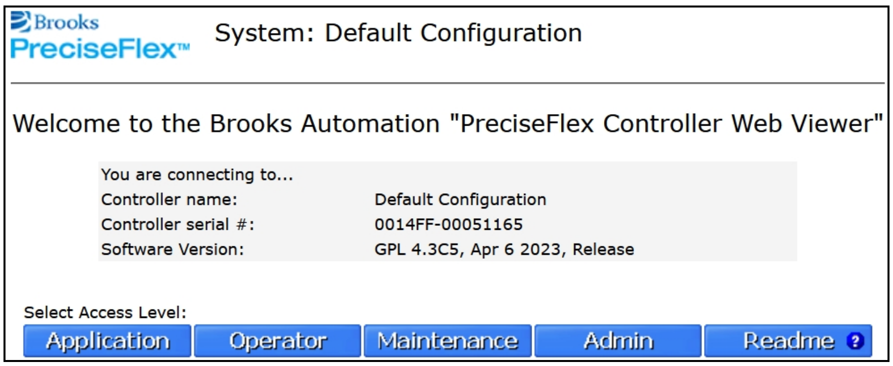
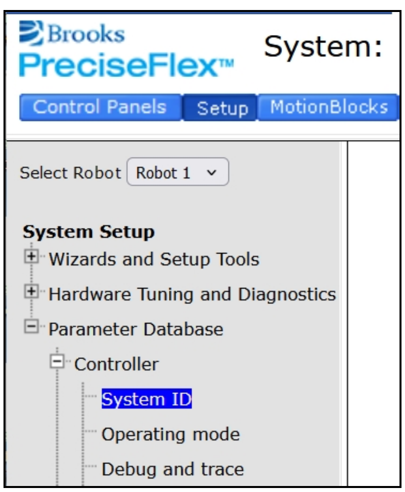
Use SPDT relay to connect 48 V supply to 48 V input. The robot max power draw is 400 W.

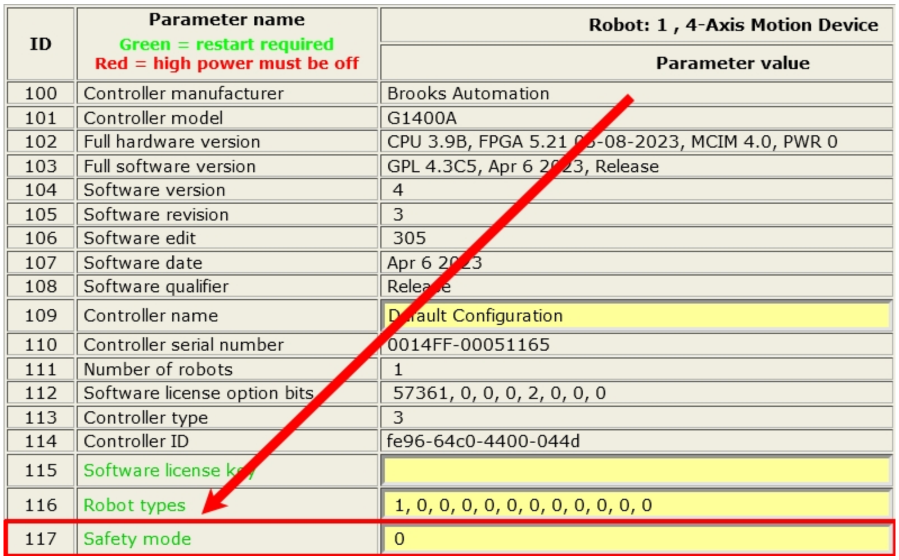
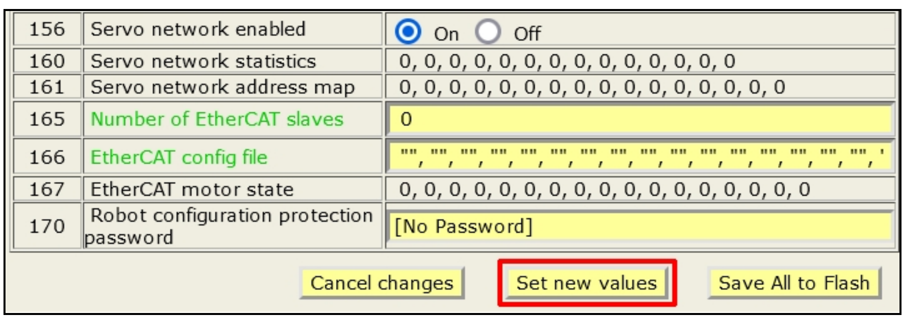


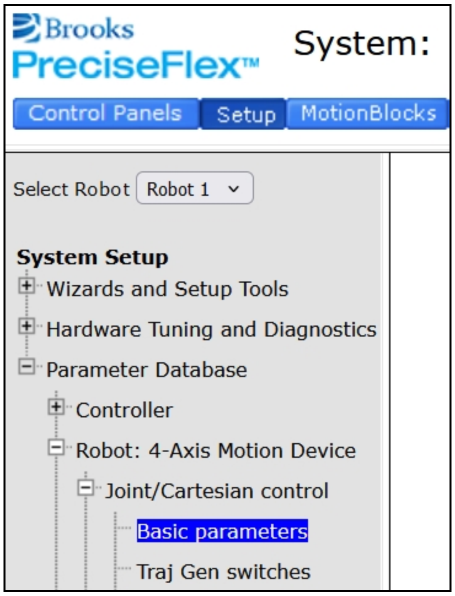
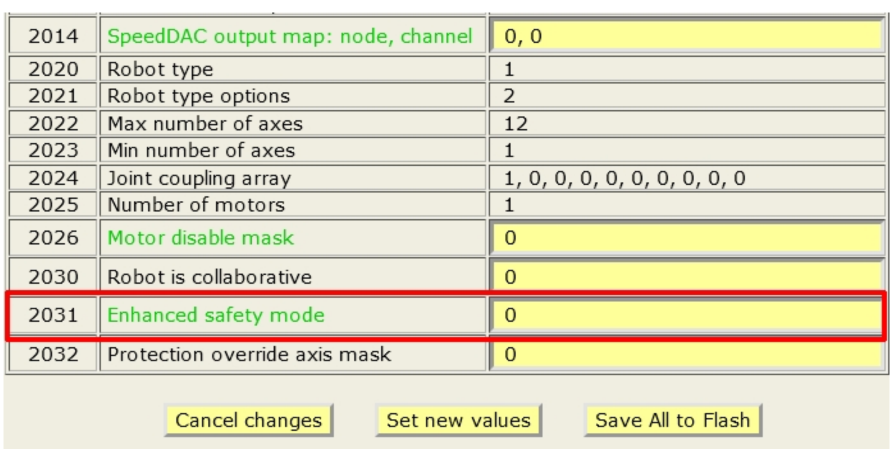
Step	Action
1.	Select relay with contact rated for >8.3 A and 24 V coil.
2.	Connect the positive end of the relay coil to 24 V.
3.	Connect negative end of relay coil to EN1.
4.	Select R based on relay. 1 kΩ typical. Do not draw more than 100 mA through EN1.
5.	Connect EN2 to ground.

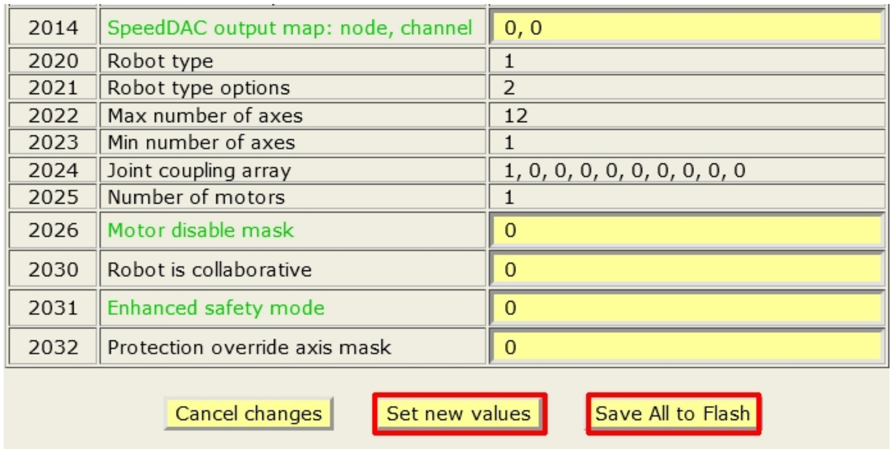
Disabling High Power Enable

The safety feature can be disabled in the robot's configuration by following the steps below.

<table>
<tr><th>Step</th><th>Action</th></tr>
<tr><td>1.</td><td>Connect a PC to the robot, open a browser, and enter the IP address 192.168.0.1 in the browser to display the controller interface.

</td></tr>
<tr><td>2.</td><td>Navigate to Admin > Setup > Parameter Database > Controller > System ID

</td></tr>
</table>

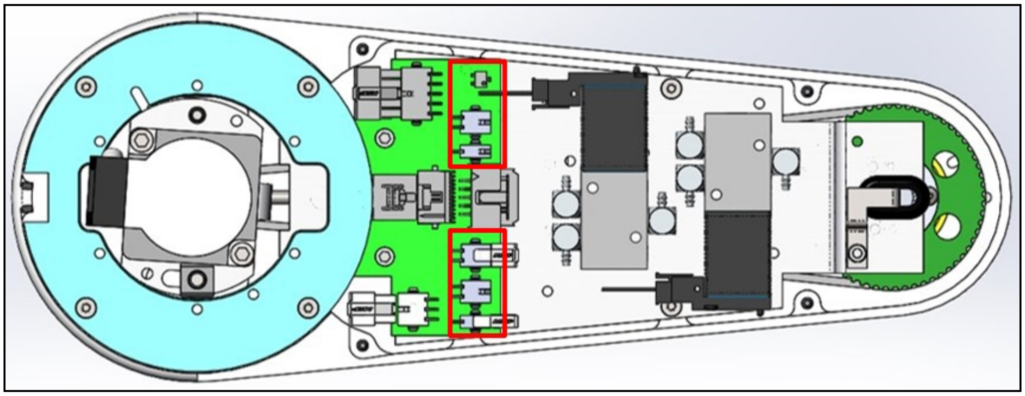
<table>
<tr><th>Step</th><th>Action</th></tr>
<tr><td>3.</td><td>
Set ID 117 (“Safety mode”) = 0.

<table>
<tr><th>ID</th><th>Parameter name
Green = restart required
Red = high power must be off</th><th>Robot: 1 , 4-Axis Motion Device
Parameter value</th></tr>
<tr><td>100</td><td>Controller manufacturer</td><td>Brooks Automation</td></tr>
<tr><td>101</td><td>Controller model</td><td>G1400A</td></tr>
<tr><td>102</td><td>Full hardware version</td><td>CPU 3.9B, FPGA 5.21 0?-08-2023, MCIM 4.0, PWR 0</td></tr>
<tr><td>103</td><td>Full software version</td><td>GPL 4.3C5, Apr 6 2023, Release</td></tr>
<tr><td>104</td><td>Software version</td><td>4</td></tr>
<tr><td>105</td><td>Software revision</td><td>3</td></tr>
<tr><td>106</td><td>Software edit</td><td>305</td></tr>
<tr><td>107</td><td>Software date</td><td>Apr 6 2023</td></tr>
<tr><td>108</td><td>Software qualifier</td><td>Release</td></tr>
<tr><td>109</td><td>Controller name</td><td>Default Configuration</td></tr>
<tr><td>110</td><td>Controller serial number</td><td>0014FF-00051165</td></tr>
<tr><td>111</td><td>Number of robots</td><td>1</td></tr>
<tr><td>112</td><td>Software license option bits</td><td>57361, 0, 0, 0, 2, 0, 0, 0</td></tr>
<tr><td>113</td><td>Controller type</td><td>3</td></tr>
<tr><td>114</td><td>Controller ID</td><td>fe96-64c0-4400-044d</td></tr>
<tr><td>115</td><td>Software license key</td><td></td></tr>
<tr><td>116</td><td>Robot types</td><td>1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0</td></tr>
<tr><td>117</td><td>Safety mode</td><td>0</td></tr>
</table>
</td></tr>
<tr><td>4.</td><td>
Click Set new values

<table>
<tr><td>156</td><td>Servo network enabled</td><td>On Off</td></tr>
<tr><td>160</td><td>Servo network statistics</td><td>0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0</td></tr>
<tr><td>161</td><td>Servo network address map</td><td>0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0</td></tr>
<tr><td>165</td><td>Number of EtherCAT slaves</td><td>0</td></tr>
<tr><td>166</td><td>EtherCAT config file</td><td>"", "", "", "", "", "", "", "", "", "", "", "", "", "", "", "", '</td></tr>
<tr><td>167</td><td>EtherCAT motor state</td><td>0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0</td></tr>
<tr><td>170</td><td>Robot configuration protection password</td><td>[No Password]</td></tr>
</table>
Cancel changes | Set new values | Save All to Flash
</td></tr>
</table>

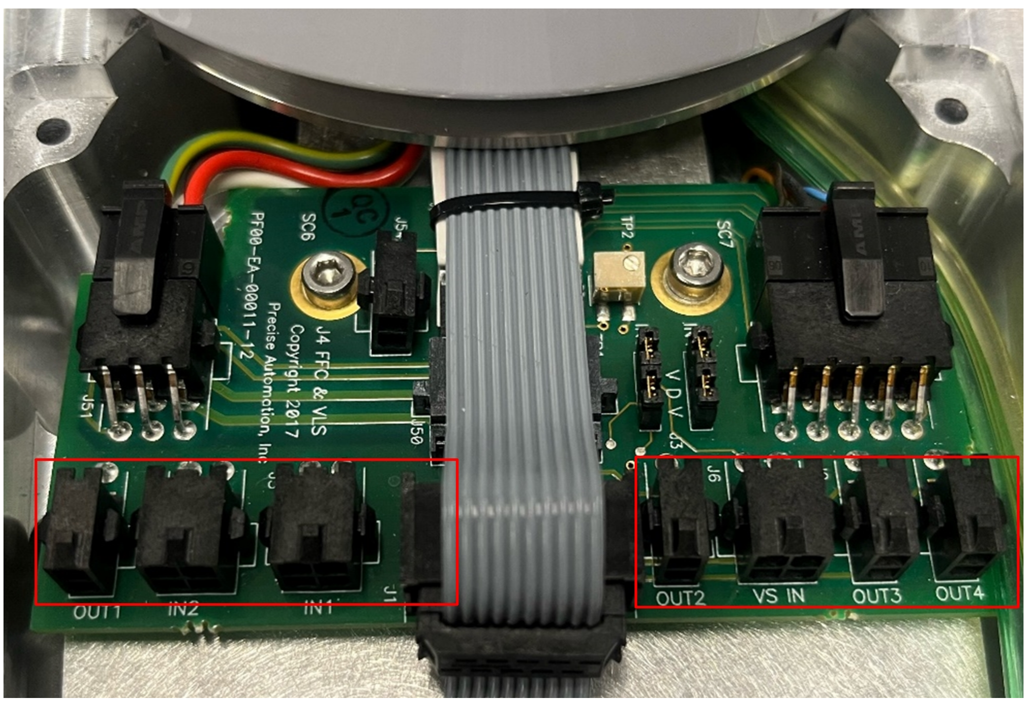
<table>
<tr><th>Step</th><th>Action</th></tr>
<tr><td>5.</td><td>Navigate to Admin > Setup > Parameter Database > Robot > Joint/Cartesian Control > Basic Parameters

</td></tr>
<tr><td>6.</td><td>Set ID 2031 (“Enhanced safety mode”) = 0

<table>
<tr><td>2014</td><td>SpeedDAC output map: node, channel</td><td>0, 0</td></tr>
<tr><td>2020</td><td>Robot type</td><td>1</td></tr>
<tr><td>2021</td><td>Robot type options</td><td>2</td></tr>
<tr><td>2022</td><td>Max number of axes</td><td>12</td></tr>
<tr><td>2023</td><td>Min number of axes</td><td>1</td></tr>
<tr><td>2024</td><td>Joint coupling array</td><td>1, 0, 0, 0, 0, 0, 0, 0, 0, 0</td></tr>
<tr><td>2025</td><td>Number of motors</td><td>1</td></tr>
<tr><td>2026</td><td>Motor disable mask</td><td>0</td></tr>
<tr><td>2030</td><td>Robot is collaborative</td><td>0</td></tr>
<tr><td>2031</td><td>Enhanced safety mode</td><td>0</td></tr>
<tr><td>2032</td><td>Protection override axis mask</td><td>0</td></tr>
</table>
Cancel changes | Set new values | Save All to Flash</td></tr>
</table>

<table>
<tr><th>Step</th><th>Action</th></tr>
<tr><td>7.</td><td>Click Set new values and then click Save All to Flash.

<table>
<tr><td>2014</td><td>SpeedDAC output map: node, channel</td><td>0, 0</td></tr>
<tr><td>2020</td><td>Robot type</td><td>1</td></tr>
<tr><td>2021</td><td>Robot type options</td><td>2</td></tr>
<tr><td>2022</td><td>Max number of axes</td><td>12</td></tr>
<tr><td>2023</td><td>Min number of axes</td><td>1</td></tr>
<tr><td>2024</td><td>Joint coupling array</td><td>1, 0, 0, 0, 0, 0, 0, 0, 0, 0</td></tr>
<tr><td>2025</td><td>Number of motors</td><td>1</td></tr>
<tr><td>2026</td><td>Motor disable mask</td><td>0</td></tr>
<tr><td>2030</td><td>Robot is collaborative</td><td>0</td></tr>
<tr><td>2031</td><td>Enhanced safety mode</td><td>0</td></tr>
<tr><td>2032</td><td>Protection override axis mask</td><td>0</td></tr>
</table>
Cancel changes | Set new values | Save All to Flash
</td></tr>
</table>

Appendix L: Optional IO FFC in Outer Link

In cases where the servo gripper is not needed, the FFC board can be used to control the gripper. The FFC comes with four digital outputs and four configurable inputs. These IOs are directly connected to the main robot controller.

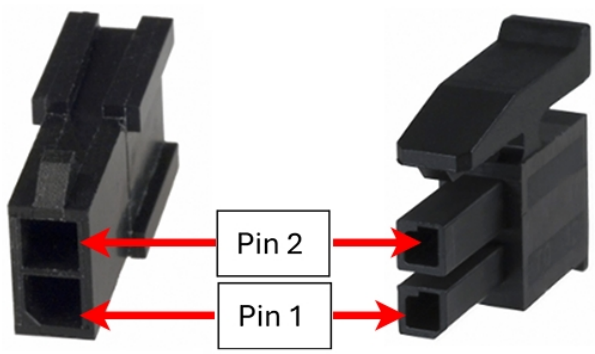




FFC Board Pinouts

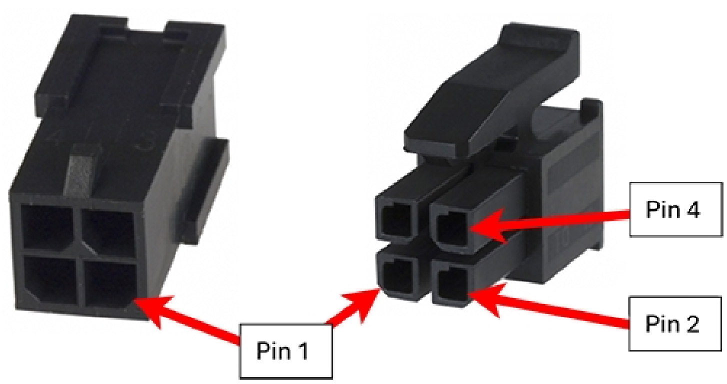
Digital Outputs

This is the pinout for the digital outputs (OUT 1-4) of the FFC Board.

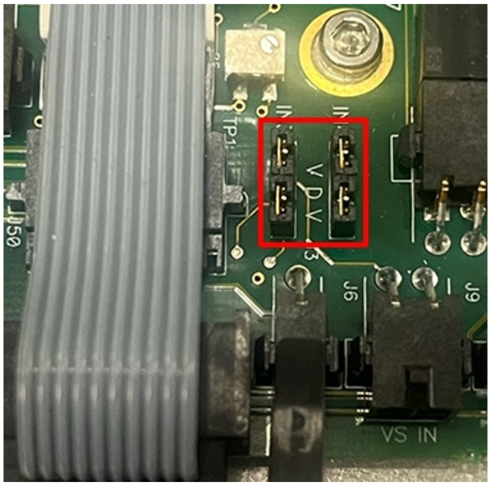


Outputs (OUT 1-4)

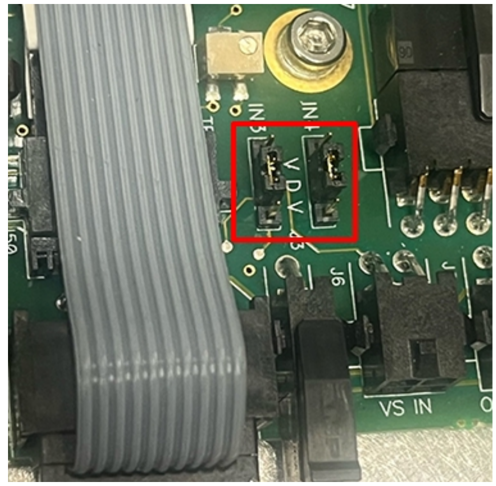
Pin	Signal
1.	Output
2.	GND



VS IN = Vacuum Sensor Input. Jumpers J7 and J8 determine VS IN's function.



Digital Inputs 3 and 4 are available (Jumpers both on pins 2-3)



Analog Input (Jumpers on pins 1-2 and 3-4)

Digital Inputs

These are the pinouts for the digital outputs (IN1-2) of the FFC Board:

Pin	Signal
1.	24 V
2.	GND
3.	Input
4.	Unused

Vacuum Sensor Inputs

The FFC Board supports two configurable inputs (IN3-4) in either digital or analog configuration for the VS IN or vacuum sensor input. Jumpers J7 and J8 determine VS IN's function. A jumper across Pins 2 & 3 puts it in digital mode, where as jumpers across 1 & 2 and 3 & 4 put it into analog mode. When in analog mode, the sensor takes an analog input between 0 VDC and 24 VDC.

VS Digital Pinout

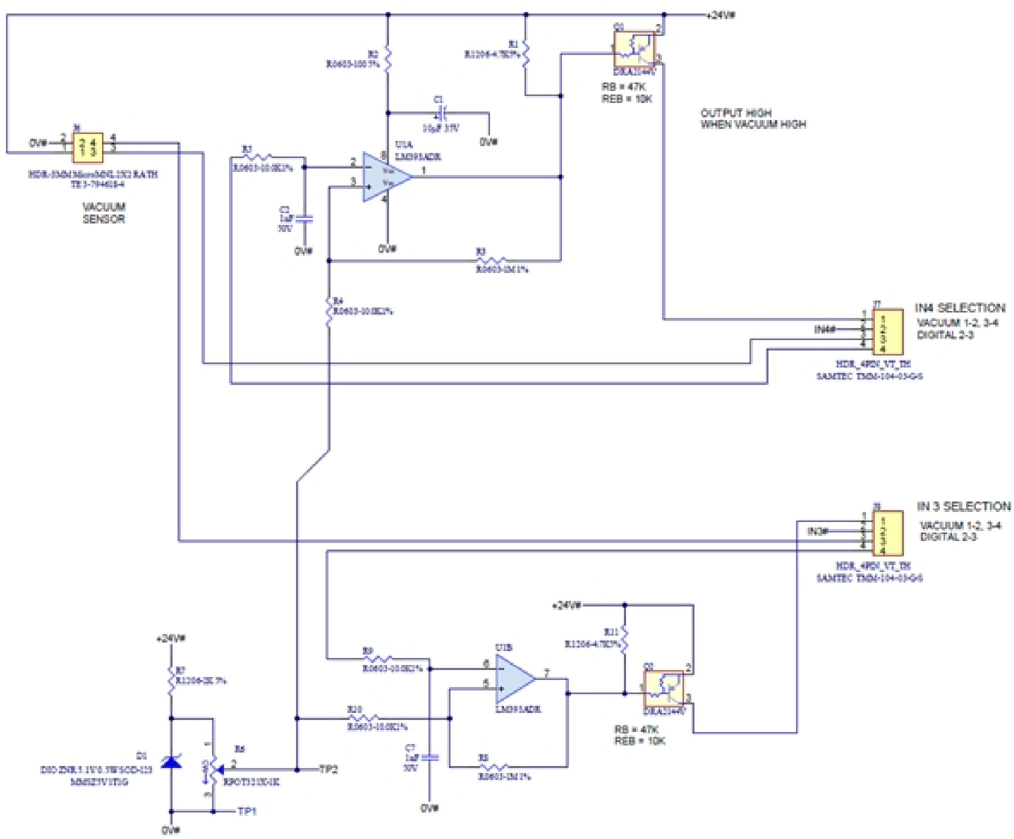
Pin	Signal
1.	24 V

Pin	Signal
2.	GND
3.	Input #4
4.	Input #3

VS Analg Pinout

Pin	Signal
1.	24 V
2.	GND
3.	Vacuum Sensor Output 1
4.	Vacuum Sensor Output 2

This is the internal electrical diagram for the FFC Board for the VS IN:



Appendix M: Torque Values for Screws

Use these torque values for all screws and fasteners unless otherwise stated.

Torque Values in Newton-Meters

	Zinc	SS	Zinc	SS	Zinc	SS
Screw Size M	SHCS	SHCS	BHCS	BHCS	FHCS	FHCS
1.6	0.18	0.15	0.00	0.00	0.00	0.00
2	0.37	0.31	0.00	0.00	0.00	0.00
2.5	0.77	0.64	0.00	0.00	0.00	0.00
3	1.34	1.12	0.56	0.51	0.83	0.75
4	3.16	2.63	1.31	1.17	1.53	1.38
5	6.48	5.40	2.66	2.39	3.11	2.79
6	10.96	9.14	4.50	4.05	5.40	4.86