



interaTM

Intera 5 - User Guide/Getting Started

Original Instructions

Please visit mfg.rethinkrobotics.com/intera for translated versions of the user guide.
Additionally, you'll find more details and links to more detailed tutorials.

The Rethink Robotics support page is here: [Rethink Support](#).



Welcome!

Thank you for purchasing Intera 5 software and Sawyer, our revolutionary new high performance collaborative robot. This user guide is designed to help you get started using Intera and Sawyer by providing you with an overview of the software and instructions on how to set up the Sawyer robot.

For the latest and most detailed information on Sawyer and Intera 5, we always recommend you see the Online User Guide at: mfg.rethinkrobotics.com/intera. The Rethink Robotics support page is here: [Rethink Support](#).

Safety Statement

Complying with ISO 10218-2 requires performing a risk assessment of each application to determine the needed safety performance and safeguarding. ANSI RIA R15.06-2012 is a U.S.-national adoption of ISO 10218-1 & 2.

Users should exercise caution while training the robot and practicing motions. The risk of injury is increased when using custom end-effectors, movements that lead with the end effector, and potentially hazardous work pieces.

Rethink Robotics recommends the use of safety glasses when interacting with robots, as is common with other equipment used in industrial environments.

The safety of any system incorporating Sawyer is the responsibility of the assembler of the system.

For additional information, reference [Rethink Robotics' Safety Documentation](#).

General Information



CAUTION: This symbol indicates that hazards may be present with the equipment. This documentation provides information on the nature of potential hazards and any actions which have to be taken to avoid them.



Intended use:

Sawyer is a collaborative robot intended for use in machine tending applications in manufacturing.

Warnings



Rethink Robotics' collaborative robots are provided as partly completed machinery. The robots are not supplied for specific applications. The integrator and/or end user is responsible for ensuring that all appropriate regulations including but not limited to safety, electrical, and environmental regulations are met for the appropriate regions or countries where the application will be deployed.



The information provided with this robot and online does not cover how to design, fabricate, install and commission a complete robotic application. If Rethink Robotics' collaborative robots are used to create a collaborative robotic workcell, the integrator and/or end user is responsible for complying with the industrial robot safety standards relevant for the region where the robotic workcell will be deployed will apply. Examples of such standards are EN ISO 10218:2011, ANSI/RIA R15.06:2012, CSA Z434:2014, and JIS B 8433:2015.



As part of complying with these standards, a risk assessment must be performed to identify and eliminate, substitute or acceptably mitigate risk associated with hazards present in the application. For more information see the relevant standards and associated documentation for your region.



Note that it is possible to integrate and use Rethink Robotics' collaborative robots in such a way that presents an injury hazard if contact is made with a person. The integrator and/or end user is responsible for evaluating the safety of the robotic application and determining and implementing any risk reduction measures to eliminate, substitute or acceptably mitigate the risks associated with the hazards. The integrator and/or end user assumes all responsibility for damage and/or harm caused by use of the robot in a hazardous manner and agrees to indemnify Rethink Robotics from all liability relating to such damage or harm.



Rethink Robotics' collaborative robots are NOT provided with a safety-rated enabling device. The robots are intended for use in applications where inherently safe design measures and/or active safety-rated limiting functions are sufficient to adequately reduce risks associated with work cell hazards. Should an integrator and/or end user determine through risk assessment that their specific application requires the use of an enabling device to reduce risk to an acceptable level, please refer to the User Guide or contact your distributor for information on how to connect a safety-rated enabling device.



Rethink Robotics' collaborative robots are NOT provided with a safety-rated mode selector switch nor a mode indicator light, as the robots are capable of being collaborative at all times, without a non-collaborative mode. Should the robot be incorporated into a robotic system where the application involves the robot being operated in two modes, please refer to the User Guide or contact your distributor for information on how to implement a safety-rated mode selector switch and indicator light.

Note: In some applications, the light integrated into the robot may meet the requirements of a mode indicator light.



Rethink Robotics' collaborative robots are not intended for use in explosive atmospheres or any environment where intrinsic safety of equipment is required.



Rethink Robotics' collaborative robots ship with an E-Stop device that may be used in the event of emergency to remove power from the actuators and immobilize the arm. The E-Stop device is connected to the controller box by a cable which allows for flexibility in its positioning. Ensure that the E-Stop device is positioned such that it is easy for an operator to access it during operation.



As is common practice with other industrial equipment, Rethink Robotics recommends personnel interacting with Rethink Robotics' collaborative robots wear appropriate personal protective equipment such as safety glasses.



Rethink Robotics' collaborative robots are not serviceable or repairable by end-users. In the event servicing or repairs are required for the robot, please contact your distributor or Rethink Robotics for technical assistance.



When the robot is moving a heavy part (>2.5 kg) and a user removes the part from the gripper or the part unintentionally falls (and no logic has been trained to handle these issues), the arm will still try to compensate for a mass that is no longer there and the arm may move unexpectedly. This includes having the arm point straight up. In order to mitigate these behaviors, please train your task accordingly so that it may handle these error cases. In addition, always perform a Risk Assessment so you may understand the risk levels and ways to mitigate these.



Use caution when servicing robot workcell, including following OSHA's Lockout/Tagout Procedures 1910.147 if Safety Assessment of application recommends it.



If a supplementary audible means of robot operation is necessary, it shall exceed the ambient noise at the end-use application.



If controller is placed inside the robot workspace, caution needs to be taken when training tasks to avoid coming in contact with it.



In Europe, Rethink Robotics' collaborative robots are provided with a Declaration of Incorporation (DoI) per Annex IIB of the EC Machinery Directive. The Machinery Directive requires that the integrator and/or end user must ensure that all incomplete machinery must be incorporated into a complete machine and certified to the Machinery Directive requirements resulting in an EC Declaration of Conformity certificate being generated, and the machine being CE marked. Only then can the machinery be operated. The system integrator and/or end user is responsible for the following tasks:

- o Installing the industrial robot



- o Connecting the industrial robot
- o Performing risk assessment
- o Implementing the required safety functions and safeguards
- o Issuing the Declaration of Conformity
- o Attaching the CE mark
- o Creating the operating instructions for the complete system

Manufacturer address:

For technical assistance, please contact:

Rethink Robotics, Inc.
27-43 Wormwood St
Boston, MA 02210

Website: <http://www.rethinkrobotics.com>

Customer support: [Rethink Support.](#)

Disclaimer

Every effort is made to ensure that the information in this manual is accurate. This publication could include technical or typographical errors or other inaccuracies. Rethink Robotics, Inc[®] may make changes to the product described in this publication or to this publication at any time, without notice.

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Table of Contents

Welcome! 3

Warnings 4

Table of Contents 1

Getting to Know Sawyer 7

Hardware Overview of Your Robot 8

Dimensions 9

Sawyer Reach 10

Sawyer Nomenclature 11

Workspace and Robot Joint Limits 11

Head 12

Controller 13

Navigator 15

Training Cuff 17

Brakes 17

Active Collision Avoidance 18

Included accessories: 19

Tool Plate 19

Optional accessories: 20

Safety Symbols 21

Getting Started with Sawyer 22

Setting Up Sawyer 22

Power 22

Disconnecting power 22

Turning On Sawyer 23

Moving the Arm 24



Getting Started with Intera 5 26

- Some Intera Terms 30
- Components of the Intera Studio Screen 32
 - Top Bar* 32
 - Studio Menu* 33
 - Node Palette* 37
- Behavior Editor 38
 - Node Colors - Meaning* 38
- 3D View 49
 - How to Change the View of the Simulated Robot Arm* 51
 - How to Move the Simulated Robot Arm* 52

End of Arm Tooling 54

- Attaching End of Arm Tooling* 54
- How to Configure End Effectors 54
 - ADDING A CLICKSMART GRIPPER* 56
 - Using the Gripper in a Task* 61
 - How to Calibrate the Rethink Electric Parallel Gripper* 65
 - To Add End of Arm Tooling with Dual Tools* 67
 - How to Actuate the Tips of Third Party End Effectors* 70
 - Assigning a Signal* 71

Train a Simple Pick and Place on the Head Screen 72

Train Pick and Place Patterns on the Head Screen 80

- Train the Pick Pattern* 81
- Train the Place Pattern* 95

Intera Insights 98

- Intera Insights Overview 98
 - Intera Insights Panel* 99
 - Tracking Cycle Time* 103
 - Tracking Cycle Time in the Intera Insights* 103
 - Viewing Data on Robot when Task is Paused* 104
 - Setting Head Angle* 105



Force Sensing and Selective Arm Stiffness 106

A Practical Application for Using Force Sensing, Selective Stiffness, and Force Limitations 106
How to Access and Modify Force Data in Intera Studio 108
Compliance, Impedance Mode, Force Mode 108

I/O Devices 111

Controller I/O 111
I/O Wiring Diagram 114
External I/O 116
Safety Rated Controller 119

TCP/IP 124

Definitions 124
Intera TCP/IP Communications 125
To Create a Device for TCP/IP 126

Fieldbus Devices 129

Setup Notes 129
Enabling the Fieldbus Protocol 130

Sawyer and Safety 135

Safety Statement 135
How these unique collaborative robots safely manage operational risks 136
Rethink's Collaborative Robot Safety Features 136
Rethink's Collaborative Robot Regulatory Certifications 138
IEC 6100-4-2 139
North America 139
Canada 139
Mexico 140
EU 140
China 140
Japan 141

Maintaining and Supporting Sawyer 142

Powering Down Sawyer Properly 142
Maintaining Sawyer 142



Cleaning Sawyer 142
Calibrating Sawyer 143

Appendix A: Glossary 144

Glossary 144

Appendix B: Support & Warranty 146

Appendix C: Certifications and Information for Integrators 147

Third Party Certifications 147
Declaration of Incorporation 150
 EC Declaration of Incorporation (Original) 150
Information for Integrators 151
 Risk assessment 151
 Use considerations 152
 End-effectors 153
 Installation 153
 PPE 153
 General safety 153
 SOPs & training 153
 Awareness 154
Useful References 154

Appendix D: Ratings and Performance Specs 156

Supply Ratings 156
I/O Ratings 156
Environmental Ratings: 157
Tool Tip Speed 158
E-Stop Performance 160
Payload vs. Reach 161
Performance with Advanced End-effectors 164

Appendix E: Warnings & Notices 169

Warnings & Notices 169



Appendix F: Safety Subsystem 171

The Safety Subsystem 171

The Banner Safety Controller 172

Appendix G1: Intera PROFINET Reference 178

Overview 178

Default Connection - Standard Modules 178

Setup Resources 179

Summary of Modules 180

From-Robot Modules Summary 180

To-Robot Modules Summary 181

Modules Data Tables 182

Fixed Data 112 From Robot 183

Standard Booleans (113: To-Robot / 114: From-Robot) 184

Standard Integers (115: To-Robot / 116: From-Robot) 184

Standard Floats (117: To-Robot / 118: From-Robot) 185

Small Booleans (119: To-Robot / 120: From-Robot) 185

Small Integers (121: To-Robot / 122: From-Robot) 186

Small Floats (123: To-Robot / 124: From-Robot) 186

Small Strings (125: To-Robot / 126: From-Robot) 187

Large Bools (127: To-Robot / 128: From-Robot) 187

Large Integers (129: To-Robot / 130: From-Robot) 187

Large Floats (131: To-Robot / 132: From-Robot) 188

Large Strings (133: To-Robot / 134: From-Robot) 188

State Flags Definitions 189

Bit Definitions for State Flags 189

Robot State Flags Meaning 190

Data Addressing and Format 191

Appendix G2: Intera EtherNet/IP Reference 193

Overview 193

Default Connection - Standard Assemblies 193

Setup Resources 193

Summary of Assemblies 195

From-Robot Assemblies Summary 195

To-Robot Assemblies Summary 196

Assembly Data Tables 197

From-Robot Standard Assembly (112) 197

To-Robot Standard Assembly (113) 198



<i>Small Assembly (114: From-Robot / 115: To-Robot)</i>	199
<i>Large Assembly (116: From-Robot / 117: To-Robot)</i>	200
<i>FLOATS+ (118: From-Robot / 119: To-Robot)</i>	201
<i>STRINGS+ (120: From-Robot / 121: To-Robot)</i>	202
State Flags Definitions	203
<i>Bit Definitions for State Flags</i>	203
<i>Robot State Flags Meaning</i>	204
Data Addressing and Format	205

Index **206**

For the latest and most detailed information on Sawyer and Intera 5, we always recommend you see the Online User Guide at: mfg.rethinkrobotics.com/intera. The Rethink Robotics support page is here: [Rethink Support](#).



Getting to Know Sawyer

For the latest and most detailed information on Sawyer and Intera 5, we always recommend you see the Online User Guide at: mfg.rethinkrobotics.com/intera. The Rethink Robotics support page is here: [Rethink Support](#).

Transportation and Handling:

Use a Pallet Jack when transporting pallet.

Robot Arm:

Dimensions: 35x20x20 inches (89x51x51 cm)

Weight: Gross: 58 lbs (26 kg), Net: 48 lbs (22 kg)

Controller:

Dimensions: 27x13x20 inches (69x33x51 cm)

Weight: Gross: 55 lbs (25 kg), Net: 45 lbs (20 kg)

Accessory Box (Without Grippers):

Dimensions: 23x26x20 inches (58x66x51 cm)

Weight: Gross: 13lbs (6 kg), Net: 10 lbs (4.5 kg)

Pedestal:

Dimensions: 48x39x19 inches (122x99x48 cm)

Weight: Gross: 240lbs (109 kg), Net 220 lbs (100 kg)

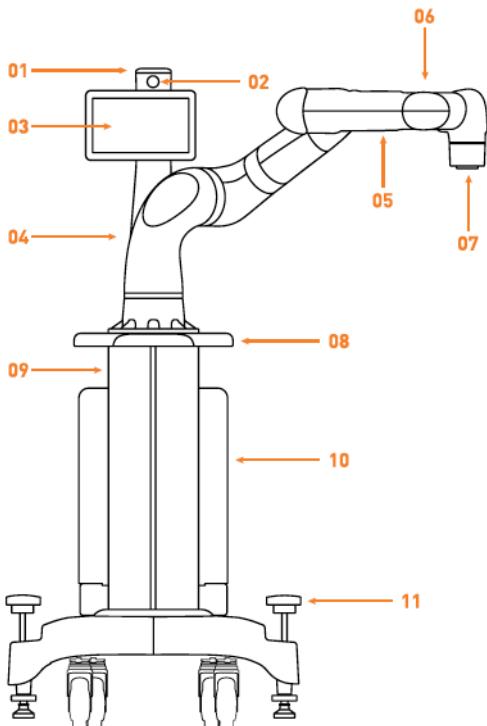
Full Kit (Robot, Controller, and Accessory Box on Pedestal Crate. No Grippers):

Dimensions: 48x39x39 inches (122x99x99 cm)

Weight: Gross: 365 lbs (166 kg), 323 lbs (146.5 kg)



Hardware Overview of Your Robot

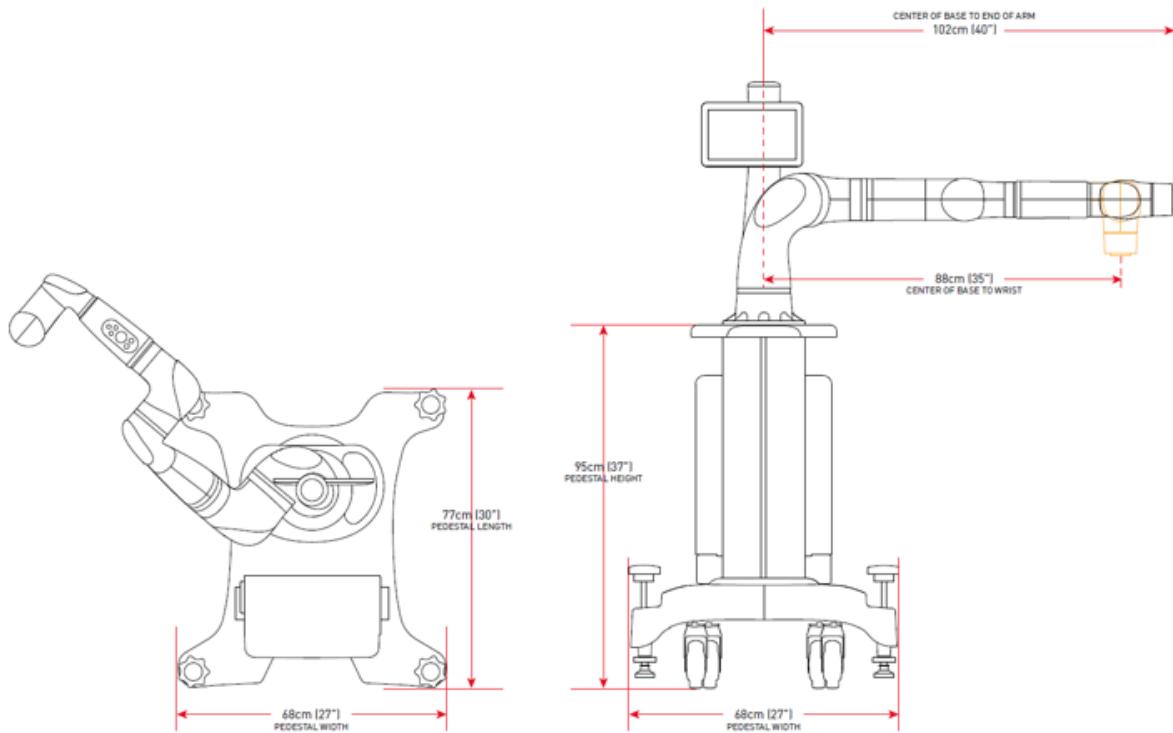


Meet Sawyer

- 01 Condition Light
- 02 Head Camera
- 03 Display
- 04 Navigator (Base)
- 05 Navigator (Arm)
- 06 Camera
- 07 Training Cuff with Light
- 08 Pedestal Handle
- 09 Pedestal
- 10 Controller
- 11 Leveling Feet

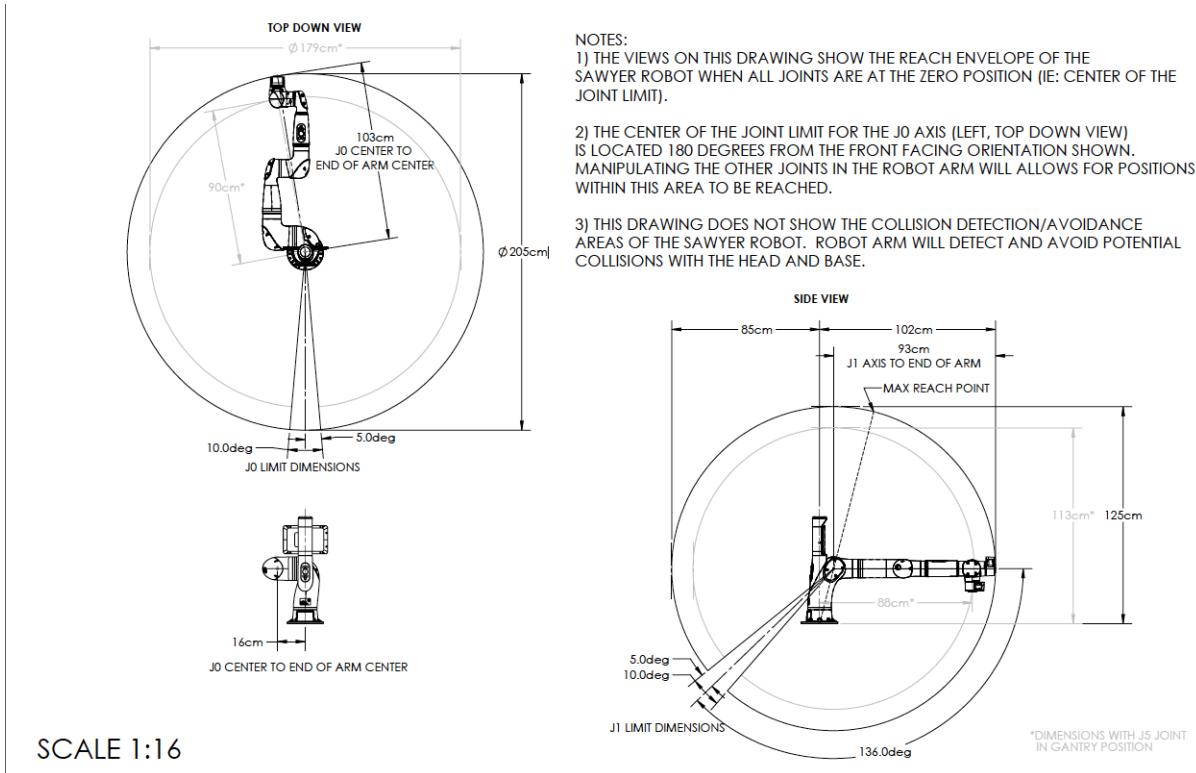


Dimensions



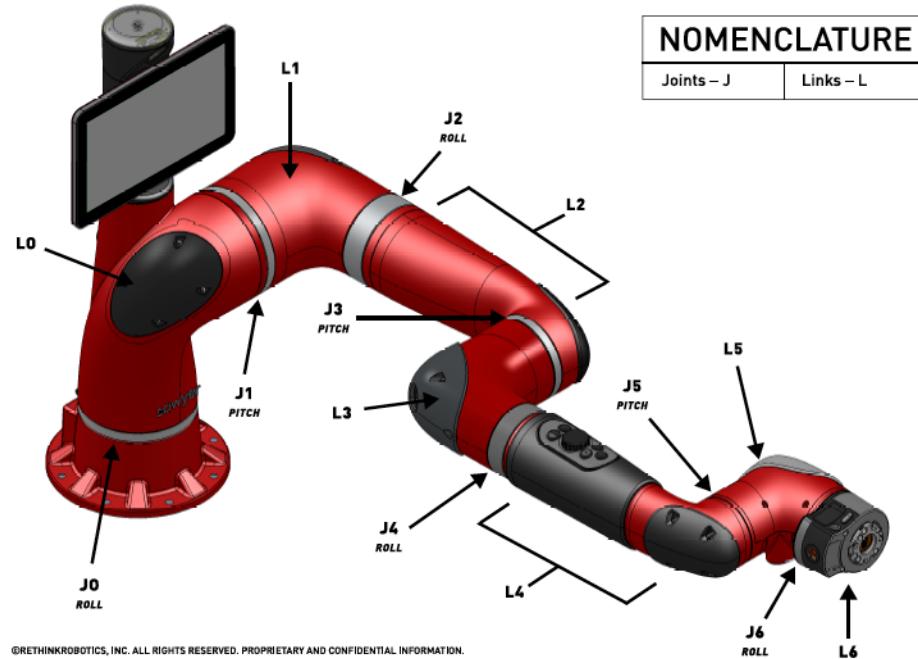


Sawyer Reach





Sawyer Nomenclature



	Base	Head	L0	L1	L2	L3	L4	L5	L6	Total
Assembly Mass (kg)	2.07	1.58	5.32	4.50	1.74	2.51	1.11	1.56	0.33	20.73

Workspace and Robot Joint Limits

The ability of Sawyer to perform actions at any given location is affected by the physical limits of the arm. When training an action, consider:

- The robot's joints J0 through J3 can rotate a maximum of 350 degrees. Joints J4 and J5 can rotate 341 degrees and J6, the wrist/training cuff, can rotate 540



degrees. The closer you are to the edge of these limits, the greater the chance the robot will be unable to train an action.

- If you notice Sawyer cannot reach a location, try moving the location closer to the robot, or re-train the location.
- The training cuff can rotate 540 degrees. If, when training, the orientation of the training cuff is twisted near its limit, the robot may have trouble when you run the task.

The possible vertical range of an action is reduced as you move closer to the edges of the maximum available workspace of the robot.

The robot's software, including collision avoidance, can also limit the movement and capabilities of the arm. For example, you cannot incorrectly train the robot so the arm crashes into itself.

In Intera Studio, you can click on the Joints Tab to see the extent of rotation of each of Sawyer's joints. A slider near either end of the slider range indicates proximity to a joint limit. You can also see the joint position indicators on the right side of the robot's display screen.

Head

Sawyer's "head" is the LCD display that sits on top of the robot. It houses the Graphical User Interface (GUI). The head also contains a camera and a light that communicates the robot's condition.

The head is back drivable. It has a motor in it, which means you can physically move the head whether or not the robot has power. The head can be moved along the same joint/axis that it moves itself. It rotates a total of approximately 350 degrees.

There are two modes for head movement: passive and active. Passive means you can move the head manually. In active mode, the head automatically follows the movement of the training cuff.

IMPORTANT: It is relatively easy to move the head. Even a single tap of the finger can move it, so do not use force when moving the head. When you feel resistance, stop.



Controller

The Controller is the housing for the computer (which runs the Intera software that controls Sawyer), the I/O, the vacuum connections, and the power to the wall outlet. The controller can be placed on the Rethink Robotics Sawyer pedestal or nearby, for example, on a shelf.

When installing Sawyer, make sure that the air inlet and exhaust fan ports on the controller are not blocked or obstructed. These ports must be clear to allow the controller to be properly ventilated.

Right side:

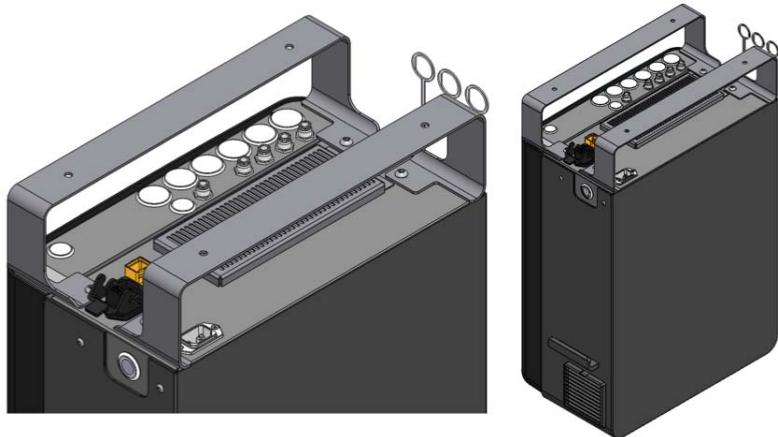
- 1 Ethernet port
(cannot be used on industrial fieldbus network)
- 2 USB ports



Left side:

- Power button
- Output Air filter





Bottom View

Inputs

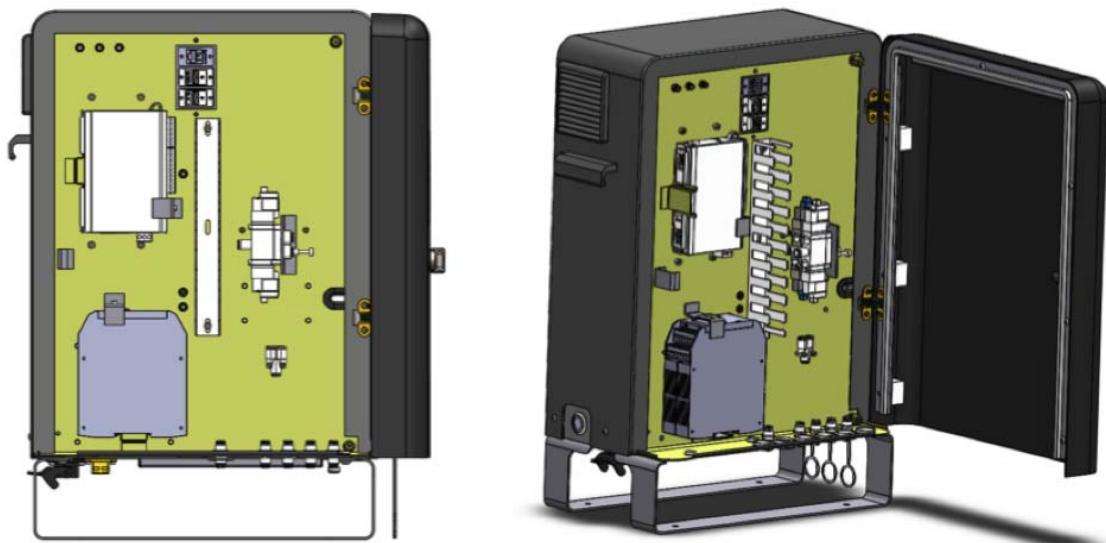
- Power
- Air Input

Outputs

- (4x) Air
- Power and Data
- Video



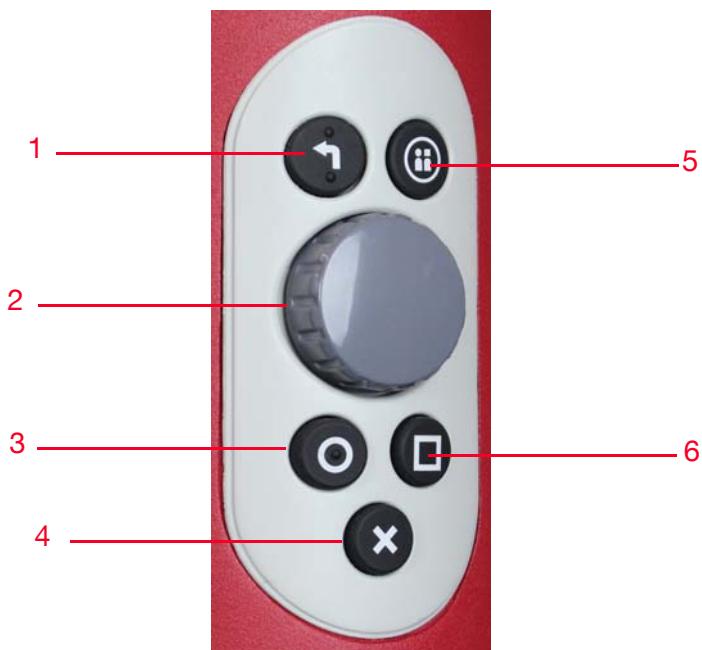
Inside View



- Terminal Unit (8 Digital Inputs, 8 Digital Outputs)
- Safety Rated Controller
- (2x) Solenoid Valve
- (1) Ethernet Port used for Fieldbus Networks
- (2) USB Ports
- Wifi antennas (reserved for future use)

Navigator

The Navigator refers to the two physical user interfaces on the robot, one on the forearm and one on the back of the torso. Each Navigator is made up of indicator lights, a set of five buttons, and a selector knob. Use the Navigator to scroll to and interact with options on the screen. When you press the OK button on the selector knob (or the action button on the cuff), the light indicators on the Navigator light up.

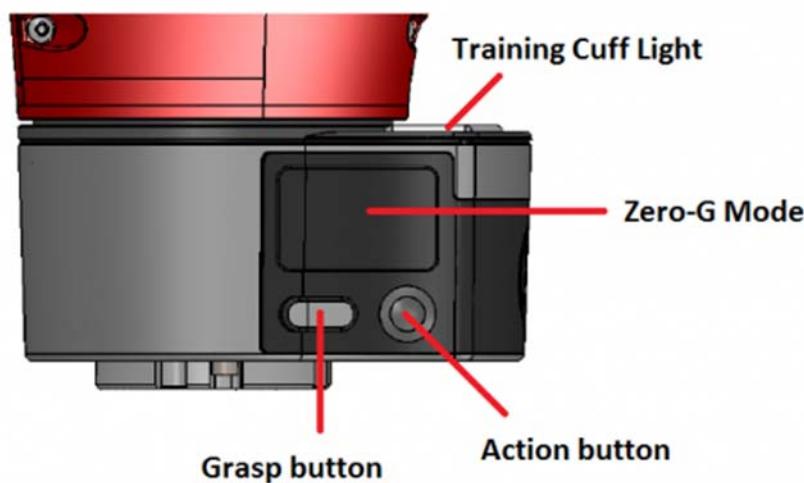


1. Back button
2. Selector knob
3. Zero G button
4. X button
5. Rethink button
6. Square button

-
- 1. Back button:** Press to exit the current screen and return to the previous screen. Will also cancel the last action.
 - 2. Selector Knob:** Scroll the knob to move between onscreen options. Press the knob (OK) to choose an option. Click OK on a node to drill down to the next node or to display a menu with additional options.
 - 3. Zero-G mode button:** Press and hold this button to place the arm in “zero-G” mode (similar to grabbing the training cuff), which makes the arm easier to move.
 - 4. X button:** Press and hold to display the quick end effector change menu.
 - 5. Rethink button:** Press to display the Head Screen Menu.
 - 6. Square button:** Press and hold to toggle the Head Screen to follow the robot arm. Also used to select features when prompted on the display screen.
-



Training Cuff



The Training Cuff refers to the robot's wrist joint and physical interfaces that include the Zero G Mode button, Grasp button, and action button. The training cuff can be used to move the arm, change the state of the installed gripper, and to select on screen options.

- Zero G button - Press and hold this button to enable Zero Gravity mode.
- Grasp Button - Press this button to display the train by demonstration menu. Also, a “long hold” (pressing the Grasp button for two seconds) toggles the gripper open and closed.
- Action Button - Press this button to display the Insert Action menu with options to create a move, sequence, or loop node. You can also use this button to make an onscreen selection.

Brakes

The robot is equipped with brakes located in the J1, J2, and J3 joints that stop the arm from falling onto fixtures in the workspace. The brakes are activated when:

- the arm motors are turned off
- E-stop is engaged
- the robot loses power or is turned off



J3 brake release



Each robot axis is capable of being moved without using drive power. In some cases, a brake release may need to be engaged in order to enable axis movement. If any of the brakes are released manually, gravitational pull may cause the arm to fall.

Active Collision Avoidance

Rethink robots are designed to “know” where their arm joints are at any given time and where the head and torso are so as to avoid collisions with any parts of itself.



Included accessories:

- ClickSmart Robot Side Adapter
- Power cord
- E-stop button and 10-foot cable
- Landmarks #1-4 for use with Robot Positioning System.

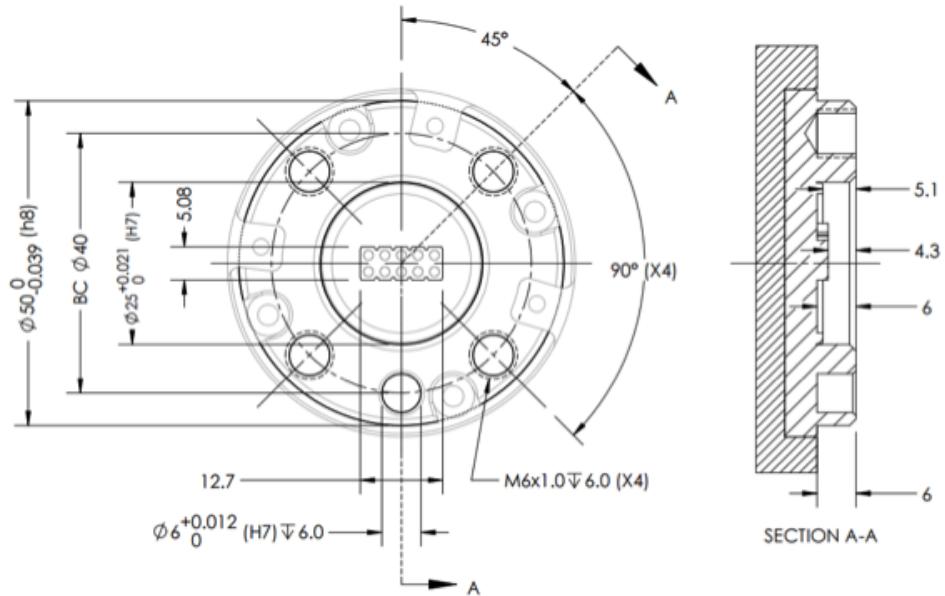
Tool Plate

The tool plate on the Sawyer robot arm is designed per the ISO 9409-1-40-4-M6 specification.

The robot tool plate has four M6 thread holes for attaching end-of-arm tooling to the robot. The holes need to be tightened with 9 N m. If very accurate repositioning of the end-of-arm tool is required, the Ø6 mm hole is provided for use with a pin.

CAUTION:

- Make sure the end-of-arm tooling is properly and securely bolted in place.
- Make sure that the end-of-arm tool is built and configured such that it cannot create a hazardous situation by dropping a part unexpectedly.
- If Sawyer is equipped with vacuum grippers in the end installation, ensure that a clean air supply is provided for connection to Sawyer's pneumatic system and that the maximum air pressure does not exceed 90 PSI.



Optional accessories:

- [Rethink Robotics Family of ClickSmart Gripper Kits](#)
- Sawyer pedestal
- Landmarks #5-20 - for Robot Positioning System
- Robot Mounting Plate - for positioning Sawyer precisely without the pedestal



Safety Symbols



CAUTION: Mechanical and electrical hazards may be present with the equipment and personnel must exercise caution and use standard safety practices during its use. This documentation provides information on the nature of potential hazards and any actions which have to be taken to avoid them. Review this documentation in its entirety prior to operating the equipment. Refer to the sections, "Sawyer and Safety," "Information for Integrators" and "Warnings & Notices" for specific safety information.



HAZARDOUS VOLTAGES: Hazardous live voltages are present inside the controller box. The controller box has no end-user serviceable parts. Please contact your distributor or Rethink Robotics in the event servicing or repairs are required.



Getting Started with Sawyer

Setting Up Sawyer

For the latest and most detailed information on Sawyer and Intera 5, we always recommend you see the Online User Guide at: mfg.rethinkrobotics.com/intera. The Rethink Robotics support page is here: [Rethink Support](#).



Ensure that you have reviewed safety guidance provided in this document prior to installing and operating the robot.

To set up Sawyer:

- Locate the installation card that ships with the robot. Follow the instructions to assemble the pedestal (if ordered), and attach Sawyer to the pedestal or alternate work surface.
- Follow the instructions included with the gripper kit to install a gripper.

Power

Sawyer ships with a detachable power cable with an integrated ground terminal. Sawyer's power cable must be connected to an earthed mains outlet that is installed near the equipment and that is easily accessible during operation of the robot. Use only Rethink supplied power cables. Sawyer may be connected to 100VAC - 240VAC single phase mains supplies.

Disconnecting power

Under normal conditions, Sawyer may be powered down by selecting the Power option using the navigator controls.

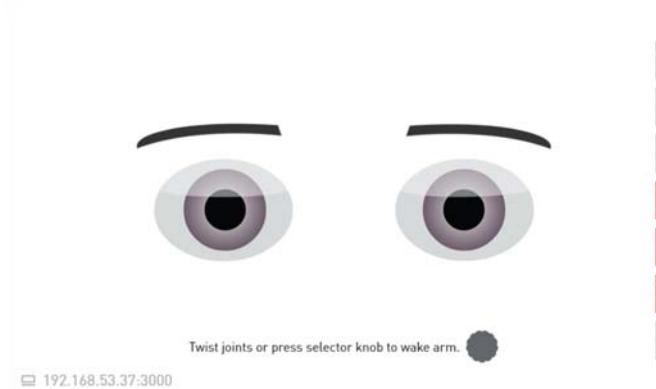


Sawyer ships with an E-Stop device that may be used in the event of emergency to remove power from Sawyer's actuators. The E-Stop device is connected to Sawyer's controller box by a cable which allows for flexibility in its positioning. Ensure that the E-Stop device is not positioned in a manner that will make it difficult for an operator to access it during Sawyer's operation.

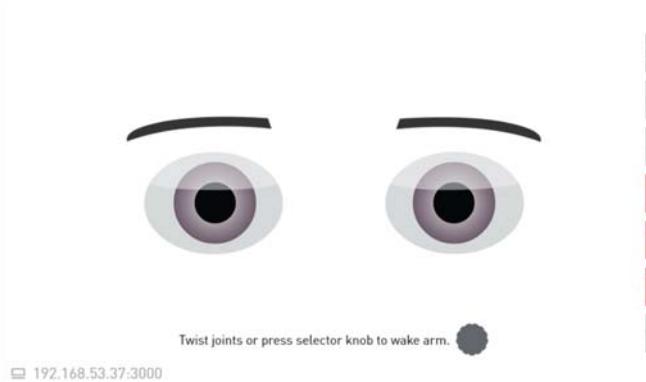
Sawyer's power cord may be disconnected from the AC outlet to disconnect power to the entire system in the event of emergency. Ensure that the power plug is not connected to an outlet that is difficult to access during Sawyer's operation.

Turning On Sawyer

Press and release the power button on the controller. The lights on the head turn on, the main screen appears on the Sawyer display, and the robot begins its boot up sequence.



For the robot to understand and recognize where each of its joints is in real space, the arm will perform a Homing Sequence. During this sequence, each joint moves approximately five degrees. To start the homing sequence, press the Selector Knob on the robot's arm. The arm will move each joint.



When homing, the joint limit indicators running vertically along the right side of the display appear. When a joint is twisted effectively, its indicator turns green. Joints that are not yet twisted are gray.

Note: You can also manually home the arm by physically moving each joint five degrees.

Moving the Arm

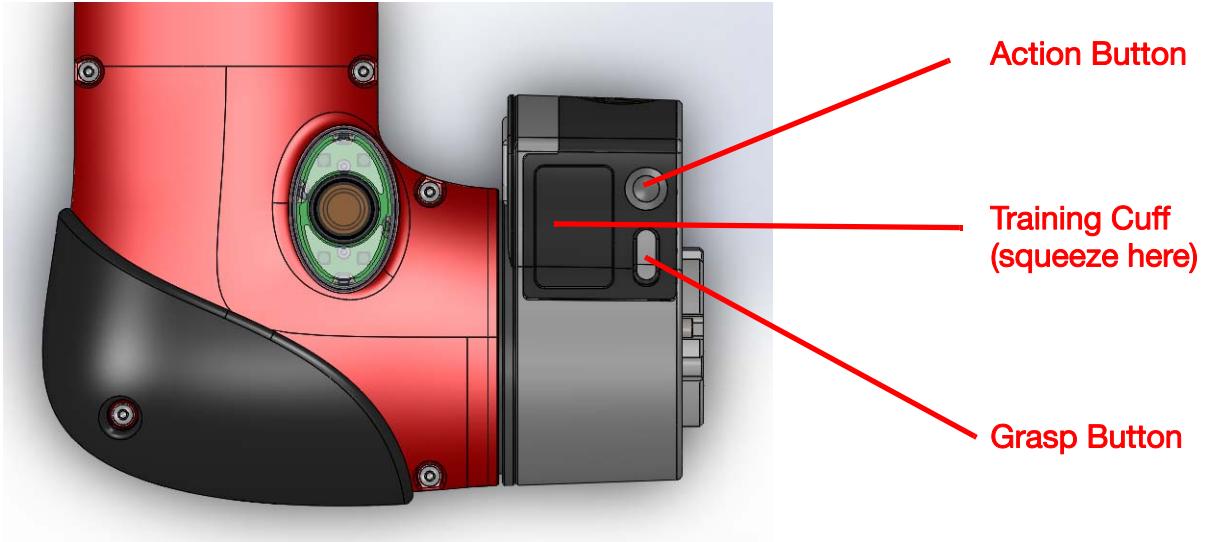
The robot has three physical interfaces used to manipulate the robot and train a task: two Navigators and one training cuff.

One Navigator is located on Sawyer's arm. The other is on the torso. A Navigator is a set of buttons and a knob you use to make selections on Sawyer. The selections are shown on Sawyer's display.

The training cuff is located at the end of Sawyer's arm, between the wrist and end of arm tooling.

Grab anywhere along Sawyer's arm and push and pull on it slightly to feel its resistance. Notice that the arm is stiff yet compliant. Now, grab the indented portion of the training cuff above the buttons and squeeze it. Notice that the arm becomes fluid and easy to manipulate. This is what we call "Zero G" mode. It is the mode in which you train Sawyer to perform a task. While the arm is in Zero-G mode, the motors are enabled, essentially counteracting the effect of gravity on the robot.

You can also press and hold the **O** button on the Navigator to enable Zero G mode.



Release the training cuff and the arm becomes (semi-) rigid again. Note that the arm stays in the location and orientation it was in when you stopped squeezing the training cuff. The location and orientation of the arm (its shoulder, elbow, wrist, and so on) is called its *pose*.



Getting Started with Intera 5

For the latest and most detailed information on Sawyer and Intera 5, we always recommend you see the Online User Guide at: mfg.rethinkrobotics.com/intera. The Rethink Robotics support page is here: [Rethink Support](#).

Before proceeding with this chapter, connect a Sawyer robot to your computer:

1. Plug one end of a straight-through CAT5 or CAT6 networking cable into the RJ-45 port outside Sawyer's controller.

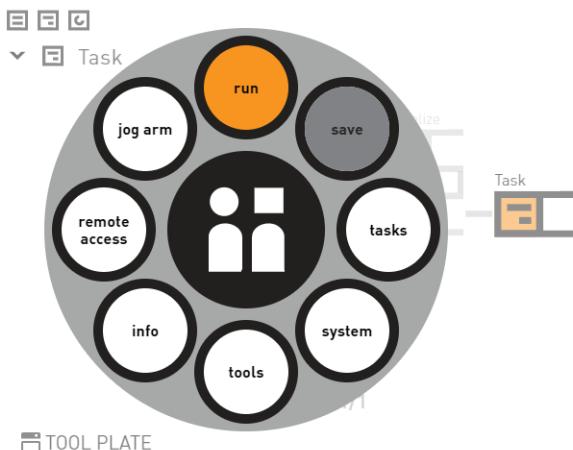


2. Plug the other end of the cable into your computer.

Note: Alternatively, it is possible to connect to the robot via a network. To do this the robot and the PC need to be connected to the in-house factory network. The DHCP server on the network will assign the robot an IP address automatically. It would be necessary to configure your PC to accept an IP address from the network server if that is not the current setting.

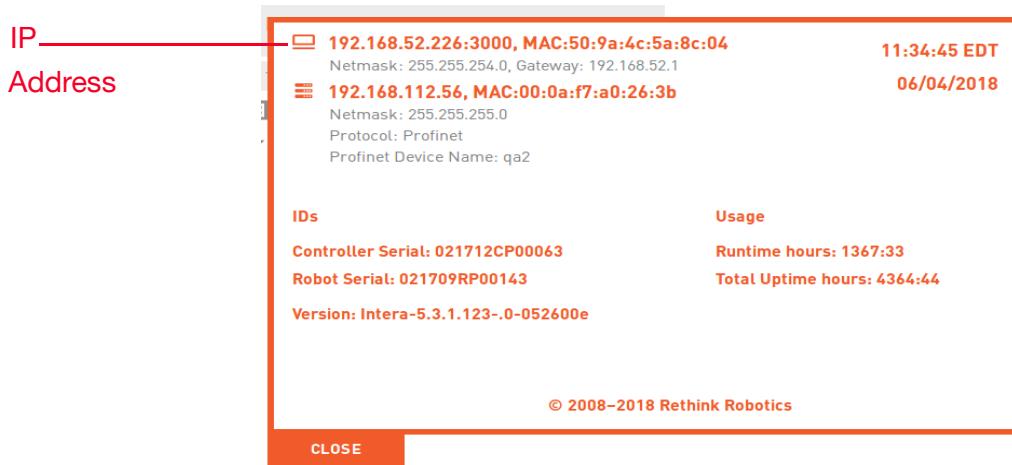


3. Press the Rethink Button  on one of Sawyer's Navigators to display the Head Screen Menu.



4. Using the Navigator Scroll Knob, select the Info menu option. Note Sawyer's IP address in the About pane.

Note: It may take 30-60 seconds for the IP address to appear in the About window. You may need to select the Info menu option several times before the IP address appears.



5. Open Google Chrome and enter Sawyer's IP address in the Browser address window, followed by colon (:), followed by the port number: 3000 and press the Enter key.

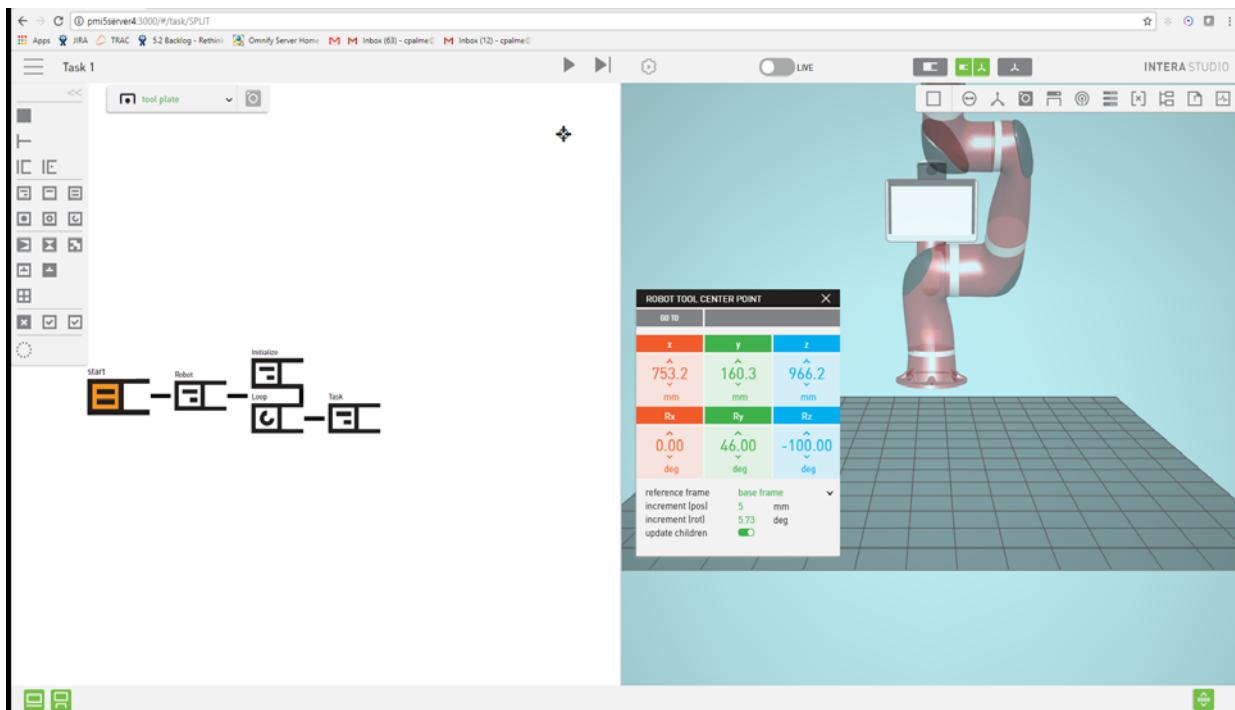


Use the latest version of Chrome browser to access Intera Studio.

Note: To achieve a working connection, you may need to change some settings. For example, if your PC or Sawyer is set to a static IP address, you will need to change them to DHCP. You may also need to make sure WiFi is disabled on your PC because it can cause addressing problems.



6. Intera Studio appears in a split screen view with the Behavior Editor on the left and the 3-D View on the right.



7. To link Sawyer and Intera Studio, click on the Sawyer icon in the Bottom Bar. It will turn from gray to green when it connects.



8. You also need to request control of Sawyer because someone else may be using that particular robot.



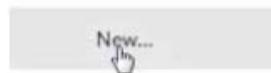
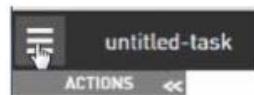
9. After clicking Grant, the connection is established and the icon turns green, as above.

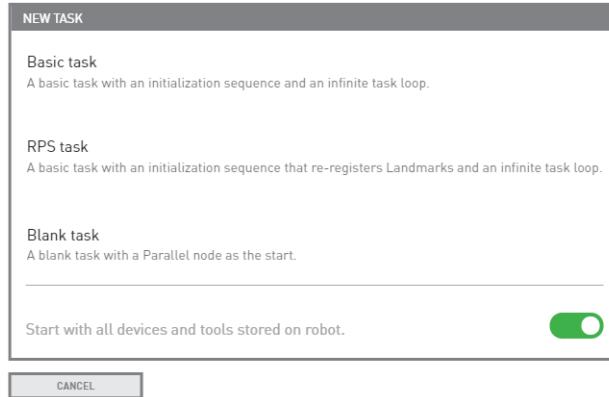
Note: If you try to use Intera Studio to move the robot arm before it's connected, you will see the following:



Click OK in Intera to request control, then Grant in the Head Screen on Sawyer.

10. Sawyer is now connected to Intera Studio and ready to start a new Task.
11. To start a new Task, select the Intera Studio menu and select New, then Basic Task.





BEST PRACTICES

- A network switch is not required when Sawyer is connected directly to your computer.
- Use a straight-through cable to connect Sawyer to your computer.

TROUBLESHOOTING

- You may need to select the Info menu option several times before the IP address appears in Sawyer's About window.
- If your computer is not connecting to Intera Studio, check that:
 - A straight-through cable, not a crossover cable, is used.
 - You are using Chrome, which is the only fully-tested and compatible browser.
 - If connecting Studio directly to the robot, make sure there are no other network connections also connected, for example, a corporate network connected via WiFi.
 - Clear the History in the browser, close the browser and try again.

Some Intera Terms

To get started with Intera, it is necessary to be familiar with some of the terms it uses.

The Head Screen refers to the head display User Interface on the Sawyer robot itself.



Intera Studio refers to the Intera software accessed through a Google Chrome browser, which features a Behavior Editor of the task and a simulated Sawyer robot. Optionally Intera Studio may be connected to, and communicate with, an actual Sawyer robot.

Most of the programming of the logic of Sawyer's tasks will take place on Intera Studio.

A node is the basic building block of the behavior editor. Each node performs a specific function depending on the type of node it is, and the value of the node's properties. Examples of node functions: moving the robot; interacting with signals; using vision; waiting for instructions from an external machine.

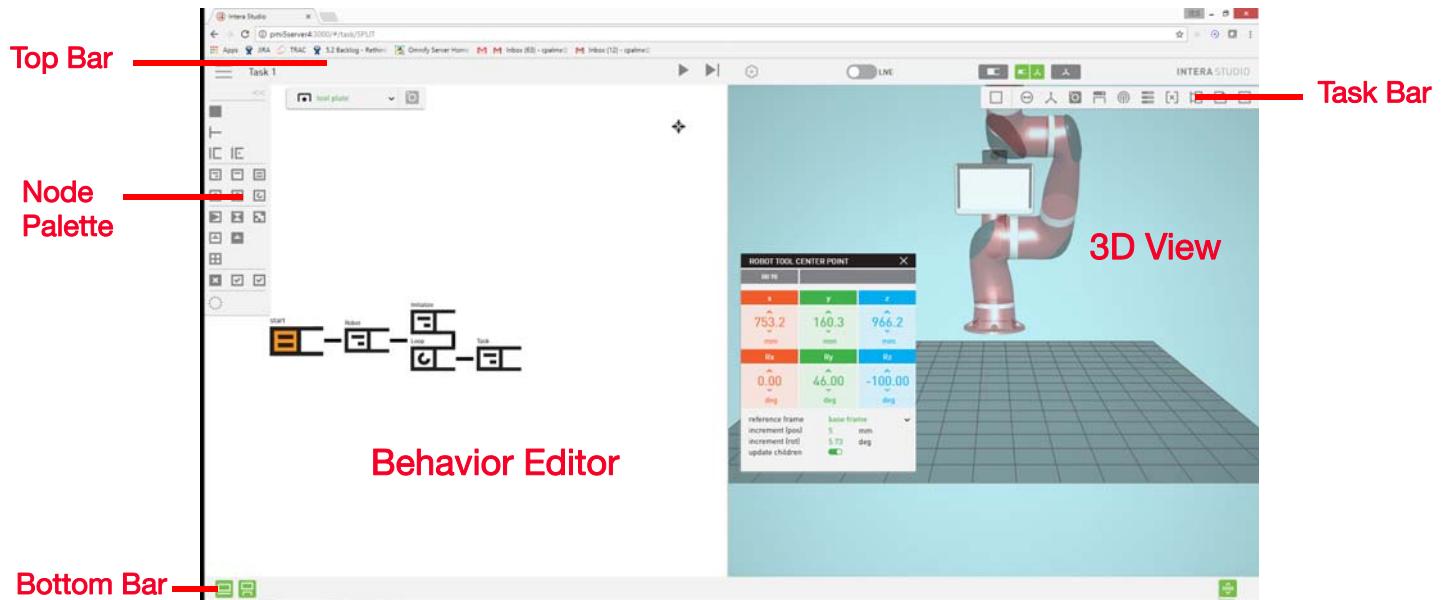
The behavior editor is a collection of nodes, organized in a tree-like structure (although displayed on its side in the software) that collectively accomplish a task. The nodes that constitute the tree and the way in which the tree is structured determine what is to be done when. The behavior editor grows and branches out from the left side of the screen and is made up of parent and child nodes.

A Task is the complete description of what the robot uses to accomplish the job. A task is the behavior editor combined with all the resources that the nodes in the behavior editor rely on to accomplish the desired job. Examples of resources: the kind of end effectors attached, frames, landmarks, location of points in space, configured devices.

When a branch of the Behavior Tree is active, it is said to be running. It will return a status that indicates whether the branch ended in success, failure, or error. (Other statuses can be imposed on a branch, for example: paused, stopped, terminated, disabled.)



Components of the Intera Studio Screen



Top Bar



The top bar contains main functions for creating tasks, changing how Studio displays, and running Sawyer.



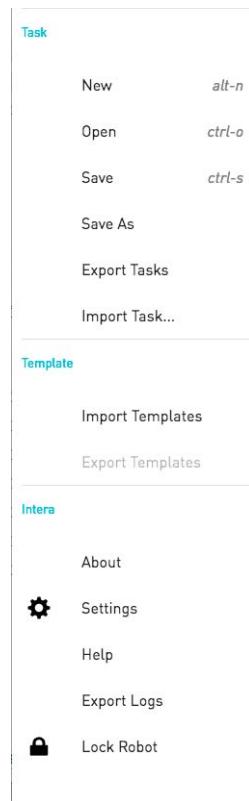
The Studio Menu Button displays a menu of Task, Template, and Intera options, described below.

*Task 16

The Task name is displayed in the upper left. If a * is displayed, as in this example, there are changes to the task available to be saved. Note that exiting the browser or losing the internet connection does not lose these changes, but powering off the robot would.



Studio Menu



TASK

- New... -- Create a new task.
- Open -- open task from a list of existing tasks. You can also delete a highlighted task by clicking on the delete icon, then confirming your deletion. Search the list by entering the first letters of the task on the search line.
- Save -- Save the current task on the robot.
- Save As... -- Enter a different name for the task; click SAVE.
- Export Tasks -- Download the current task or all tasks to your computer.
- Import Task... -- Opens browser on your computer where you store folders, files. etc.



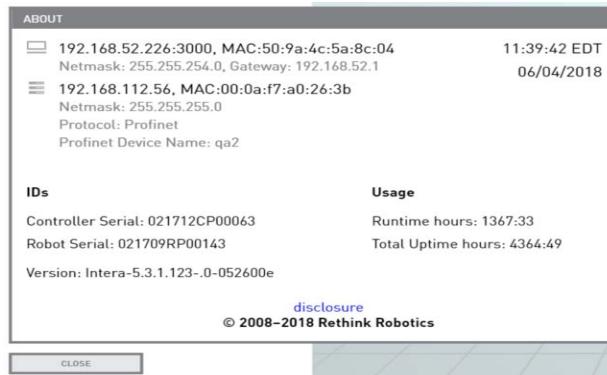
TEMPLATE

Note: A template is a basic or "skeleton" subtree behavior that can be inserted into a task as needed. Templates do not contain unique properties of the nodes, for example, references to poses, signals, or other variables.

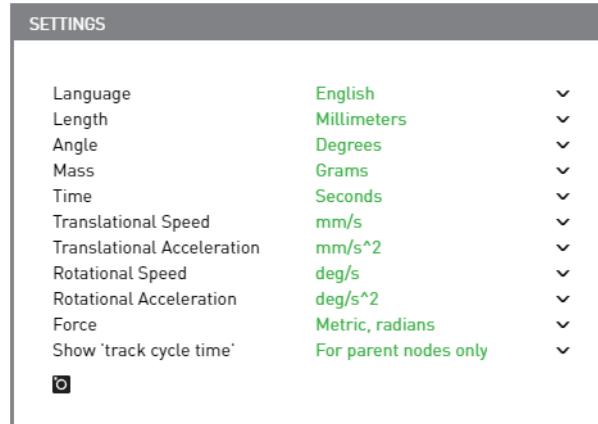
- Import Templates -- Open browser on your computer where templates are stored.
- Export Templates -- Downloads template files to your computer (file extension .json).

INTERA

- About -- Displays robot information, IP address, Intera software version number, serial numbers and usage counter, both runtime and total power-on.



- Settings -- Use this dialog box to change the basic settings of Intera, including which language is used, units of measurement, time, speed, etc.



Note: Be careful changing to another language, because you will need to understand that new language to change the settings back if you want to revert to your original language.

- Help -- Provides a link to the Intera Online User Guide at: mfg.rethinkrobotics.com/intera, including an option to download this PDF. (You need to be connected to the internet to access the guide.)
- Export Logs -- Downloads log data from the robot to your computer.
- Lock Robot -- Toggle between locking and unlocking Sawyer. This feature helps prevent unauthorized personnel from tampering with the tasks stored on the robot. If it is locked, users can only run, reset, clear errors/confusion, or power cycle on the robot. Tasks cannot be created, modified or changed.

RUN BUTTON ICONS



Restart, Run, and Step - Run the task defined by the behavior editor. You can run the entire task from the beginning, run the task, step through it one node at a time, and stop the task. (The square stop button appears while the task is running.)



DISPLAY OPTIONS

Select here whether to display, in the order shown, only the behavior editor, a split screen with both behavior editor and 3D view of the robot arm (default view), or only the robot arm 3D view.



SAWYER CONNECTION



These icons on the lower left corner of the screen display whether the Intera software on your computer is connected to a Sawyer robot.



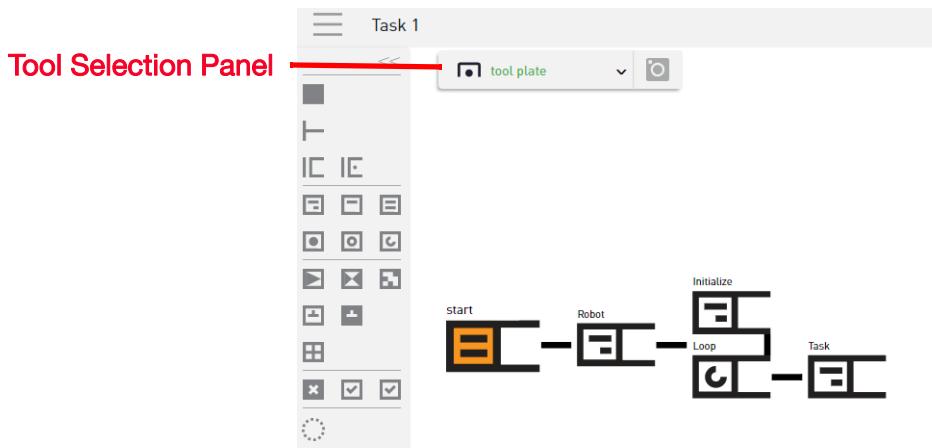
Node Palette

The Node Palette contains all the nodes you'll use to create a behavior tree. Click on the arrow on the top, right of the panel to display/hide the full list of icons.





Behavior Editor



The Behavior Editor is used to create, view, and edit all nodes in the Task.

A task is structured to activate nodes branching from left to right between parent and child nodes, and top to bottom between sibling nodes.

The Tool Selection Panel displays the current tool in use.

Node Colors - Meaning

Orange (Gold) - Selected: The node is selected and its properties display in the Node Inspector.

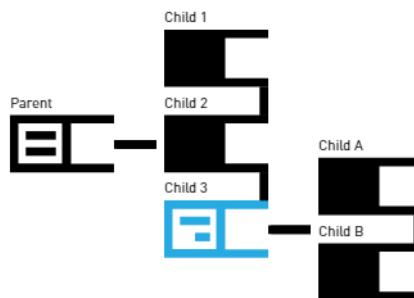
Blue - Incomplete: required information has not been entered for this node.

Black - Inactive: an inactive node is not running, but can become active if its parent gives it the opportunity to start running.



Grey - Disabled: a disabled node and its children, if it has any, are ignored by its parent, and thus never run.

Green - Running: the node is currently being executed in the running of the task. It is active until it either succeeds, fails or encounters an error.



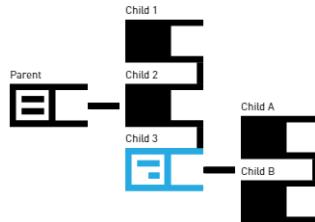
BEHAVIOR EDITOR NAVIGATION

- Left Click - select a node. Will display in the Node Inspector
- Right Click - displays modification options. (See Right Click Menu, below.)
- Double Click a node - opens the Node Inspector
- Shift + Click a node - selects the node and all its children
- Click and Drag - move the center of view
- Zoom in - Scroll up
- Zoom out - Scroll down
- Arrow keys - select neighboring node
- Shift + Arrow keys - move selected node in the specified direction; it will move under the node above it
- Delete - will delete the selected node, or nodes
- CTRL + Click - enables multi-selection of nodes
- Clicking a node from the Node Palette adds the node as a child of the selected node. If the selected node is a Primitive Node, (i.e. it does not accept children), the node will be added as a sibling.



- The Behavior Editor can be expanded to fill the entire Studio screen or split to display both the Behavior Editor and the 3D view. See “display options” on page 36.
- CTRL + X - Cut
- CTRL + C - Copy
- CTRL + V - Paste

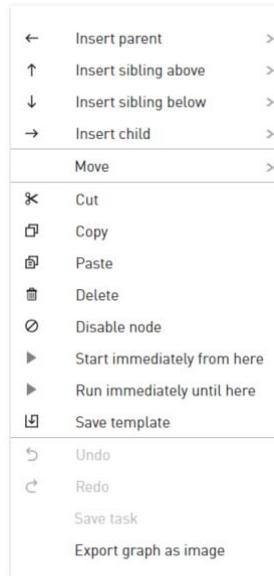
RIGHT CLICK MENU



In the above example, Child 3 has 2 children Child A and Child B, and is a child of Parent. Child 1 comes before Child 2. And Child 3 comes after Child 2.



Right clicking on a selected node, or nodes opens the Right Click Menu.



- Add Child - Opens options to add a selected node as a child of a parent node. In the above example, "Child 3" has 2 children "Child A" and "Child B", and is a child of "Parent".
- Insert Parent - Opens options to insert a node as a parent of the selected node.
- Insert Before - Opens options to insert a sibling node above the selected node
- Insert After - Opens options to insert a sibling node below the selected node.
- Move Node - Allows you to select a direction to move the selected node. Same function as Shift + Arrows.
- Copy
- Paste
- Cut
- Delete
- Undo - undo last action (Keyboard shortcut - Ctrl + Z)
- Redo - redo last action (Keyboard shortcut - Shift + Ctrl + Z)
- Disable Node - disables the selected node and its children, causing it to be ignored by its parent, and thus never run.
- Save Template - saves the structure of the selected node and its children ("the entire branch") as a Template. This structure of nodes, the Template, can then be



added in another location in this task or another task. The unique properties of the nodes are not transferred.

- Save - saves the task
- Export Graph to SVG - saves the entire Behavior Tree as an SVG file which can be opened in a browser and viewed as an image.
- ❖ Reset Zoom -- Zooming in on the behavior editor nodes can sometimes lead to it being difficult to see the whole tree on the screen. When that happens, click this icon to re-center and zoom its view.
- ❖ Node Move Hot keys -- Click to show the hot keys for moving nodes in the behavior editor. These keyboard keys can make it easier to move through the behavior editor nodes.



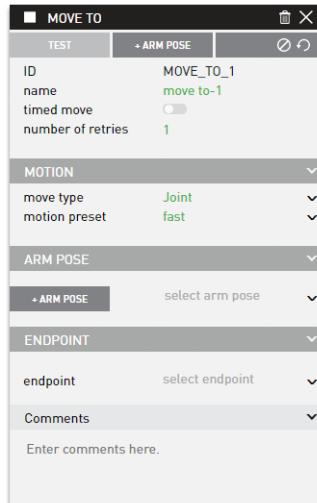
Task Bar



NODE INSPECTOR -- The node inspector displays the attributes associated with the node selected in the behavior editor. For example, the node inspector for a Move To node displays its ID, the name

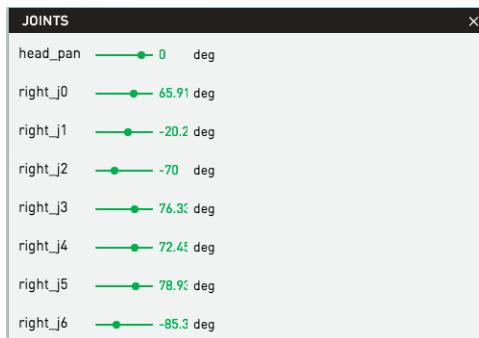


it has been given, type of motion, etc. You can also add your own comments for each node.



Toggle the node inspector button to turn its display on or off. You can also hide it by clicking on the x in its upper-right corner.

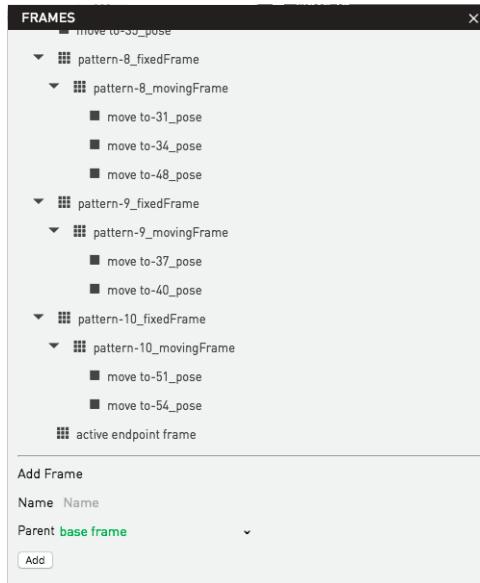
JOINTS -- Control each Sawyer joint with sliding bars or by entering specific numbers in degrees. A slider near either end of the slider range indicates proximity to a joint limit.



FRAMES -- Displays all frames created. Frames can be associated with the end effector, patterns, landmarks, or user defined.

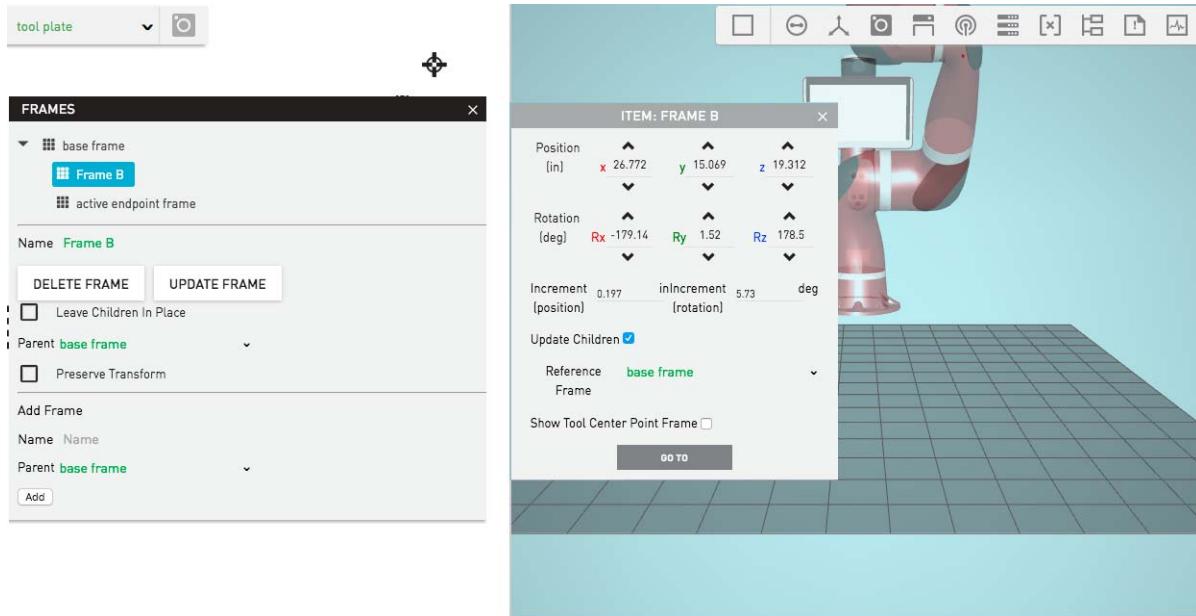


Frames reference a parent frame until reaching the Base Frame. Each child is shown indented.



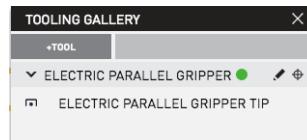


In this example, Frame B and Active Endpoint Frame are children of the Base Frame.



SNAPSHOT EDITOR -- The Snapshot Editor allows you easily to: train snapshots used in the task, including arm camera-locating and -inspecting; add landmarks; and cross register an external vision system to the base frame of the robot.

TOOLING GALLERY -- Use Tooling Gallery to create and edit end of arm tooling and tools. Virtually any amount of tooling data can be saved and stored.



SIGNALS -- The Signals Tab is used to edit signals for input and outputs of devices connected to Sawyer.

DEVICES -- The Devices Panel is used to set up Modbus, TCP/IP, and Fieldbus (PROFINET®, EtherNet/IP™) devices.



The internal Moxa I/O unit of Sawyer shows automatically as device "Robot IO."



A green status light indicates the device is communicating properly. Red indicates it is not communicating. Orange means an attempt at establishing communication.

To delete a device, check its green square and select the delete icon. (You cannot delete the internal Moxa I/O.)

You can click on the pencil icon to display the details for the Robot IO device. This device has 8 inputs and 8 outputs shown as ports, corresponding to the physical connections on the device. DI corresponds to the 8 inputs 0-7, and DO corresponds to the 8 outputs 0-7. You can also edit the device's name prefixes and signal ranges.

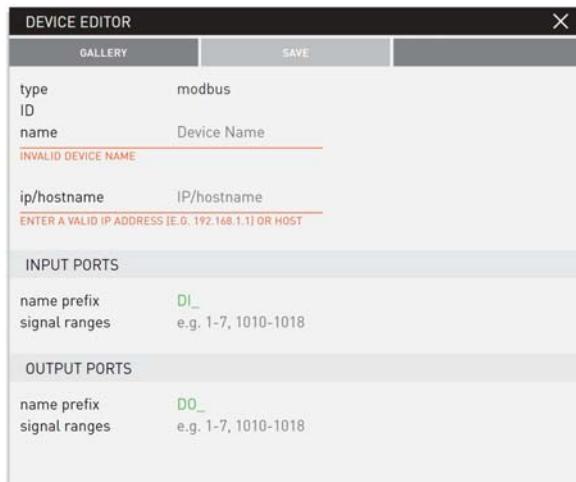




To create a device, return to the gallery of devices (if necessary) and click on the + icon. The following panel is displayed.



Choose Modbus or TCP/IP.



The above image is the device editor panel for a modbus device. The new device requires a user specified name and IP address. The IP addresses of the device and robot must be configured correctly in order to communicate. The Input and Output Port Signal Ranges correspond to the Modbus lines used to communicate with the device's specific ports or registers. Click Save when done.

The procedure is essentially the same for creating a TCP/IP device.

For addition of Fieldbus devices, please refer to “Fieldbus Devices” on page 129.



DEVICE EDITOR

← GALLE...

NAME + IP : NULL, -4000

SAVE CANCEL

ID
name Device Name
INVALID DEVICE NAME

Sawyer will connect to a device
ip/hostname IP/hostname
ENTER A VALID IP ADDRESS (E.G. 192.168.1.1) OR HOST
port 4000

UNPACK DATA - IN
DEFINE DATA - IN
PACK DATA - OUT
DEFINE DATA - OUT



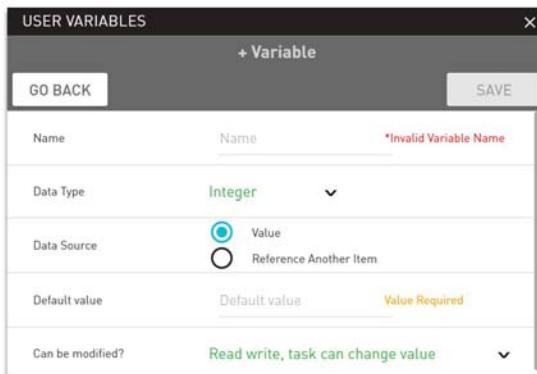
VARIABLES -- Create user-defined variables that can be used in conditions.

USER VARIABLES

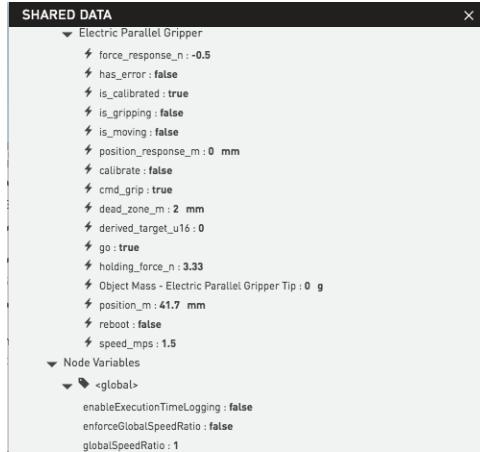
+ Variable

GO BACK SAVE

Name	Name	*Invalid Variable Name
Data Type	Integer	
Data Source	<input checked="" type="radio"/> Value	<input type="radio"/> Reference Another Item
Default value	Default value	Value Required
Can be modified?	Read write, task can change value	



SHARED DATA -- Stores all the data for each item in the workspace. Displays the current status of variables and signals, whether created by the system or the user. You can view and set the value of some of these variables directly from Shared Data if you want to do so independent of the behavior editor. Variables are added automatically to Shared Data when, for example, a user adds a signal, creates an endpoint, or creates a loop node.



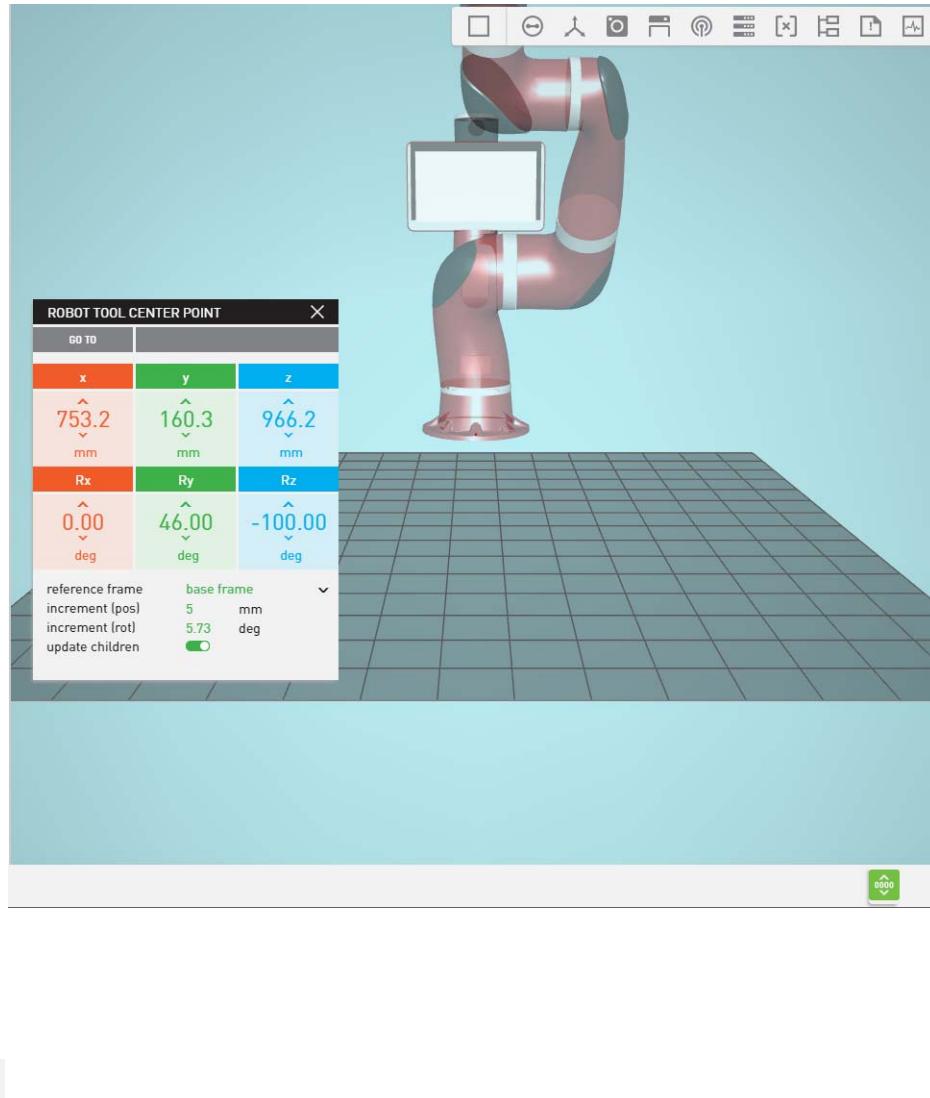
ERROR LOG -- Displays error messages and other error information, the most recent being on top.

3D View

The 3D view on the right side of the screen acts out the actions you have created via the nodes. The robot arm simulator can also run in parallel with an actual Sawyer under control of the Intera Studio



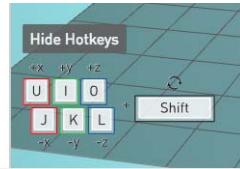
software.



The Live vs. Sim switch -- Toggles the mode between LIVE (on robot) and SIM (virtual simulation). Virtual simulation runs in the software only when a robot is connected. However the robot will not move.



Click to display the jog hot keys for the simulator.



The U, I, and O and J, K, L keys move an endpoint on an axis. Hold Shift while pressing those keys to move an endpoint around an axis.

How to Change the View of the Simulated Robot Arm

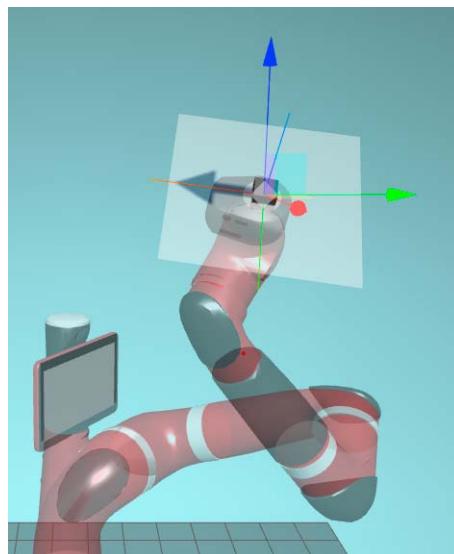
There are several ways to change the view of the image of the simulated robot arm.

- To "translate" (pan the image left and right, up and down), press and hold the right mouse button first, then press and hold the left button and drag. You can also hold down the space bar, click and drag.
- To rotate the image, hold down the right mouse button and drag.
- Zoom in and out with the scroll wheel.



How to Move the Simulated Robot Arm

Click on the simulated robot to select it. The 3D controller appears.



The 3D controller is similar in function and operation to the controller used in 3D computer graphics programs.

Be aware that where you click on the image of the robot is important. If you click close to the end of the arm, for example, you may click on a pose that has already been created (indicated by a blue dot). If you click further up the arm, you will highlight the arm, but you won't create a pose.

Click on an axis arrow and drag to constrain the movement to the selected axis.

- x - red
- y - green
- z - blue

GO TO

To update the robot arm's position, click on the Go To button. The simulated robot arm will then move to that location. If there is an active Sawyer robot connected to Intera Studio, its arm will move, slowly, along with the simulated robot arm.



"Cartesian view" - Interface in 3D view that both displays the information associated with the selected item in 3D space, and allows you to edit it. This example shows the attributes of a waypoint: its position, rotation data, etc. You can change its data by entering new numeric values or by clicking on the up and down arrows. That would change the position and/or rotation data of the selected waypoint in the x, y, and z directions.



End of Arm Tooling

For the latest and most detailed information on Sawyer and Intera 5, we always recommend you see the Online User Guide at: mfg.rethinkrobotics.com/intera. The Rethink Robotics support page is here: [Rethink Support](#).

“End of arm tooling” is the term for what is attached to the end of the robot’s arm that allows the robot to interact with parts in its environment. Rethink offers optional accessories for use with Sawyer, the ClickSmart Family of Gripper Kits. Refer to the corresponding Rethink Robotics guides for instructions on connecting these accessories to Sawyer.

Attaching End of Arm Tooling

The Sawyer end plate is designed per the ISO 9409-1-40-4-M6 standard bolt pattern with M6 bolts.

If you’re using a ClickSmart Plate and/or Gripper Kit, you must first attach the ClickSmart Plate (Robot Side), which comes in the accessory box that ships with Sawyer. Then attach the ClickSmart Plate (Tool Side), which comes in every ClickSmart Gripper Kit, to the Robot Side of the system.

How to Configure End Effectors

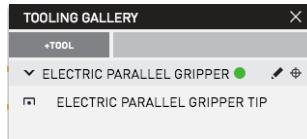
After attaching end effectors according to the instructions included in the gripper kits, you must configure the grippers before use.

Click on the Tooling Gallery icon in the Top Tool bar:





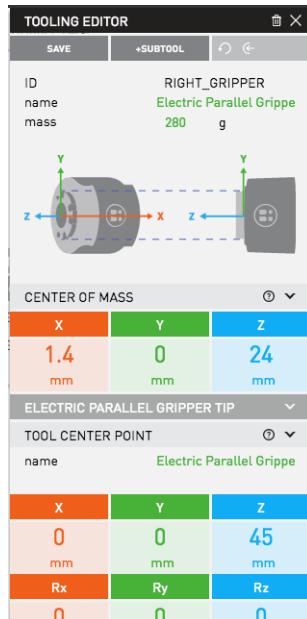
The Tooling Gallery information is displayed:



Note: The green dot next to the name of the tool means the tool is calibrated. See “How to Calibrate the Rethink Electric Parallel Gripper” on page 65.

In this example, Intera Studio recognizes and displays Rethink's Electric Parallel Gripper and its tip. (Intera 5 does not recognize third party end effectors at this time, so the configuration and actuation process is different. See “How to Actuate the Tips of Third Party End Effectors” on page 70.)

Select Electric Parallel Gripper and then click the pencil (edit) icon to display the gripper's details and edit its characteristics.

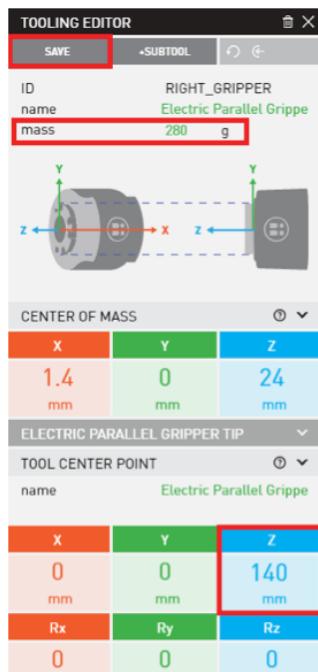


Ensure the Mass, Center of Mass (you can leave this as default) and Position Z are correct. The reason for inserting the Mass of the gripper is so that Sawyer knows how much mass to expect and where it is when the arm moves.



FYI, here is a [reference](#) on how to calculate center of mass.

Note: Note the Tool Center Point position Z should be measured from the top of the adapter tool plate that meets with the cuff to the end of the fingertip.



Once updated, click **Save**.

ADDING A CLICKSMART GRIPPER

Note: For the most up-to-date information, refer to the Online User Guide at: mfg.rethinkrobotics.com/intera.

Summary of Steps

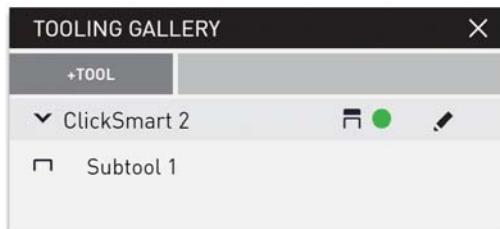
- Set up Gripper Name.
- Set up mass and center of mass. Please note that setting up the mass, COM, and tool center points is critical to get the best possible performance out of the robot.
- Set up TCP.



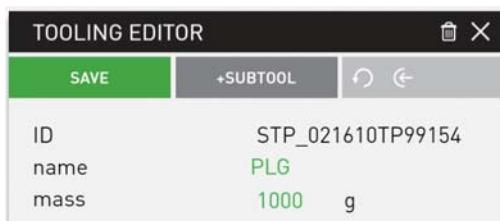
- Select Gripper Type.
- Test Grip, Open and Closed signals. Invert signals and adjust sensor positions if necessary.
- Save your settings and exit.

Detailed Steps

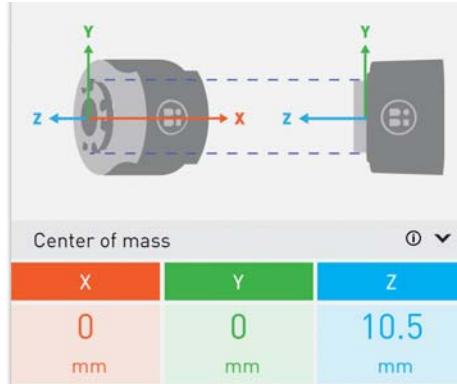
1. Follow the instructions in the latest User Guide to assemble this gripper and attach it to the robot.
2. The ClickSmart gripper will be recognized by the software and appear in the Tooling Gallery.



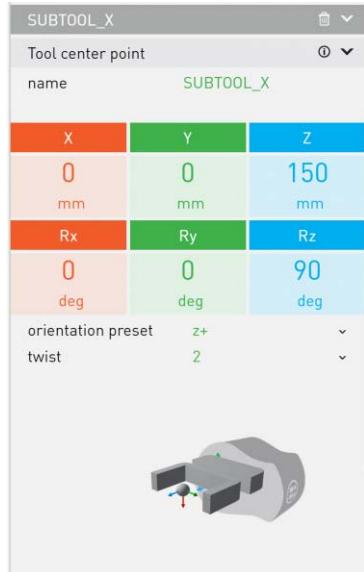
3. Select the pencil icon to expand the Tooling Editor for the Smart Plate.
4. At the top of the panel, rename the gripper and enter the mass of the gripper plus the ClickSmart Plate.



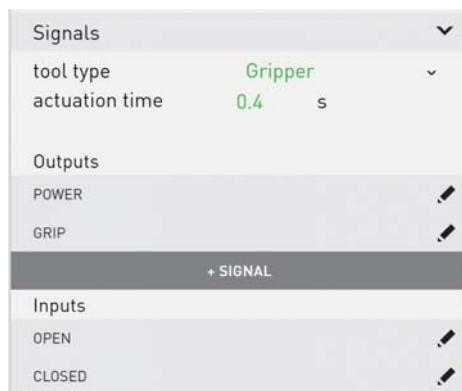
5. Enter the coordinates of the center of mass based on the CAD drawing of the gripper or measurements. Follow the definitions of x, y and z axes as illustrated.



6. Edit the Tool Center Point (TCP) to provide the best representation of the finger tips. For example, if the gripper is centered on the ClickSmart Plate, provide the distance in the z-direction from the Training Cuff to the tip of the gripper fingers. The TCP position z should be measured from the top of the ClickSmart Plate Robot Side that meets with the cuff to the end of the fingertip.
7. Set the orientation preset and twist to match the physical configuration of the gripper. Note that this will change the x, y, and z orientation of the active endpoint. If a PLG is built according to the User Guide, select z+ and 2.



- Working your way down the Tooling Editor, select the tool type. For a pneumatic gripper, select Gripper. For a vacuum gripper, select Vacuum. When a gripper type is selected, the signals are mapped automatically.



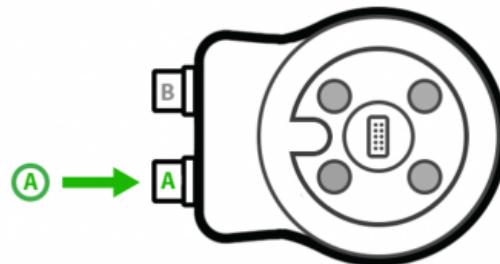
- Actuation time is the time it takes for the gripper to close or the vacuum cup to firmly grasp the object. A default time may be assigned that can be adjusted as necessary.
- The channel used in configuring the gripper is determined by which port the gripper is connected to on the ClickSmart Plate. **If only one pneumatic actuator is being used, use Port A.** The Intera software automatically populates the four sig-



nals. Select the pencil icons to verify the signals are configured correctly, but this is not necessary when using a ClickSmart gripper kit.

The figure consists of four separate windows, each titled "SIGNAL EDITOR".

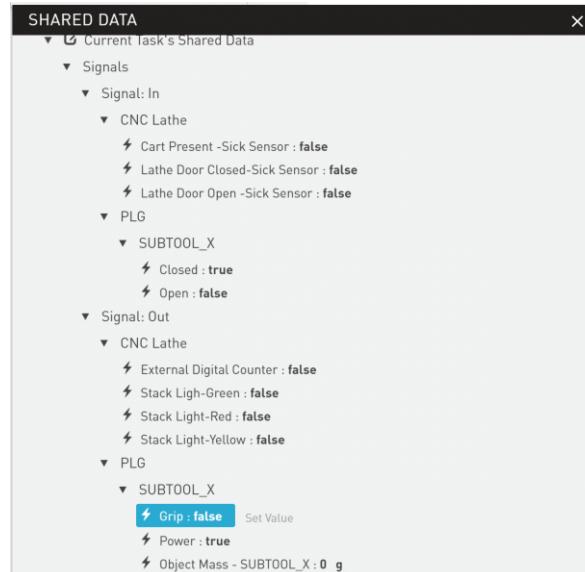
- Power Signal:** id: power_HkW3Rlkqie, name: Power. Device: PLG, Subtool: SUBTOOL_X, Direction: Output. Port: A_out1, Data type: Boolean, Default value: true [1]. Invert signal: checked.
- Grip Signal:** id: grip_SyUQP3hzZW, name: Grip. Device: PLG, Subtool: SUBTOOL_X, Direction: Output. Port: A_out2, Data type: Boolean, Default value: true [1]. Invert signal: checked.
- Open Signal:** id: open_Hyb1mP3nZW, name: Open. Device: PLG, Subtool: SUBTOOL_X, Direction: Input. Port: A_in1, Data type: Boolean, Default value: false [0]. Invert signal: checked.
- Closed Signal:** id: closed_H14kmPhnZZ, name: Closed. Device: PLG, Subtool: SUBTOOL_X, Direction: Input. Port: A_in2, Data type: Boolean, Default value: false [0]. Invert signal: checked.



11. Any of the signals can be changed except for Power. The Grip, Open, and Closed signals can be defined based on the setup and task. For example, open and closed will be different for gripping an object from the outside versus from the inside. The Open and Closed signals are determined by the position of the sensors on the gripper. An explanation of the default signal settings can be found at the end of this section.

Note: If a PLG is built according to the User Guide, turn off "invert signal" for the Grip signal.

12. To test the signals, open the Shared Data and toggle the Grip signal to test if the Open and Closed signals respond as expected.



Note: For PLG and PSG, the Open and Closed Inputs are from the two magnetic sensors that slide in the tracks on either side of the pneumatic gripper. The sensor positions may need to be adjusted using the smallest hex key in the gripper kit. Please follow the instructions on the following pages in the Online User Guide to adjust the sensor position.

Pneumatic Large Gripper (PLG)

Pneumatic Small Gripper (PSG)

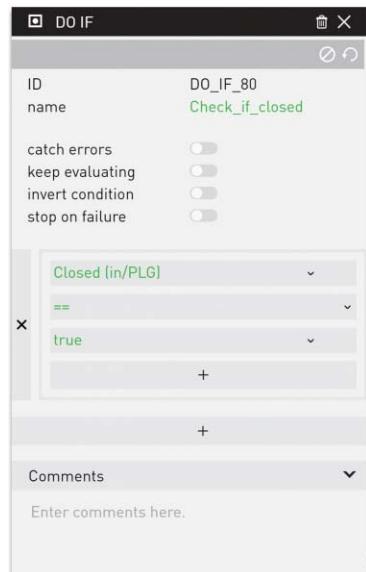
13. Select the Save button at the top of the Tooling Editor panel to save all the configuration settings to the ClickSmart Plate. The gripper is now ready to be used in a task.

Using the Gripper in a Task

To open or close the pneumatic gripper, use a SET TO node to set Grip to false/0 or true/1 respectively as shown below.



To check if the gripper is opened or closed, use a DO IF node. Check for the condition Open == true or Closed == false.





Default signal settings of ClickSmart grippers in Intera:

For pneumatic grippers:

I/O	Signal	Default Value	Invert Signal
Outputs	Power	True	Off
Outputs	Power	True	On
Inputs	Open	False	On
Inputs	Closed	False	On

- The Grip signal needs to be inverted so that when the pneumatic valve is powered off, the parallel actuator is in the closed state to keep the part in hand instead of dropping it accidentally.
- The gripper should not be actuated when it is first plugged into a robot, so the default value of Grip is set to true, which becomes false after inversion.
- The Open and Closed input signals should be inverted because the magnetic sensors used to detect open and closed states are PNP sensors. This means when the sensor is on, it sends an off signal; when the sensor is off, it sends an on signal. The Open and Closed signals must be inverted so that when the sensor is on, the corresponding signal is on, too.
- When using the Pneumatic Small Gripper, both Port A and Port B should have the same signal settings.
- Changing the air hose connections may affect the settings of the Grip signal.



For vacuum grippers:

I/O	Signal	Default Value	Invert Signal
Outputs	Power	True	Off
Outputs	Vacuum On	True	On
Inputs	Vacuum Sensor	Sensor Voltage = 5V	N/A
Inputs	Vacuum Threshold	50	N/A

- The Vacuum On signal needs to be inverted so that when the pneumatic valve is powered off, the vacuum generator is still on to keep the part in hand instead of dropping it accidentally.
- The gripper should not be actuated (air turned on) when it is first plugged into a robot, so the default value of Vacuum On is set to true, which becomes false after inversion.
- When the valve is powered on (indicated by the orange light on it), vacuum should be off. When the valve is powered off (no light), vacuum should be on.
- Adjust the vacuum threshold value so that when the gripper picks up an object of interest, the sensor value in Shared Data exceeds this threshold.
- When using the Vacuum Small Gripper, both Port A and Port B should have the same signal settings.

Setup Notes

Please follow the instructions below to set up your ClickSmart gripper in Intera Studio:

- Set up Gripper Name.
- Set up mass and center of mass.
- Set up TCP.
- Select Gripper Type.
- Test Grip, Open and Closed signals. Invert signals and adjust sensor positions if necessary.
- Save your settings and exit.



Best Practices

- Toggle the Grip signals in the Shared Data to verify the Grip, Open, and Closed signals are set correctly with respect to the actual gripper motions.
- Add the cap provided in the gripper kit to the channel port on the ClickSmart Plate that is not connected to a gripper.
- Do not remove the ClickSmart Plate while the configuration is being saved.

Troubleshooting

- If the arm moves to the miss-pick position all the time, check to be sure the Closed Sensor is not on when the gripper closes on the part, but is on when the gripper closes and misses the part.

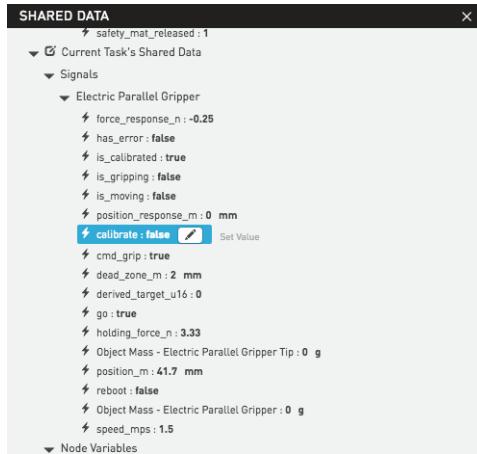
How to Calibrate the Rethink Electric Parallel Gripper

The Rethink electric parallel gripper must be calibrated before it can be used. Calibration opens and closes the gripper, so the gripper should not be holding an object when it is calibrated.

1. With the gripper plugged in to Sawyer, click on the Shared Data icon in the Top Tool Bar:



2. The Shared Data panel is displayed. Under Electric Parallel Gripper, calibrate is set to false:



3. Click calibrate: false to highlight it.

Note: Do not confuse “calibrate” with “is_calibrated.”

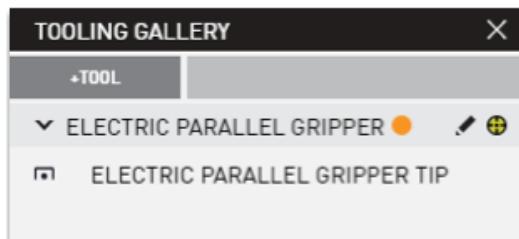
4. Click Set Value and type in **True** or the number **1** and press Enter.

You can see some of the numbers quickly change on the shared data panel as the grippers are calibrated. The values for is_calibrated and calibrate both change from false to true.

If there is an object in the gripper, is_gripping will also change to true.

To open and close the gripper, change the set value of cmd_grp. Open the gripper by entering the value 0. Close it with the value 1.

You can also calibrate the gripper by clicking on the yellow dot next to the gripper name in the Tooling Gallery. The tool is calibrated when the dot turns green.





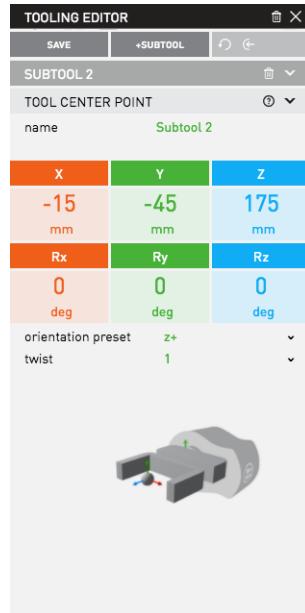
To Add End of Arm Tooling with Dual Tools

1. Click on the Tooling Gallery icon to display the Tooling Gallery.
2. Click the + TOOL icon.
3. Add a name for the end effector, its mass, and its center of mass.
4. Add a name for the first tip, its X, Y, and Z positions, and its orientation in X, Y, and Z. For example:

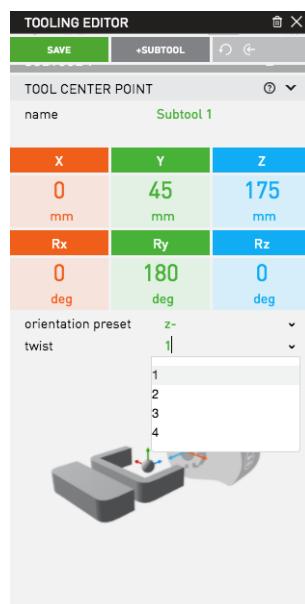




5. To add the second tool, click on **+ SUBTOOL**.



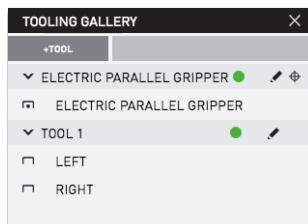
6. Give the second tool a name, position, and orientation, if needed. You can select a new orientation from dropdown menus, for example:



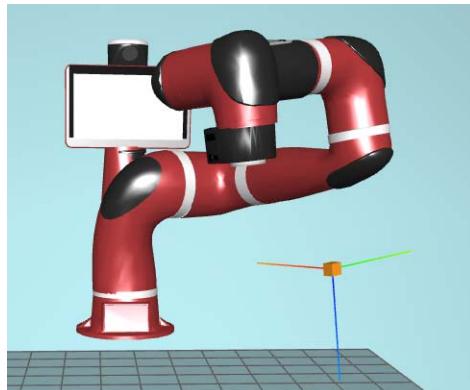


7. Click **Save**.

Here is the Tooling Gallery panel for end of arm tooling with two tools, "LEFT" and "RIGHT":

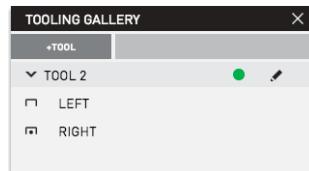
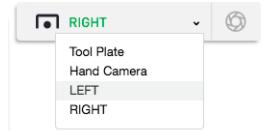


The new tools show up as orange blocks on the robot in 3-D view.



There are three cubes visible in this example. The black cube on the end of the arm represents the tool plate. The other two green cubes are the "LEFT" and "RIGHT" endpoints, which show you where in 3-D space the robot will perform its actions. The "RIGHT" tool has been selected as the active tool center point; its axes are displayed.

You can select which endpoint will be active by making a selection from the Tool dropdown menu on the upper left of the window or by selecting the tool from the Tooling Gallery. Only one tip can be active at a time.



How to Actuate the Tips of Third Party End Effectors

To actuate third party end effectors without using a ClickSmart Plate, you have to create signals using the Moxa I/O device housed in the robot's controller.

1. Click on the Signals icon  in the top tool bar to display the Signals panel.

Name	Current Value	Device
DI_0	false	Robot IO
DI_1	false	Robot IO
DI_2	false	Robot IO
DI_3	false	Robot IO
DI_4	false	Robot IO
DI_5	false	Robot IO
DI_6	false	Robot IO
DI_7	false	Robot IO
DO_0	false	Robot IO
DO_1	false	Robot IO
DO_2	false	Robot IO
DO_3	false	Robot IO
DO_4	false	Robot IO
DO_5	false	Robot IO
DO_6	false	Robot IO
DO_7	false	Robot IO

2. Select a signal corresponding to your hardware configuration. For example, if you connect Digital Output 1 on the MOXA I/O device to a digital input pin on your



end effector, you may want to select DO_1. You will want to rename it and change its default state based on your application.

3. To do that, click the pencil icon to display the Edit Signal panel.

Edit Signal	
GO BACK	SAVE
ID	PORT_SOURCE_0
Name	DI_0
Device	Robot IO
Direction	Input
Port	DI_0
Data Type	bool
Default value	false

4. Enter a name for the signal.
5. Select Save.

The signal is edited.

Assigning a Signal

After editing the signal, create a task in the behavior editor that contains a Set Value node and assign the edited signal to that node. Then set the value of the signal to 1 or 0 depending on whether you want the tool open or closed.

Finally, add the weight for the end effector in the Set Value node: out/Object Mass-(name of end arm tooling).



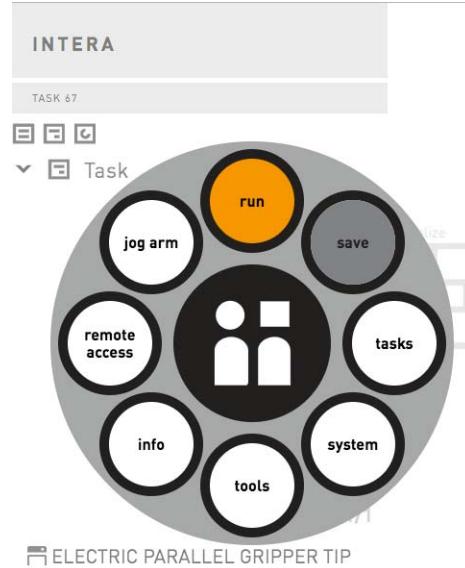
Train a Simple Pick and Place on the Head Screen

For the latest and most detailed information on Sawyer and Intera 5, we always recommend you see the Online User Guide at: mfg.rethinkrobotics.com/intera. The Rethink Robotics support page is here: [Rethink Support](#).

This tutorial shows you how to create a simple pick and place using the Robot's train by demonstration capabilities, and can be completed entirely on Sawyer's Head screen. Train by demonstration is only supported by Rethink grippers and ClickSmart grippers.

To complete this tutorial, you need a robot equipped with a Gripper Adapter Plate and a properly configured Rethink Electric Parallel Gripper or Rethink Vacuum Gripper. The gripper must be calibrated. Refer to "How to Calibrate the Rethink Electric Parallel Gripper" on page 65 if necessary.

1. Boot up the robot.
2. Press the Rethink button on the Navigator to display the Head Screen Menu.



3. Use the Selector Knob to scroll to and then select **tasks** (by pressing the knob), then scroll to and select **new**.



1/1

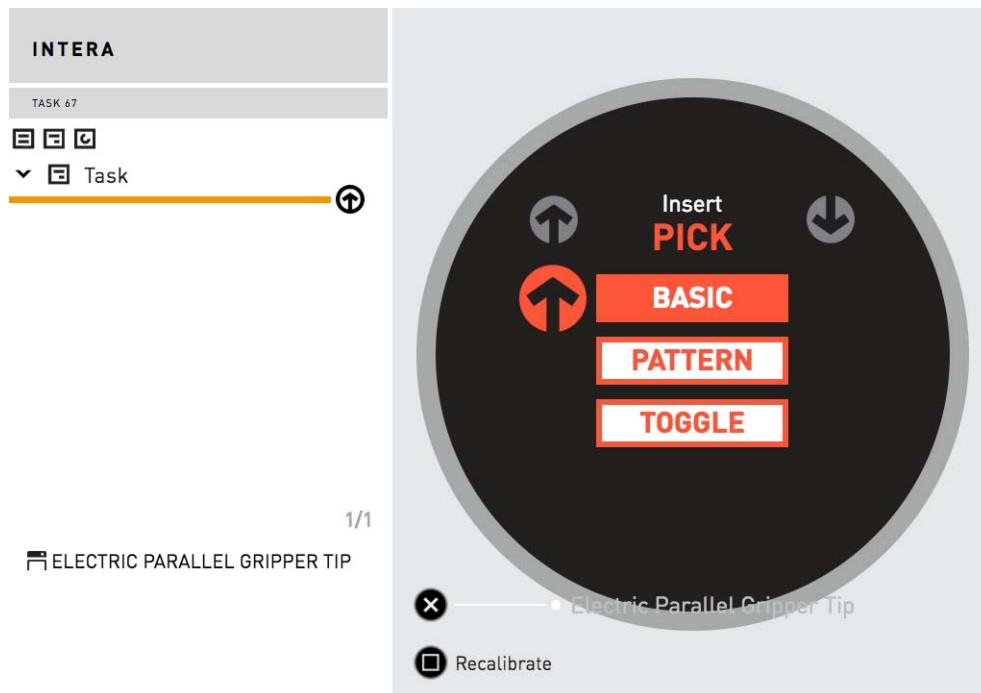
ELECTRIC PARALLEL GRIPPER TIP



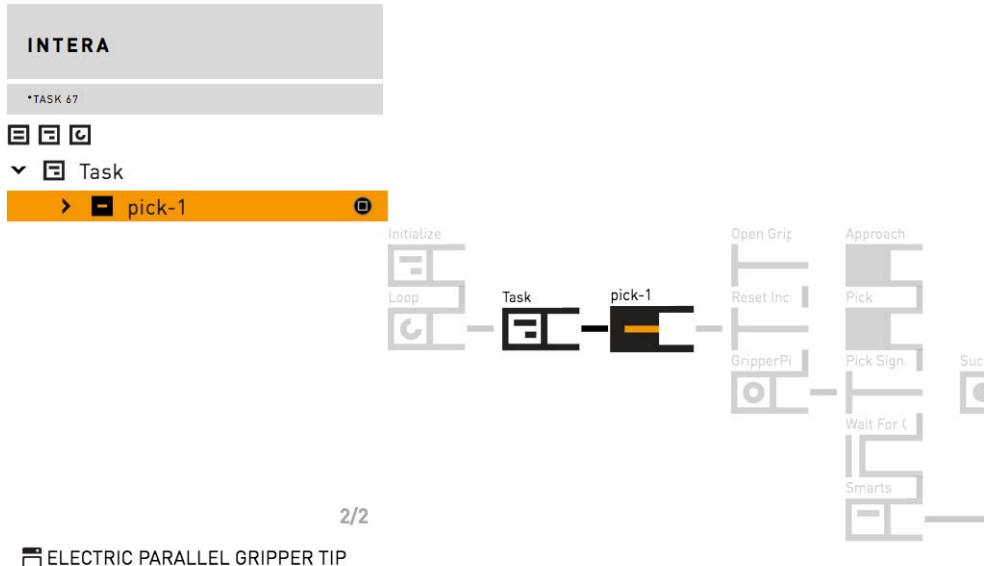
The left side of the screen shows the list view of the task with the currently selected tool displayed in the lower left corner (Electric Parallel Gripper Tip). The right side shows the tree view. Note that the task node is already selected.

4. Move the robot arm in zero-G mode to the location of the pick -- where the gripper is in position to pick up the object -- and press the Grasp button (the long button on the cuff).

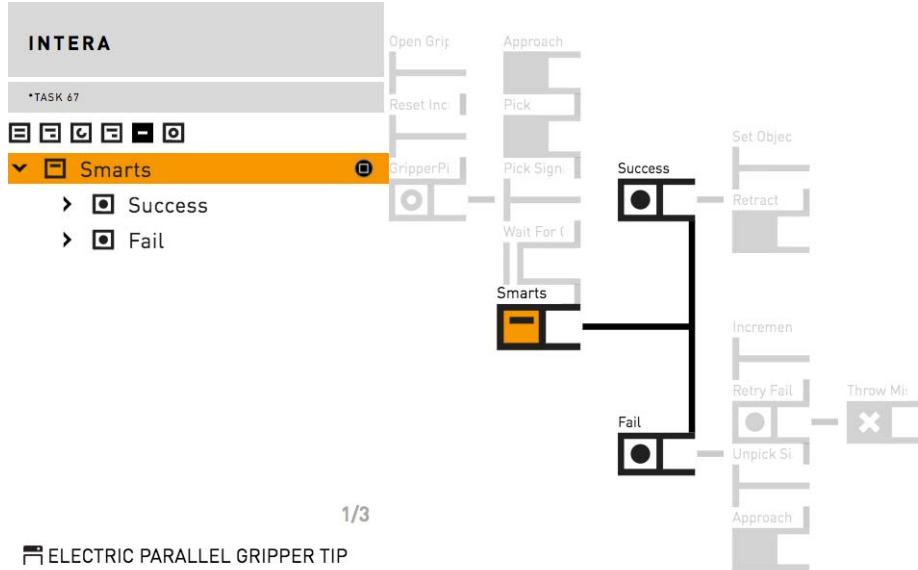
A menu of pick options is displayed. The default selection is Basic.



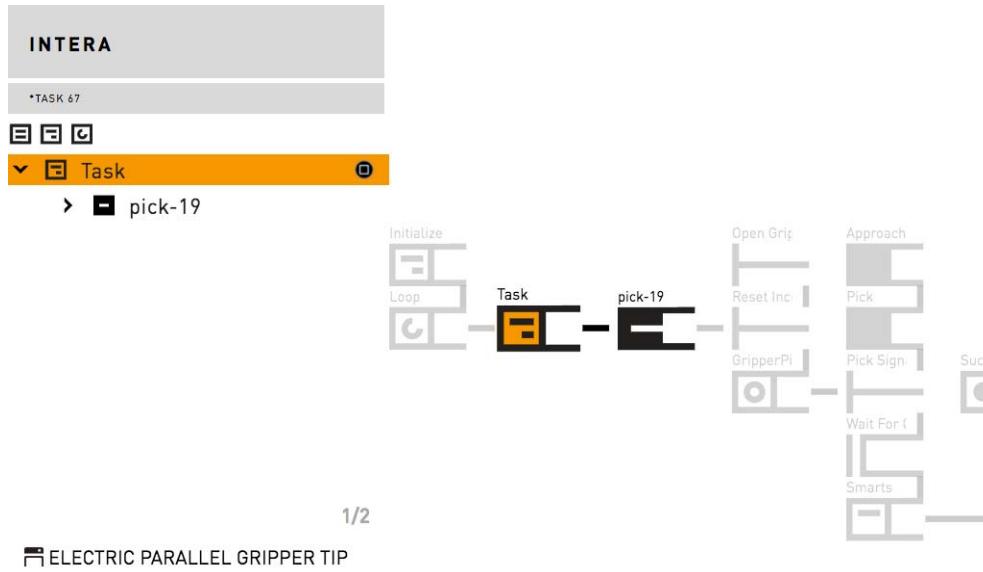
5. Press the Grasp button to accept the Basic Pick option. The gripper will close and create the pick branch.



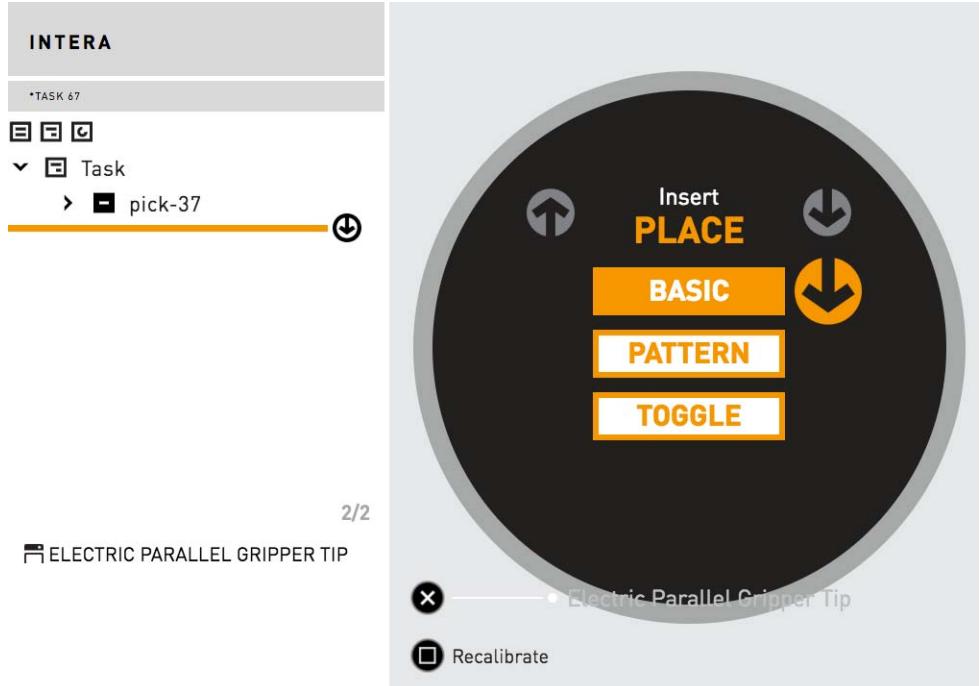
FYI, if you were to scroll to the Smarts node on the tree to display it in more detail, you would see the following branch, where the actions of the Success and Fail nodes are already defined. (Success means the grippers feel the force of an object when gripping; Fail means a failure to feel the force of an object.)



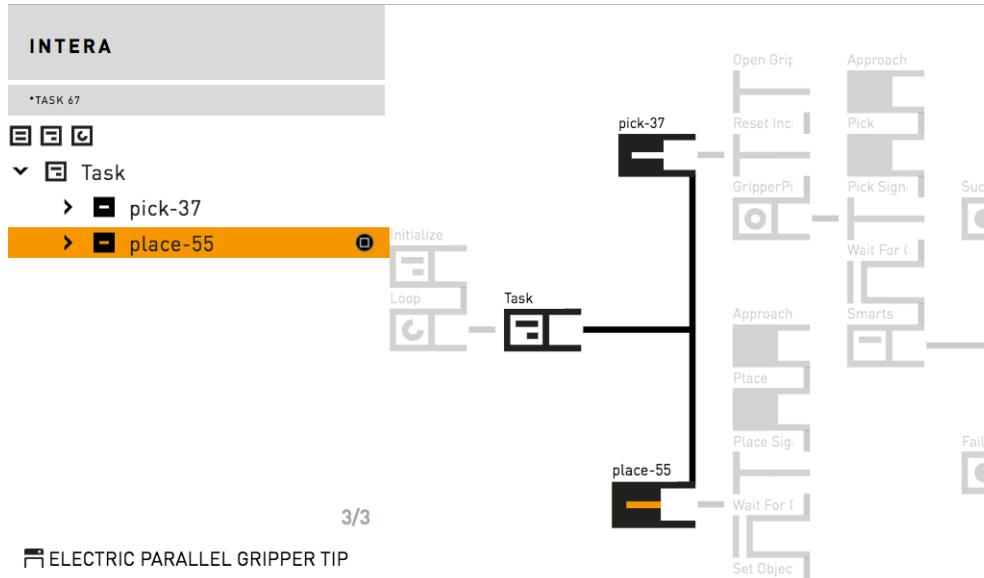
6. Scroll back to the Task in the list view.



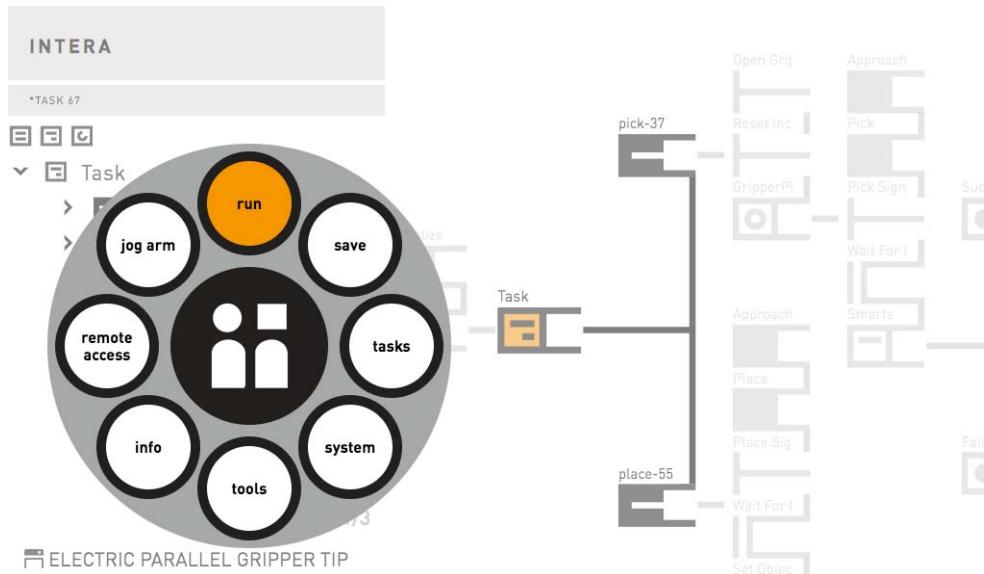
7. Move the robot arm in zero-G to the location of the Place.
8. Press the Grasp button to display the Place options.



9. Press the Grasp button to select the Basic Place option. A Place branch is created.



10. Press the Rethink button to display the Head Screen Menu.

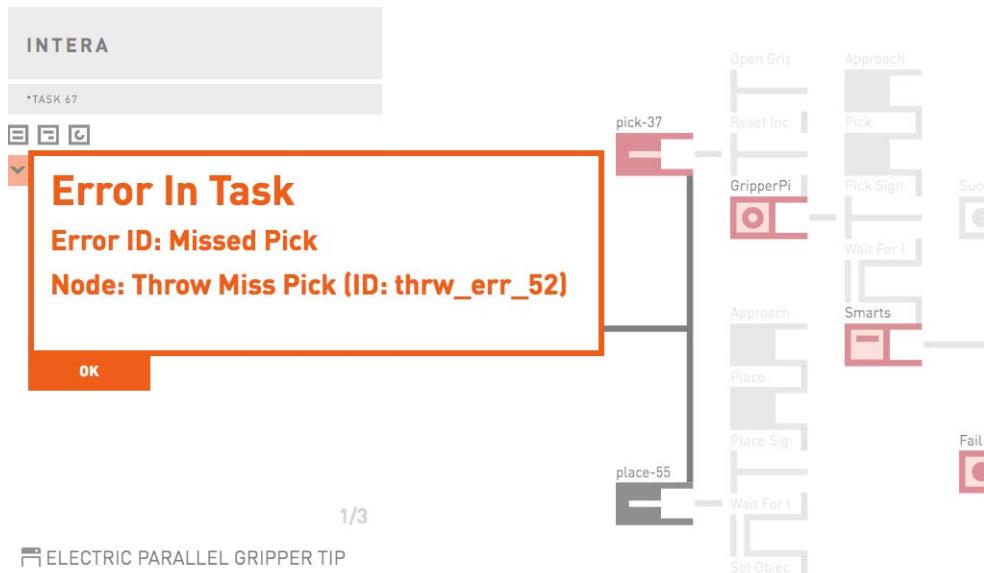


11. Select **run** and then **restart** to run the task.



The basic pick and place task should run as trained.

Sawyer will recognize mispicks and display an error message should two mispicks occur.





Train Pick and Place Patterns on the Head Screen

For the latest and most detailed information on Sawyer and Intera 5, we always recommend you see the Online User Guide at: mfg.rethinkrobotics.com/intera. The Rethink Robotics support page is here: [Rethink Support](#).

This tutorial shows you how to create a pick and place task using the robot's train by demonstration capabilities and Patterns.

In Intera, a pattern is a template of discernible regularity. As such, the elements of a pattern repeat in a predictable manner.

Another way to describe it -- In Intera, a pattern gives you the ability to specify the boundaries of a task, then fill that defined area with robot arm poses in a structured manner.

Patterns may be one-dimensional (for example, a row of five parts), two-dimensional (e.g. a 5x4 grid), or three-dimensional (e.g. a 5x4 grid with 3 layers, such as a box).

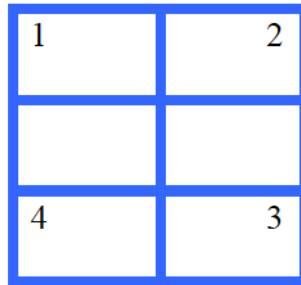
As with the previous simple pick and place train by demonstration, this task can be created entirely on Sawyer's Head screen. Please remember that, in Intera version 5.1, train by demonstration is only supported for the Rethink Electric Parallel Gripper.

If you haven't already done so, we recommend you read and complete the previous chapter, "Train a Simple Pick and Place on the Head Screen" on page 72 before continuing with this chapter.

To complete this tutorial, you will need a Rethink gripper or ClickSmart gripper.

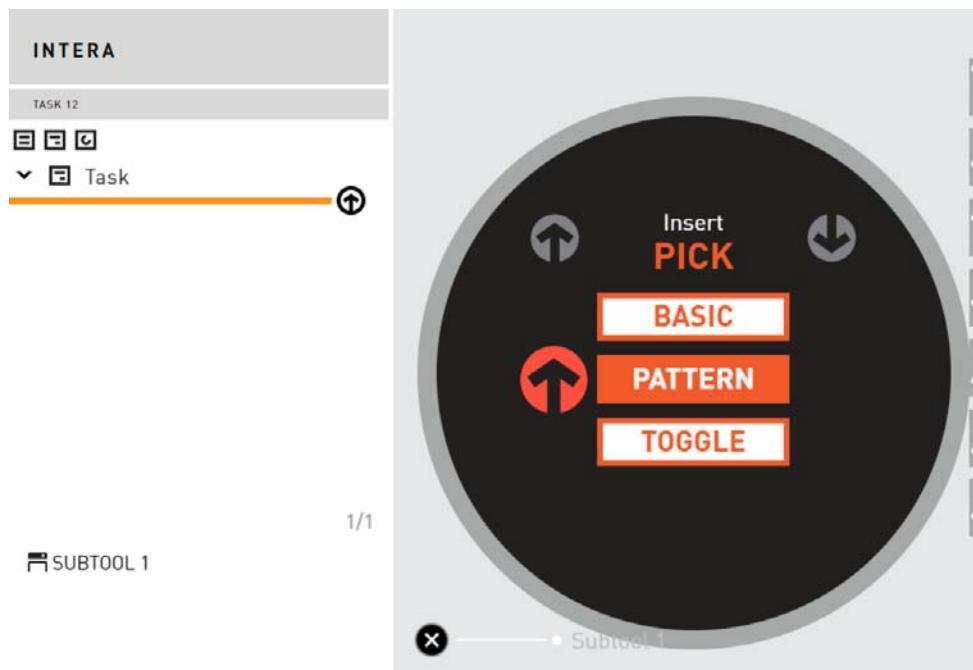


We will use the following 2x3 grid pattern to represent the pick locations and boundaries:



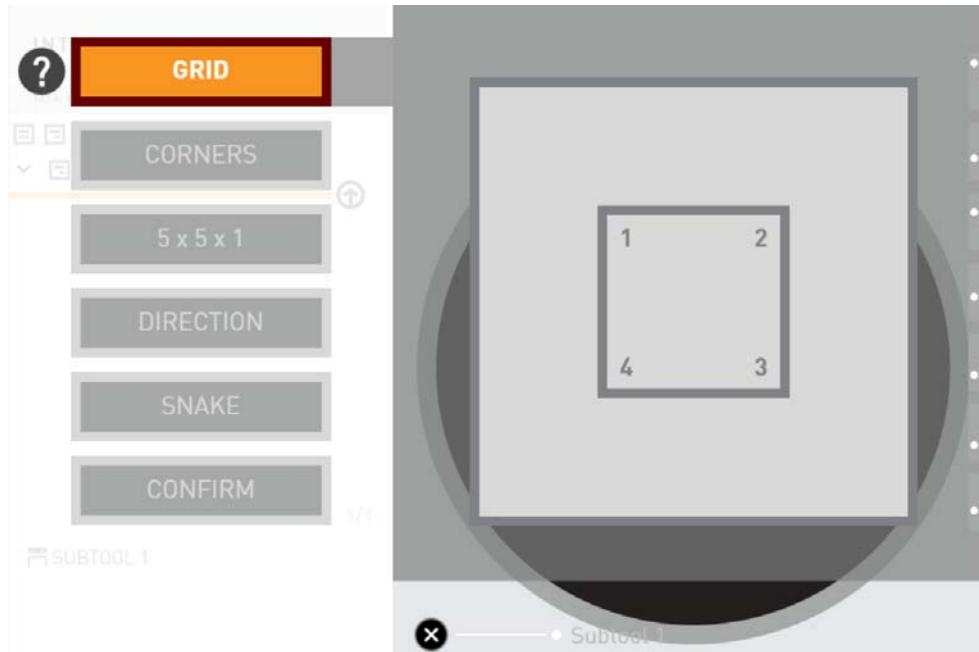
Train the Pick Pattern

1. Start a new task.
2. Move the robot arm in zero-G mode to the first point in the picking location, in this example, #1. This will be the outside boundary for this corner of the pattern.
3. Press the Grasp button. The Head Screen displays the Insert Pick menu.

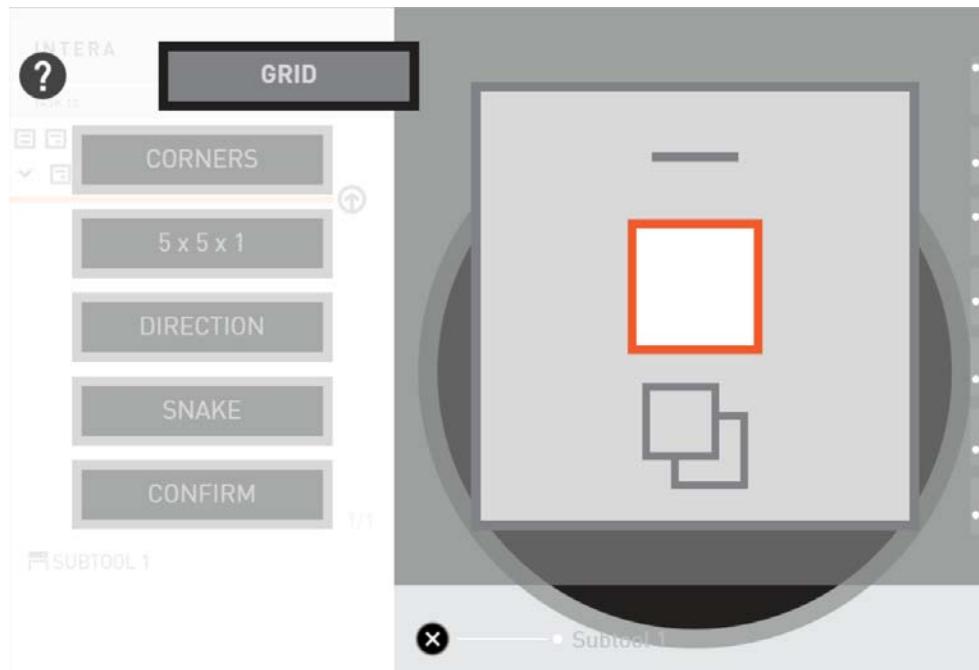




4. Scroll to **Pattern** and press the Grasp button to select it. The gripper will close on the part you are picking. The left side of the Head Screen now displays the steps you need to perform to create a pattern. The first step is to define the type of pattern.

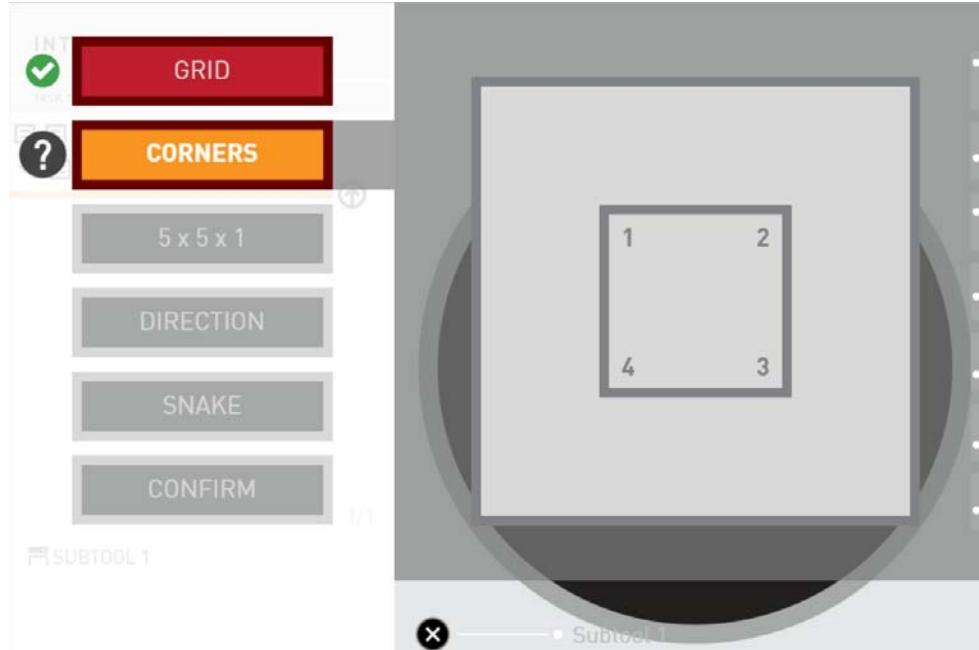


5. Press the **OK** button on the Navigator. That will display the type of pattern options: line, grid, and box.



Note: The currently active step is indented on the list of pattern-creating steps.

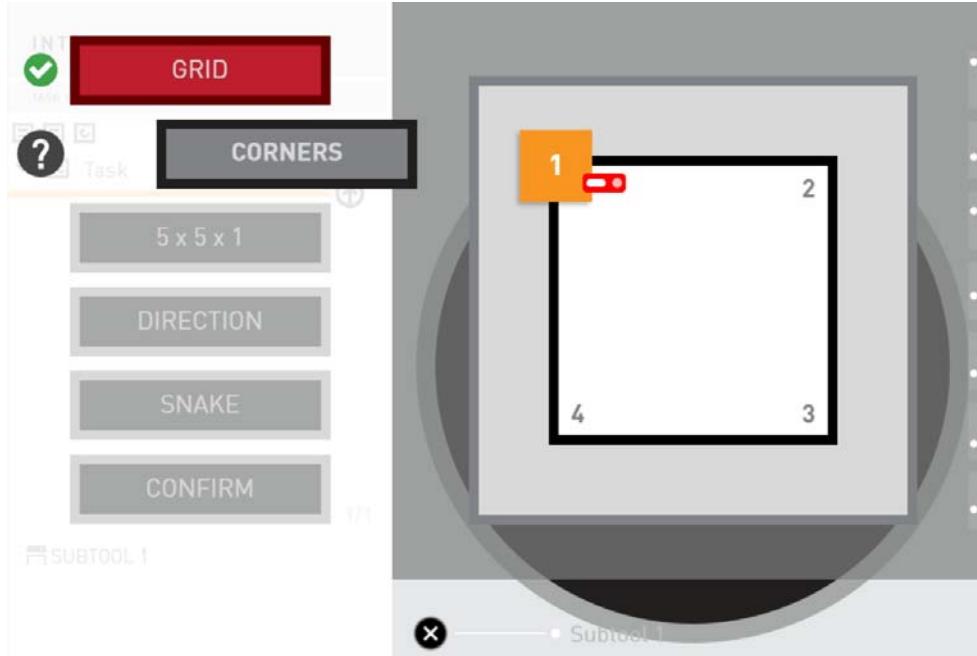
6. Select the Grid option, as shown.



Note: In the list of steps, Grid now has a green check mark, meaning its selection has been confirmed.

Since you chose to create a grid, the next step is to define its corners.

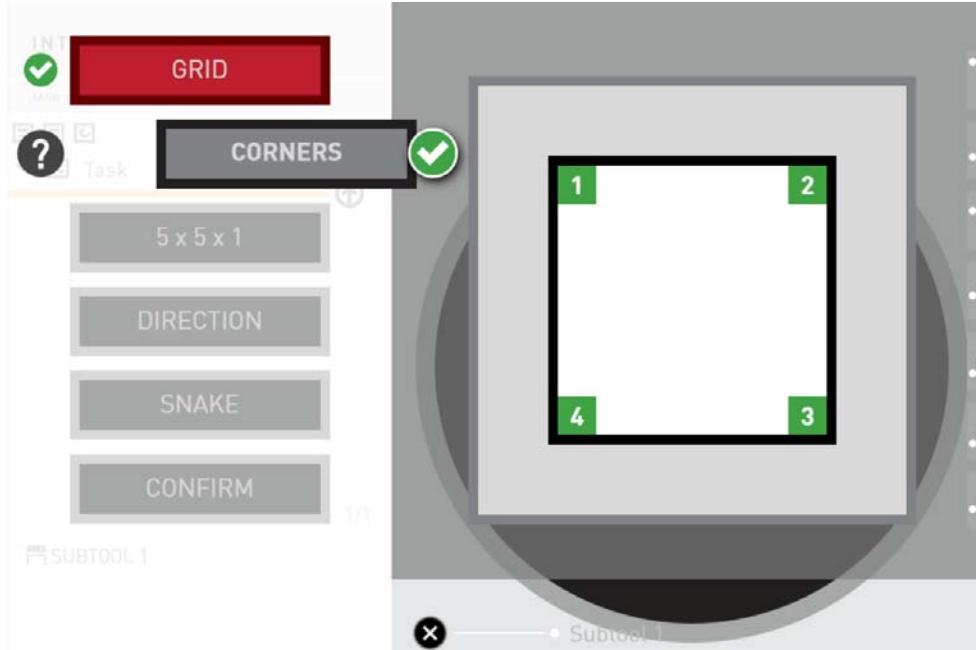
7. Press OK to start defining corners.



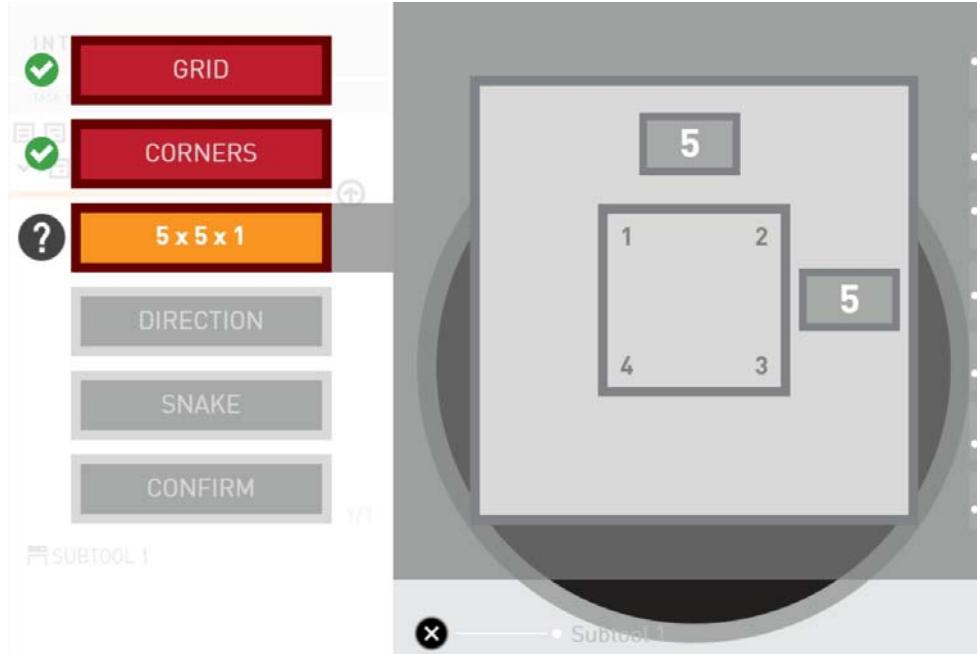
You will now set the outside corner -- the outer pick location of the first part -- for the first corner in the grid.

8. If the robot arm is not already there, move it in zero-G to the first corner, which would be #1 in our 2x3 grid example.
9. Press the OK button on the Navigator. (The Grasp button or the round Action button on the cuff will also work).
10. Repeat these steps for corners 2, 3, and 4. Make sure to define the corners *in the order shown*.

When you have defined all the corners, you will see the following display:

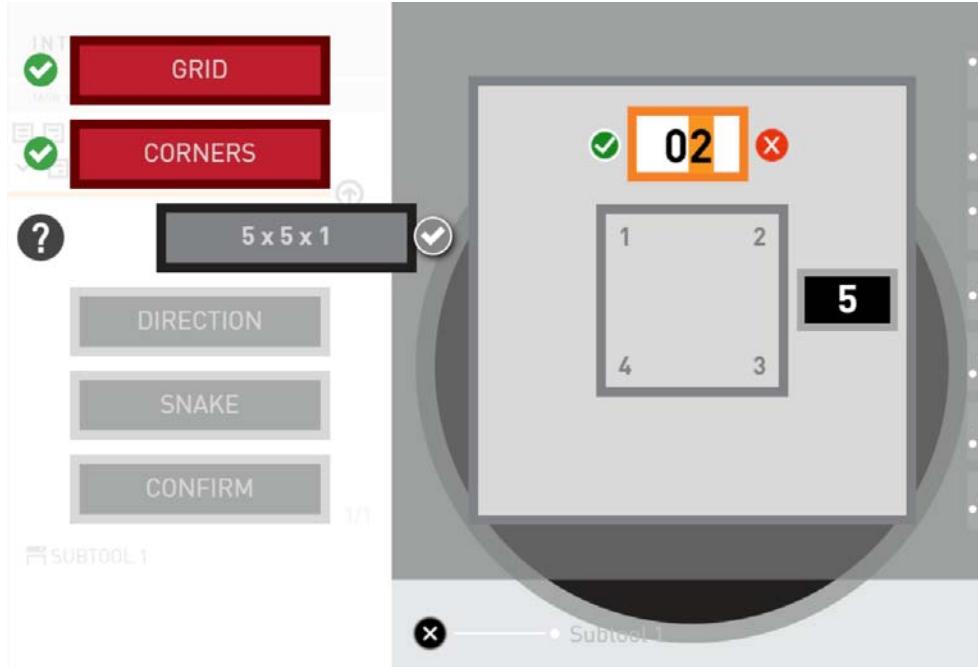


11. Press OK to go to the next step.

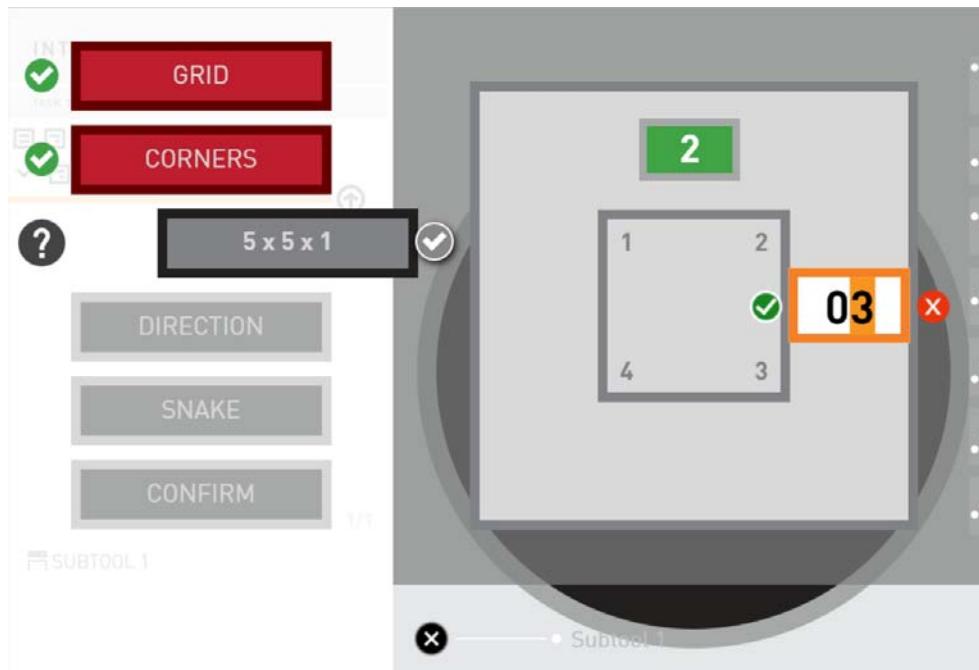


Remember that, in our example, there are 2 rows across the top of the grid, from corner #1 to corner #2, and 3 rows down, from corner #2 to corner #3.

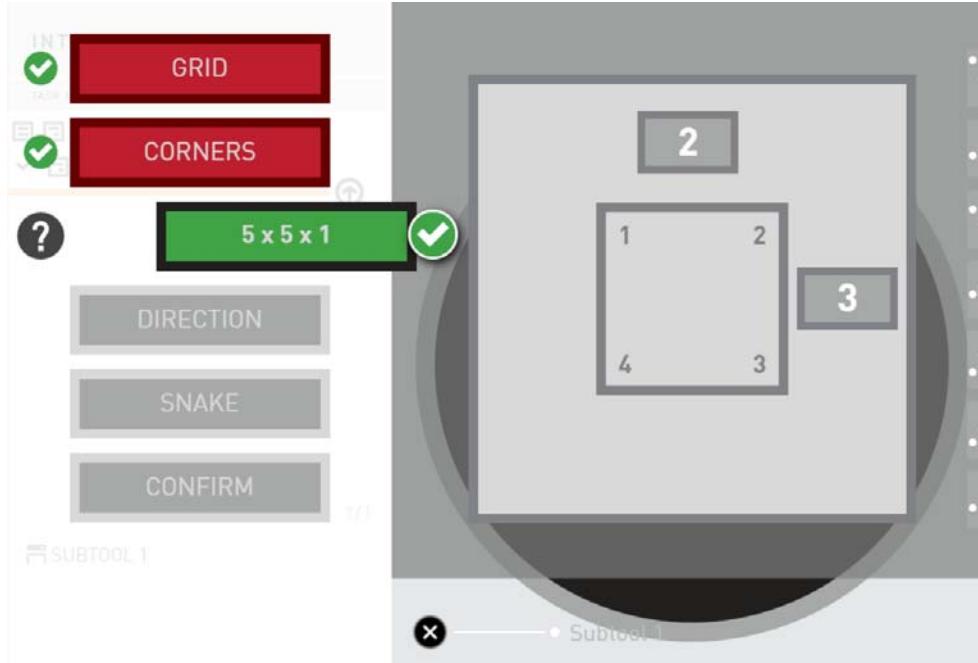
12. Scroll to display 2 in the box on top of the screen and select it with the OK button.



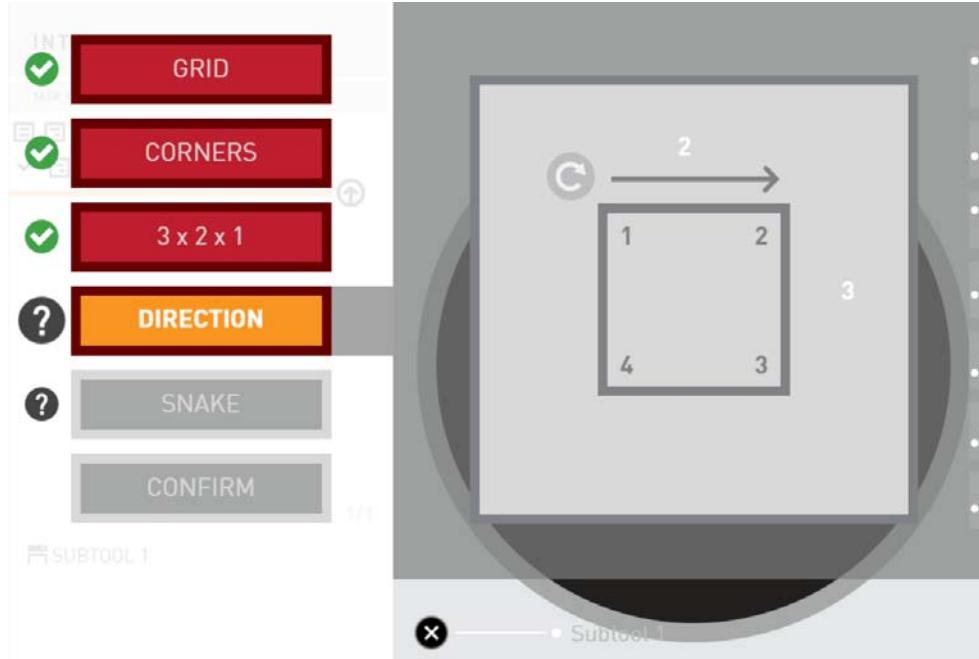
13. There are three rows from corner #2 to corner #3, so scroll to the small box on the right side of the screen and change the number to 3 and press OK, as show below.



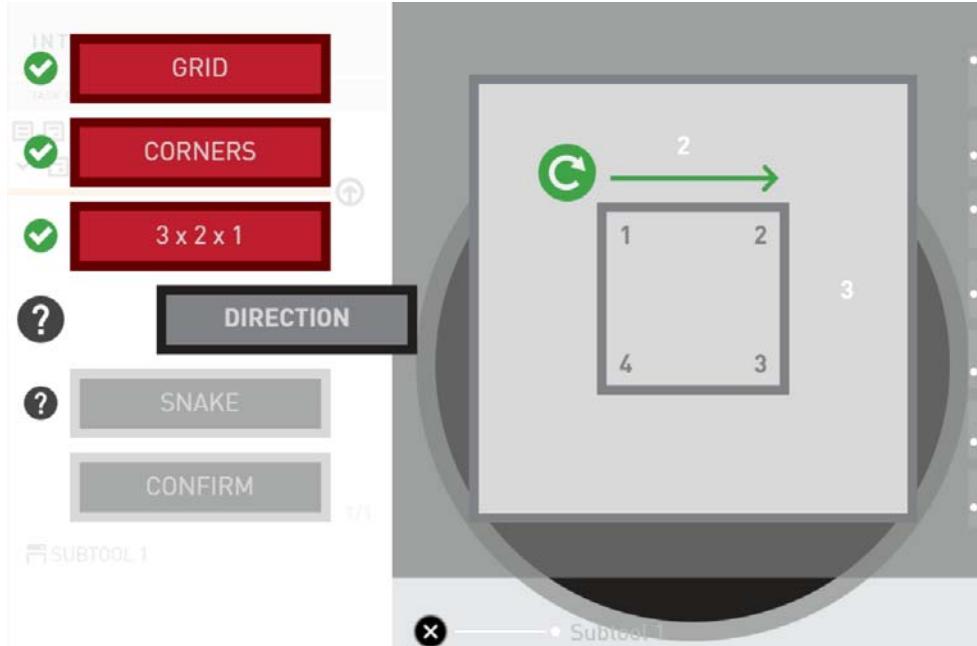
14. Scroll to the 5x5x1 checkbox and press OK. The setup of rows will look like this:



15. Press OK to go to the next step, defining the direction.



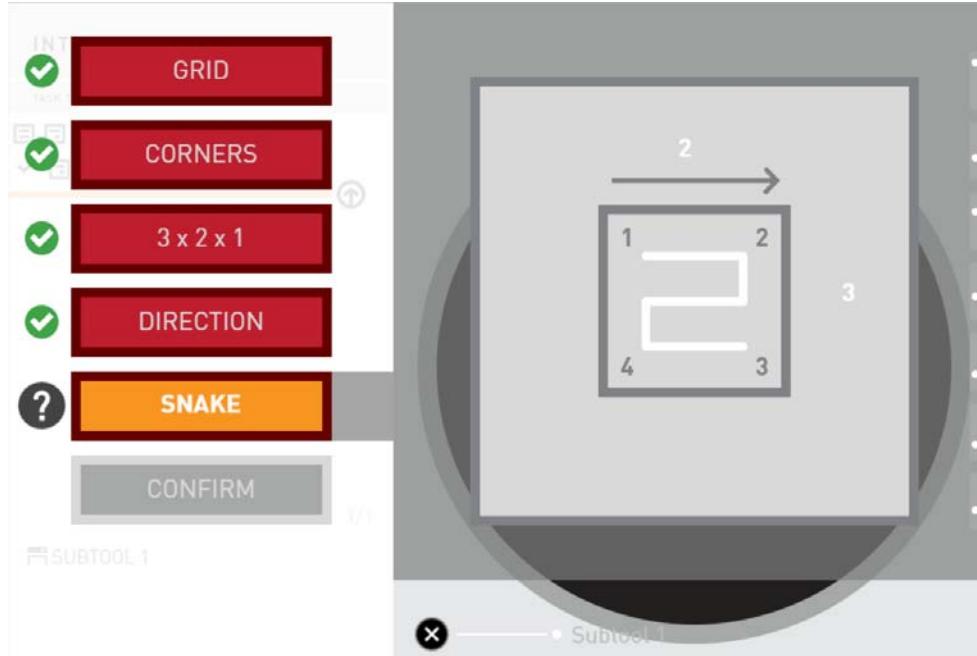
16. Press OK to allow modifications to the direction,



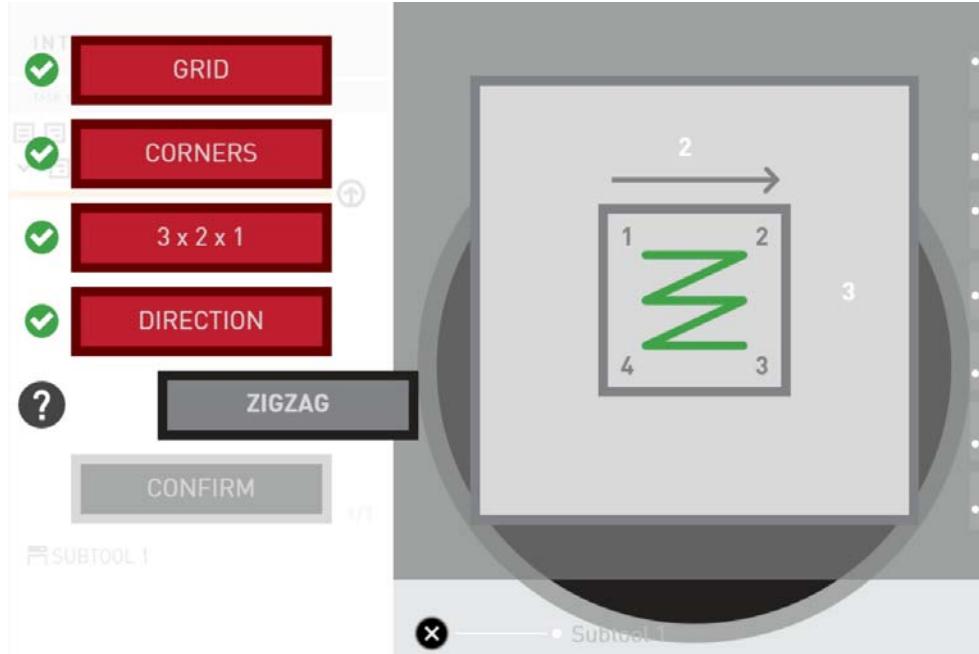
17. Scroll to choose the direction of the arm movement, that is, in which direction the first two picks are going to be.

This example shows the arm will move from 1 to 2.

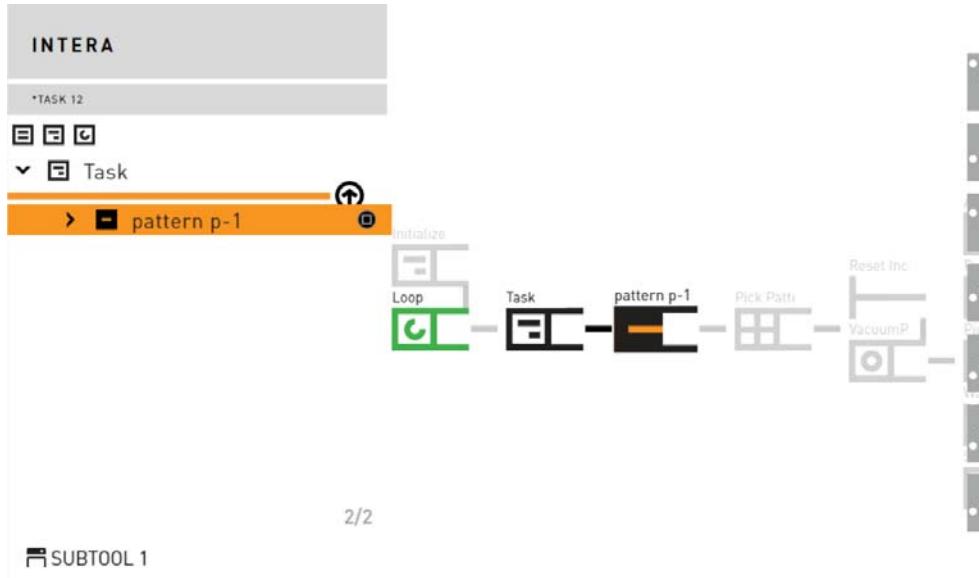
18. Press OK to confirm your choice.



19. Select the type of arm movement desired for the picks, either Snake or Zigzag.



20. The last step is to confirm the settings you have trained for your pattern. Press OK to confirm your pattern and to create the behavior tree.

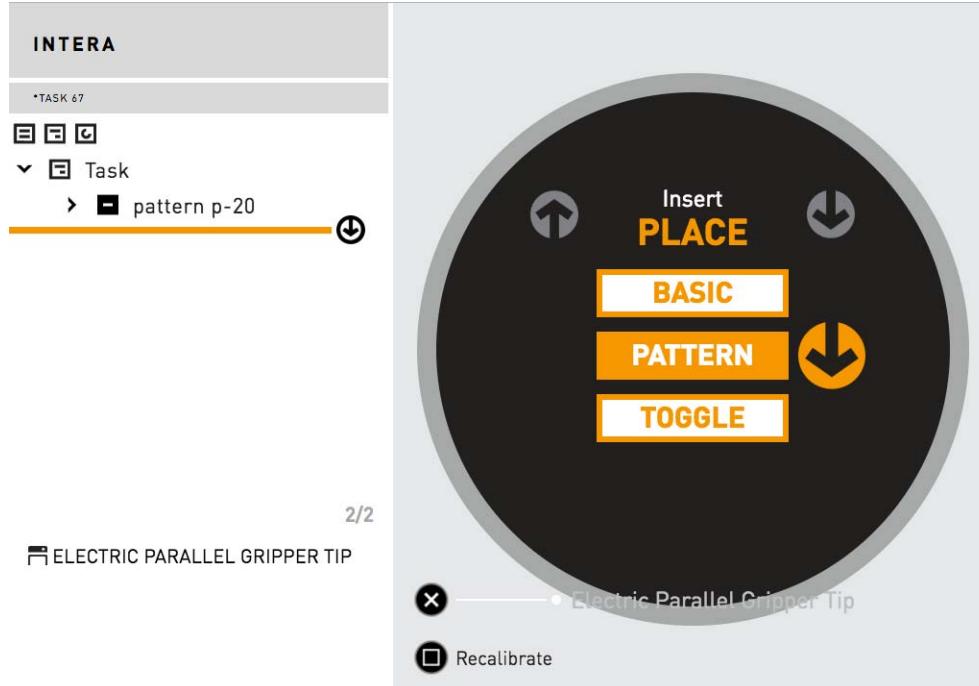


Notice how the parent node for the pick is a pattern node.

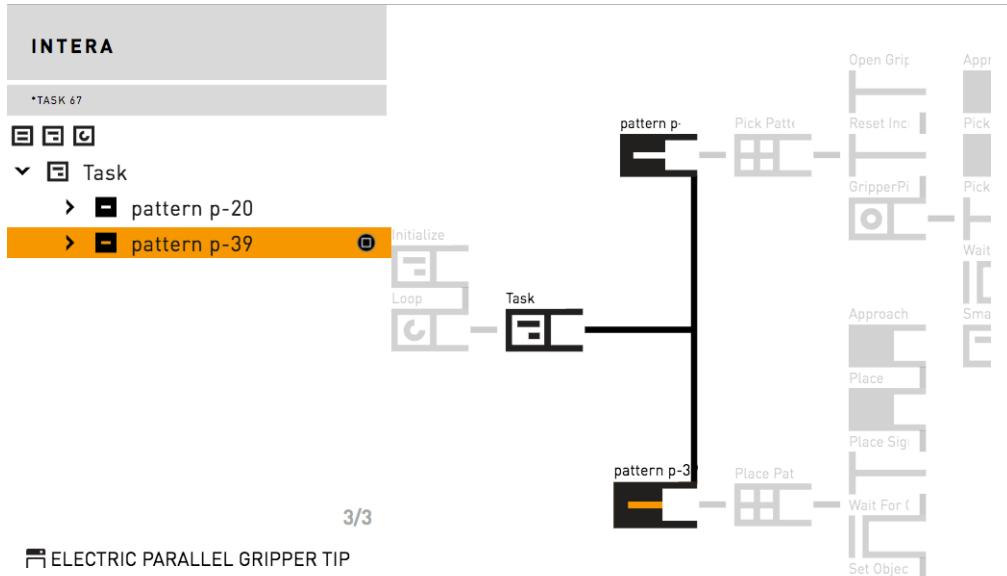
Train the Place Pattern

Now you can do the same for a Place pattern!

21. Press the Grasp button and select Pattern.



Follow the same steps you performed for creating the pick pattern. When you're done, your Head Screen should look much like this one:



You may now run the task.



Intera Insights

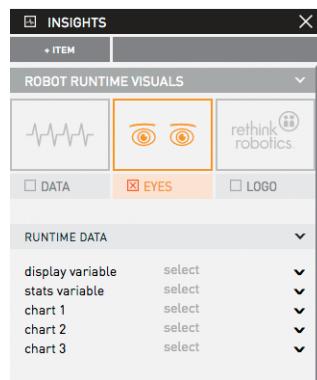
For the latest and most detailed information on Sawyer and Intera 5, we always recommend you see the Online User Guide at: mfg.rethinkrobotics.com/intera. The Rethink Robotics support page is here: [Rethink Support](#).

Intera Insights Overview

Intera Insights is a set of tools designed to allow easy real-time monitoring of task data. This includes all arm data (including position, rotation, and forces), EOAT sensor data, cycle time, and more. Data can be placed on Sawyer's Head Screen, or tracked through Studio in the Intera Insights panel.



Intera Insights Panel

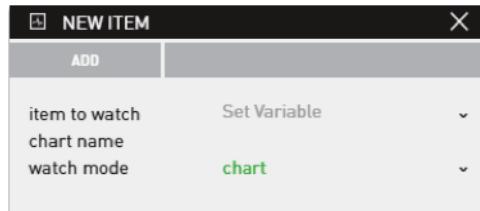


Robot Runtime Visuals

Select a Robot Runtime Visual to control what is displayed on the head screen as Sawyer runs a task. If ‘Eyes’ is selected, Intera will display Sawyer’s eyes. If ‘Logo’ is selected, the Rethink Robotics logo will be displayed on the screen during the task. If ‘Data’ is selected, the head screen will display charts and variables corresponding to the data set in ‘Runtime Data.’

Charts List

The ‘Charts List’ is used to create and monitor charts to track runtime data. To create a new chart, press the ‘+ Chart Item’ button. This will open the following interface:





Item to Watch

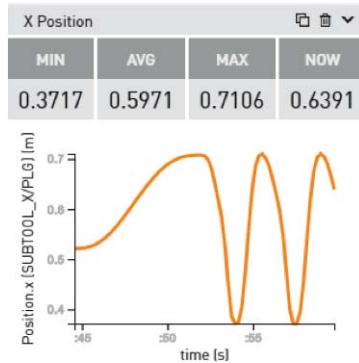
Use the ‘Item to Watch’ drop-down menu to select a specific variable to add to the chart. This can include any variable in the Shared Data panel.

Chart Name

Use ‘Chart Name’ to name the chart. This will default to the same as the name of the variable being charted; the user can change this to any valid string.

Watch Mode

This selects whether the variable will be added as a chart or as a value in the ‘My Values List.’ To add a chart, leave this value as ‘chart.’



For each chart which is added to the ‘My Charts List,’ the above interface will be generated. While a task is running, this panel displays a chart of the selected variable vs the task’s run time, as well as the minimum, maximum, average (mean), and current values. Hovering over any of these values will display the time and date for a particular event.

Press the ‘pop-out’ button (displayed as two stacked squares in the top right of the interface) to expand chart out to a larger panel within Studio.

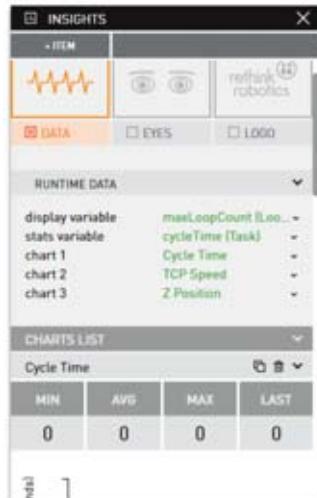


Values List

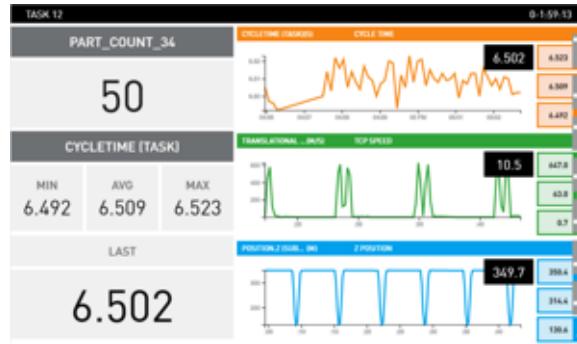
The ‘Values List’ can be used to track the value of specific variables throughout a task. To add a variable, follow the same process by which a chart was added; instead of selecting ‘chart’ under watch mode, select ‘value.’ Values cannot be given names.

Runtime Data

The Runtime Data section of the Intera Insights panel is used to control which variables and charts are monitored on the Head Screen if ‘Data’ is selected under Robot Runtime Visuals.

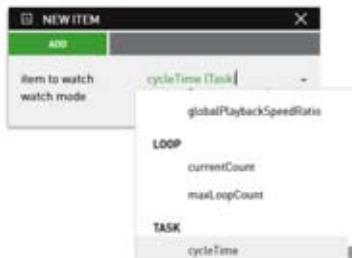


The interface displayed on the Head Screen given the above configuration is as follows:



Adding a Variable

Any variable can be monitored on the Head Screen. To add a variable, select the variable to be tracked under either 'Display Variable' or 'Stats Variable.' A display variable will print the selected value to the head screen. A stats variable will print the selected value to the head screen, along with the minimum, maximum, and average values of the variable.



Adding a Chart

Before a chart can be added to the runtime data panel, it must be created in the 'Charts List.' Up to 3 charts can be added to the head screen. Once a chart has been created, add it to the head screen by selecting it in the 'Chart 1,' 'Chart 2,' or 'Chart 3' dropdown menus. The chart will then be displayed on Sawyer's head during the task, along with the current value, maximum value, minimum value, and average value.



Tracking Cycle Time

The cycle time of any given task can be monitored using the Intera Insights.

Defining a Cycle

Before a cycle can be tracked, the user must tell Intera what is considered a cycle. The cycle time of any Loop, Sequence, Priority, Parallel, Do If, Loop If, Vision Inspector, Vision Locator, Contact Mode, or Pattern can be tracked. To enable cycle time tracking on any of these nodes, enable the 'Track Cycle Time' in the node inspector. This will create a variable which can be found under Current Task's Shared Data > Node Name > cycleTime.



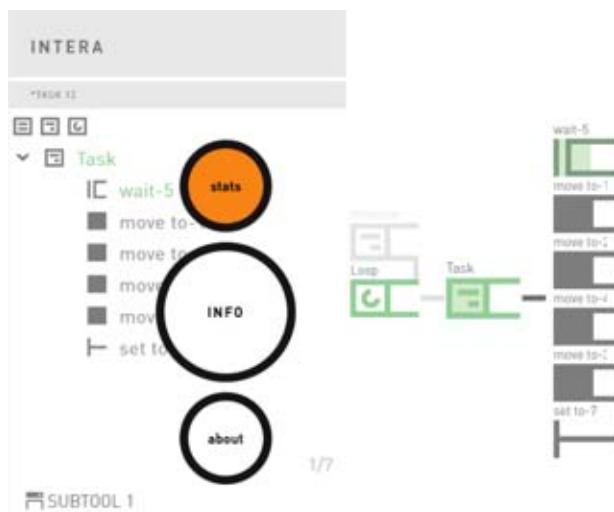
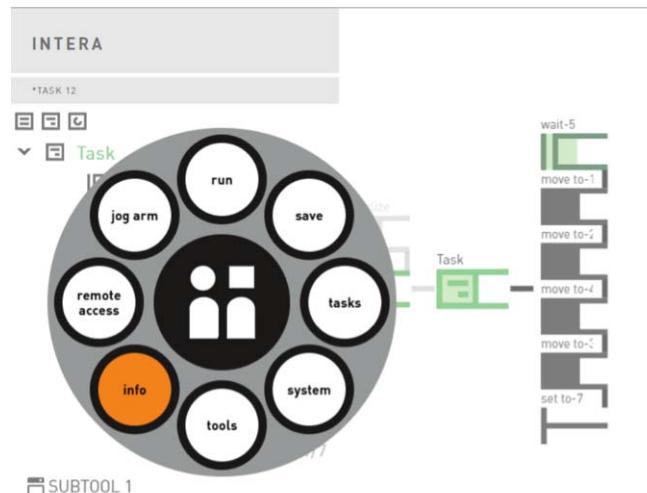
Tracking Cycle Time in the Intera Insights

To track cycle time in the Intera Insights, simply select the cycleTime variable corresponding to the node which you intend to track the cycle time of.



Viewing Data on Robot when Task is Paused

When the robot is paused, you may view the stored Intera Insights data by pressing the Rethink button > Selecting INFO > Selecting STATS





Setting Head Angle

When the task is started, continued, or restarted, the head will make a best effort to remain in that same angle relative to the base and regardless of arm movement. In order to change the angle, pause the task and move the head to desired angle. Then continue or restart a task.



Force Sensing and Selective Arm Stiffness

For the latest and most detailed information on Sawyer and Intera 5, we always recommend you see the Online User Guide at: mfg.rethinkrobotics.com/intera. The Rethink Robotics support page is here: [Rethink Support](#).

As of Intera 5, Sawyer can sense and measure force on the robot end point. It can therefore react to outside conditions, as well as make use of its own measured force when performing tasks. In addition, it is now possible to select how stiff the arm should be per axis, and the maximum amount of force the robot may use when trying to reach a point in space.

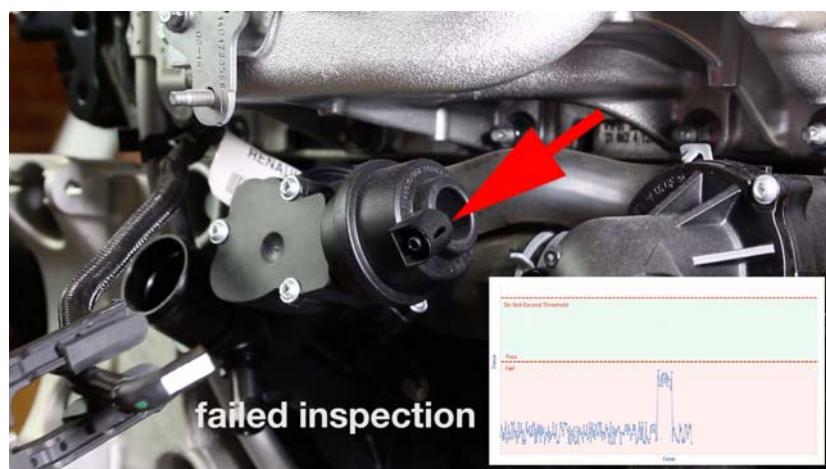
With force sensing, Sawyer can actually change what parts of a task it will perform based on the kind of force acting upon it (for example, from which direction, and/or how much force.) For example, you may be able to train Sawyer to take different strategies when inserting a part into a fixture depending on when and what forces are being sent. This will allow the robot to better deal with part and process variation. The selective stiffness will also help with this process.

A Practical Application for Using Force Sensing, Selective Stiffness, and Force Limitations

Sawyer can be trained to inspect how securely a wire is connected to an engine. Sawyer grabs and pulls on the wire (using selective stiffness to deal with how the wire is situated in space and limiting the force applied so the robot doesn't inadvertently pull the wire) with a force defined in its task. If the wire is not pulled out by that amount of force (sensing the desired force), it passes inspection.



If the wire is pulled out (doesn't sense a force resistance), it fails inspection.



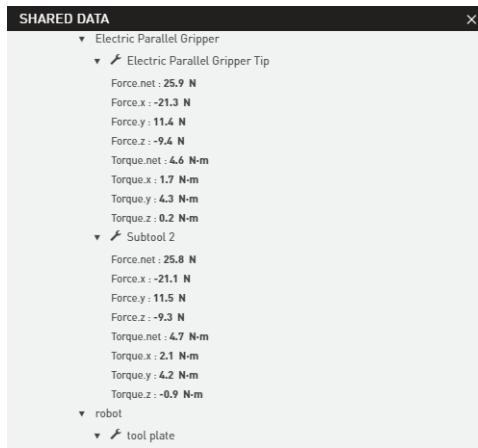
Sawyer can also sense, measure, and apply rotational force (torque). Example: The robot is trained to rotate a wheel on an engine by exerting a certain amount of force. If the wheel turns properly when that force is applied, it passes inspection. If not, it fails. And, because Sawyer is a non-rigid robot, it does not have to be positioned perfectly concentric with the center of the wheel as a rigid robot would. Instead, it only needs to be relatively close to the center of the wheel to do the job.



When it rotates the wheel, Sawyer will absorb some of the impact in the environment and perform the task.

How to Access and Modify Force Data in Intera Studio

To display current force information, select the Shared Data button from the Task Bar. The live force data is located under Robot Data.



Current forces on the arm are displayed in translation (force.x, y, and z) and rotation (torque. x, y, and z). The user may select the desired units of measure in Settings. In this example, the units are Newtons (N).

Compliance, Impedance Mode, Force Mode

To better understand the concept of impedance, think of a virtual spring connecting the commanded and actual position. During a move involving contact, the actual position is pulled along by the commanded position by the virtual spring connecting the two. When the actual position equals the commanded position the force produced by the virtual spring is close to zero. But as the distance increases between the two positions, the force increases in proportion to the stiffness of the spring and the distance. When performing a move involving contact using impedance mode, this force corresponds to the force that the active-endpoint will impart to a surface into which it comes in contact.

In Impedance Mode, the arm moves to the position you set. You define compliance by specifying how stiff the robot should be along which axes. The lower the level of stiffness (impedance), the

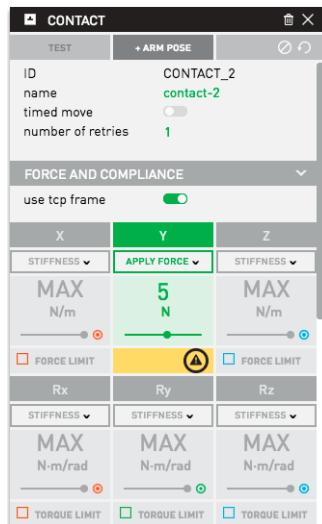


more the arm will comply to its environment. Force or torque limits define how strongly the endpoint can push to reach the set position.

To define compliance:

1. Add a Force Parent node that instructs Intera 5 to go into Interaction control, a combination of both robot position and force control.
2. Add a Contact node.
3. Set a pose by clicking on + Arm pose in the node inspector.
4. Specify Sawyer's stiffness in relation to either the Base Frame or the Active Endpoint Frame by entering a value in the x,y, and/or z boxes set to Stiffness mode. (The maximum stiffness value in any axis is 1300.)

For example, if you wanted to make the arm extremely compliant along the z axis relative to the end effector, you would select the Active Endpoint Frame as the relative frame and enter 0 for z translation (illustrated below).



The forces/stiffness where the axis is grayed out are set to the default value. Once a value is modified, the axis cell will change color.

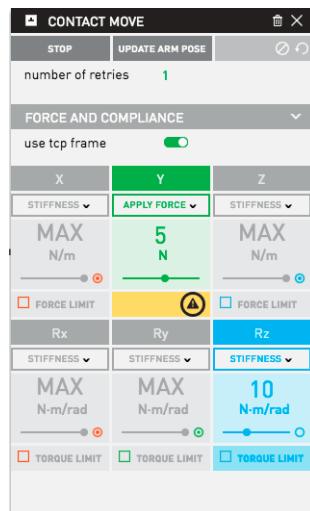
5. Click Go To at top of the node inspector.



Now, when you move the arm in Zero G mode, you'll see that Sawyer is constrained in its movement along the z axis (compliant in z) relative to the end effector, and rigid along the x and y axes.

To limit the amount of force with which Sawyer pushes, check the Force or Torque Limit box for the appropriate axis or rotation, and enter a value. Sawyer's arm will then push no more than the defined amount of force. A practical example of this would be training Sawyer to polish a curved surface with no more than a certain amount of force.

In Force Mode, the endpoint exerts a directional force on objects it comes in contact with, instead of moving to a set position. The endpoint will accelerate in the force direction until it makes contact. The force values can be either positive or negative (push or pull).



When the actual position is the same as the target position of a given Contact node, no forces are generated. So, if you are using stiffness and you want a force to be applied when the active endpoint is in contact with a surface, you need to change the position of the Contact node to below the surface.

Unless the active endpoint is in contact with a surface, no forces are imparted because the commanded and actual position are essentially the same. If you are using pure impedance mode, you will not experience the accelerations that can occur with force mode and the arm is in free space. Both modes have the effect of imparting force on a surface in which they come into contact, but impedance mode is more predictable.



I/O Devices

For the latest and most detailed information on Sawyer and Intera 5, we always recommend you see the Online User Guide at: mfg.rethinkrobotics.com/intera. The Rethink Robotics support page is here: [Rethink Support](#).

This section describes the electrical interfaces available to the Sawyer robot. The different interfaces are:

- Controller I/O
- External I/O
- Safety Rated Controller I/O

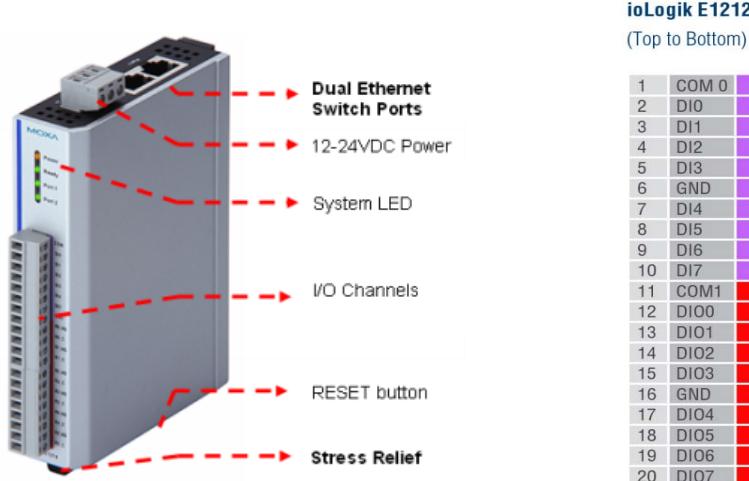
DISCLAIMER

Any advice provided to you relating to the integration of a Rethink Robotics product with any third party product into to your facility is provided “as is.” Because Rethink Robotics does not have access to the systems you are using, nor does Rethink Robotics have any control over how you may implement any integration with third party products, Rethink Robotics assumes no liability for this limited advice.

Controller I/O

The Sawyer robot controller uses a Moxa ioLogik E1212 Remote Terminal Unit for interfacing with the external world. This unit has been preconfigured to work out-of-the-box with the Intera software and shows up as the “Robot” device when configuring signals on a task.

Please refer to ioLogik E1200 Series User’s Manual for details on the ratings and specifications of the switch: <http://www.moxa.com>



Moxa ioLogik E1212 Hardware

SPECIFICATIONS

Digital Inputs (8 channels)

Sensor type: Wet Contact (NPN or PNP), Dry Contact

I/O Mode: DI or Event Counter

Dry Contact:

- On: short to GND
- Off: open

Wet Contact (DI to COM):

- On: 10 to 30 VDC
- Off: 0 to 3 VDC

Digital Output (8 channels)

- Type: Sink
- I/O Mode: DO or Pulse Output
- Pulse Output Frequency: 500 Hz



- Over-Voltage Protection: 45 VDC
- Over-Current Protection: 2.6 A (4 channels @ 650 mA)
- Over-Temperature Shutdown: 175°C (typical), 150°C (min.)
- Current Rating: 200 mA per channel

Physical Characteristics

- Wiring: I/O cable max. 14 AWG

Environmental Limits

- Operating Temperature: -10 to 60°C (14 to 140°F)
- Storage Temperature: -40 to 85°C (-40 to 185°F)
- Ambient Relative Humidity: 5 to 95% (non-condensing)
- Altitude: Up to 2000 m

Standards and Certifications

- Safety: UL 508
- EMI:
 - EN 55022; EN 61000-3-2; EN 61000-3-3; FCC Part 15, Subpart B, Class A
- EMS:
 - EN 55024, EN 61000-4-2, EN 61000-4-3, EN 61000-4-4, EN 61000-4-5, EN 61000-4-6, EN 61000-4-8, EN 61000-4-11
- Shock: IEC 60068-2-27
- Freefall: IEC 60068-2-32
- Vibration: IEC 60068-2-6
- Green Product: RoHS, CRoHS, WEEE
- Hazardous Location: UL/cUL Class I Division 2, ATEX Zone 2



LED INDICATORS

LED	State	Description
Power	Amber	System power is ON
	OFF	System power is OFF
Ready	Green	System is ready
	Flashing	Flashes every 1 second when the "Locate" function is triggered
	Flashing	Flashes every 0.5 second when the firmware is being upgraded
	Flashing	ON/OFF cycle period of 0.5 second represents "Safe Mode"
	OFF	System is not ready
Port 1	Green	Ethernet connection enabled
	Flashing	Transmitting or receiving data
Port 2	Green	Ethernet connection enabled
	Flashing	Transmitting or receiving data
EXT	Green	EXT field power input is connected
	Off	EXT field power input is disconnected

I/O Wiring Diagram

ATTENTION

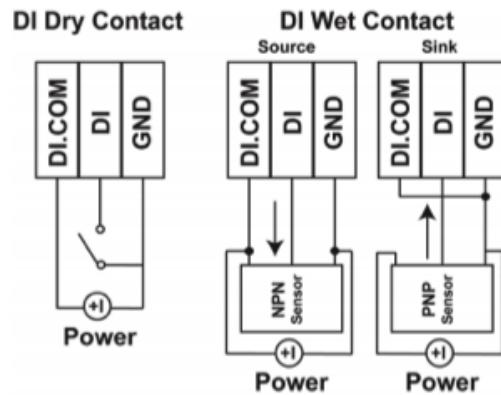


Determine the maximum possible current for each power wire and common wire. Observe all electrical codes dictating the maximum current allowable for each wire size. If the current exceeds the maximum rating, the wiring could overheat, causing serious damage to your equipment. For safety reasons, we recommend an average cable size of 22 AWG. However, depending on the current load, you may want to adjust your cable size (the maximum wire size for power connectors is 2 mm).



INPUTS

The inputs belong on channels DI0-DI7. Please follow the diagram below in order to understand how to connect an input device into the Moxa ioLogik E1212 device:

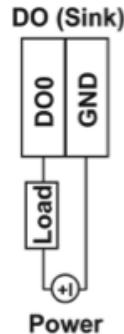


A **Dry Contact** is a contact that does not provide voltage.

A **Wet Contact** is a contact that will provide voltage when closed.

OUTPUTS

The outputs belong on channels DIO0-DIO7. Please follow the diagram below in order to understand how to connect an output device into the Moxa ioLogik E1212 device:



Note: A “load” in a circuit schematic is a component or portion of the circuit that consumes electric power. For the diagrams shown in this document, “load” refers to the devices or systems connected to the I/O unit.

IMPORTANT: Remove power (unplug) robot before wiring to I/O device.

External I/O

The Sawyer controller comes with 8 Digital Inputs and 8 Digital Outputs. If more I/O is required, Sawyer may communicate to external machines by adding an external Ethernet-connected Modbus TCP/IP Remote Terminal Unit (RTU).

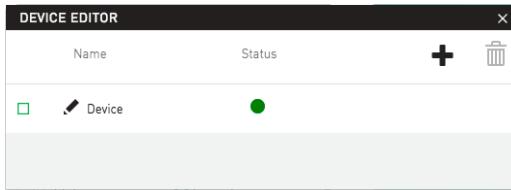
CONNECTING A MODBUS REMOTE TERMINAL UNIT (RTU) TO SAWYER

Set the IP address of the Modbus device to: 169.254.#.# where # is any number between and including 1 to 254, and the subnet mask is 255.255.0.0. (Please refer to the RTU manufacturer’s instructions for assigning the IP address.)

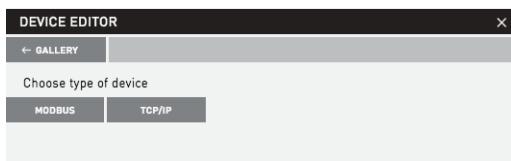
1. With Sawyer powered off, use an external network switch and connect the controller, the PC, and the device to that switch so they can all talk to each other.
IMPORTANT NOTE: Use the ethernet port on the outside of the controller, the one under the plastic cap. *Do not* use either the ethernet port inside the controller door or the port on the Moxa itself. These ports will not work.
2. Turn on the device.
3. Power Sawyer on.



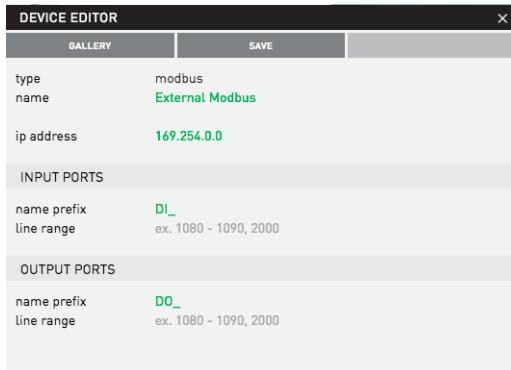
4. Connect Sawyer to a PC as described in “Getting Started with Intera 5” on page 26.
5. In Intera Studio, select the Devices icon from the Task Bar to display the Device Editor.



6. Click on the + icon to add a device.



7. Select Modbus, then configure the Modbus device as needed.



UNDERSTANDING THE MODBUS TCP PROTOCOL

This section will help explain: the Modbus TCP protocol; how to correctly configure or network an external device to communicate with Sawyer; and what information is sent or received via Modbus TCP. Sawyer is configured as the Modbus TCP Client (Master) and any external device must be



configured as a Modbus Server (Slave) and communicate using Modbus TCP in order to communicate with Sawyer.

Modbus TCP

INTERA is capable of communicating to external devices, configured as Slave Devices, with the Modbus TCP Protocol. INTERA uses the FieldTalk Modbus Master library for modbus communications and is limited to discrete inputs and outputs using two modbus function codes, which are:

- 02 - Read Discrete Inputs (Read Input Status)
- 15 - Force Multiple Coils

Intera Lines and Modbus Addresses

The following information is for connecting to a device such as a PLC for Modbus communication. Devices such as a Remote Terminal Unit (ex. Moxa E1212) may not need any further configuration to work with the corresponding addresses. The Intera software uses lines for communicating with external devices and these lines correspond to an address for communicating with Modbus addresses. The Lines are 0 based, meaning that 8 configured lines on Sawyer correspond to lines 0-7. The corresponding Modbus addresses are 1 based, meaning that 8 configured lines on Sawyer correspond to modbus addresses 1-8. (This is not a concern, however, because Intera Studio abstracts away this problem by subtracting 1 from every line.)

The addressing below works with Modbus TCP devices that have addresses that are pre-configured on the device. If a device needs to be configured to assign variables to specific addresses, those addresses and variables must be configured on the device prior to configuring the device in Intera.

NOTE: This a guideline for some but not all devices, please refer to device manufacturers' documentation.

For further assistance with configuration of a device or Intera please contact the Rethink Robotics Support Department at:

866-704-7400 (USA)

support@rethinkrobotics.com or

visit [Rethink Support](#).



The configured Modbus Device Lines/Modbus Addresses can be offset to achieve the necessary address, by changing the Input and Output Base when configuring the Modbus Device.

With Intera 5, you can set the line numbers directly in the modbus device editor (shown above). Intera 5 abstracts away the "modbus=address+1" issue, so if you want the lines 0, and 1024-1028, you can use the literal string "0,1024-1028" to configure the lines in the software.

Networking and Configuration

Sawyer is configured for DHCP addressing by default. If Sawyer is not connected to a DHCP network, the IP address will default to a link-local address.

NOTE: The link-local IP address range is 169.254.#.#, where "#" is any number between and including 1 to 254. The subnet mask for link-local address is 255.255.0.0

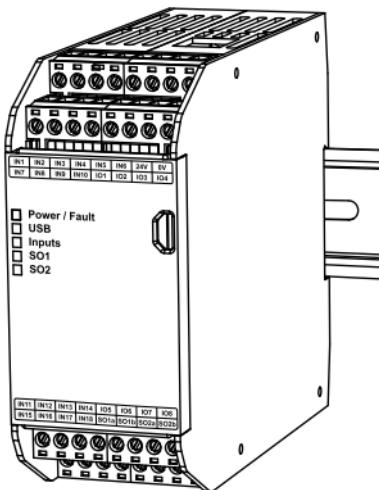
If Sawyer is connected to a DHCP network, the IP address and subnet mask will be assigned to reflect the connected network.

NOTE: Please check with your IT administrator if the IP address and subnet are not configured as expected.

Safety Rated Controller

The Sawyer robot controller is supervised by a safety system comprised of a custom and preconfigured Banner Safety Controller and associated wiring. The safety controller provides safety-rated E-Stop functionality, and provides support for safety-rated safeguarding solutions for those applications that require them. The control systems monitors a variety of input devices such as e-stop buttons, safety mats, interlocked guards, etc. and will limit or disconnect the voltage being supplied to the robot motors.

Please refer to the Banner Safety Controller Instruction Manual for additional details on the ratings and specifications of the safety controller: <http://www.bannerengineering.com/>



- Non-expandable SC26-2evm with analog voltage monitoring.
- Bus Monitor input monitors redundant analog DC voltage inputs to determine if the voltage is greater than or less than a preset level.
- Upper and lower thresholds are independently selectable from 7 V dc to 14 V dc, in 0.25 V dc increments.
- Bus Monitor Input can be used in applications up to Cat 4/PLe and/or SIL3.
- The value of the monitored voltage is accessible via the Ethernet interface.

WARNINGS

- All safety related signals shall be constructed redundantly (i.e. two independent channels). In order to prevent a single fault from leading to loss of a safety function, the two channels must be kept separate.
- Always connect safety-related signals to safety-related devices with the correct functional safety performance level. Failure to follow this practice will result in a compromised safety system that will not achieve the level of protection required for the application per the risk assessment.



PERFORMING A RISK ASSESSMENT

RIA TR R15.306:2014 provides a detailed methodology for performing risk assessments. For Power and Force Limited collaborative robots, ISO TS 15066 and ANSI R15.06/ISO 10218-2 provide guidance on the right aspects to be evaluating. It is important to evaluate the entire robotic application including not just the robot itself, but all tools, fixtures, parts, end effectors, machinery, etc. within the robotic cell. Once all hazards in normal operation, including capturing both intended operation and interaction situations as well as unintended, foreseeable misuse situations, the hazards should be scored on probability of exposure, severity of injury hazard, frequency of exposure, and avoidability.

After determining the hazards and their risks, the standards require users to attempt to eliminate or reduce them to acceptable levels. There is a hierarchy of steps to consider, starting with elimination of hazards at the top to the use of personal protective equipment as the last level. After applying any changes to the work cell to eliminate or mitigate the hazards, each hazard risk is re-scored to determine a final risk level and show the work cell meets the desired level of risk.

In the absence of specific limits or standardized, repeatable, precise force/pressure measuring techniques, customers are testing the robot's performance with respect to these hazards and determining the injury severity risk using common sense. In situations where either the part being handled presents a risk or some equipment in the collaborative work cell presents a hazard, some customers are choosing to add protective measures that slow, pause or stop the robot when something is detected within proximity of the robot or the machine it is tending.

WIRING EXAMPLES

For wiring examples, please refer to the Online User Guide at: mfg.rethinkrobotics.com/intera.



SPECIFICATIONS

Safety

Category 4, PL e (EN ISO 13849)

SIL CL 3 (IEC 62061, IEC 61508)

Product Performance Standards

See Standards and Regulations section in the Instruction Manual for a list of industry applicable U.S. and international standards.

EMC

Meets or exceeds all EMC requirements in IEC 61131-2, IEC 62061 Annex E, Table E.1 (increased immunity levels), IEC 61326-1:2006, and IEC61326-3-1:2008

Convertible I/O

- Sourcing current:** 80 mA maximum (overcurrent protected)

Test Pulse

- Width:** 200 µs max.
- Rate:** 200 ms typical

Certifications

- Certification Pending

Removable Screw Terminals

- Wire size:** 24 to 12 AWG (0.2 to 3.31 mm²)
- Wire strip length:** 7 to 8 mm (0.275 in to 0.315 in)
- Tightening torque:** 0.565 N·m (5.0 in-lb)

Removable Clamp Terminals

- Important:** Clamp terminals are designed for 1 wire only. If more than 1 wire is connected to a terminal, a wire could loosen or become completely disconnected from the terminal, causing a short.
- Wire size:** 24 to 16 AWG (0.20 to 1.31 mm²)
- Wire strip length:** 8.00 mm (0.315 in)

Safety Inputs (and Convertible I/O when used as inputs)

- Input On threshold:** > 15 V dc (guaranteed on), 30 V dc max.
- Input Off threshold:** < 5 V dc and < 2 mA, -3 V dc min.
- Input On current:** 5 mA typical at 24 V dc, 50 mA peak contact cleaning current at 24 V dc
- Input lead resistance:** 300 Ω max. (150 Ω per lead)
- Input requirements for a 4-wire Safety Mat:**
 - Max. capacity between plates: 0.22 µF
 - Max. capacity between bottom plate and ground: 0.22 µF
 - Max. resistance between the 2 input terminals of one plate: 20 Ω

Solid State Safety Outputs

0.5 A max. at 24 V dc (1.0 V dc max. drop), 1 A max. inrush

- Output OFF threshold:** 1.7 V dc typical (2.0 V dc max.)
- Output leakage current:** 50 µA max. with open 0 V
- Load:** 0.1 µF max., 1 H max., 10 Ω max. per lead

Response and Recovery Times

- Input to Output Response Time (Input Stop to Output Off):** see the Configuration Summary in the PC Interface, as it can vary
- Input Recover Time (Stop to Run):**
- Dependent on configuration



- **Safety Output SO..a to SO..b turn On differential (used as a pair, not split):**
- 6 to 14 ms typical, ±25 ms maximum
- **Output SOx to Output SOy turn on Differential (same input, same delay):**
- 3 scan times +25 ms max.
- **Safety Output On/Off Delay Tolerance:**
- ±3%

Output Protection

- All solid-state outputs (safety and non-safety) are protected from shorts to 0 V or +24 V, including overcurrent conditions

Current Feature ID

- SC26-2evm



TCP/IP

For the latest and most detailed information on Sawyer and Intera 5, we always recommend you see the Online User Guide at: mfg.rethinkrobotics.com/intera. The Rethink Robotics support page is here: [Rethink Support](#).

Transmission Control Protocol/Internet Protocol, better known as TCP/IP, is the suite of communications protocols used to connect hosts on the Internet, over Ethernet or wifi. Built into the UNIX operating system, it is used in Intera 5 to enable Sawyer to communicate with work cell devices such as PLCs, barcode readers, and cameras.

TCP/IP allows for more flexible communication than is possible with Modbus devices because it allows Sawyer to send and receive arbitrary messages.

Definitions

IP address -- A unique identifier for every workstation in the world. The address is a four byte value, e.g., 192.168.1.52.

TCP -- Responsible for verifying the correct delivery of data from client to server. Can detect errors or lost data and trigger retransmission until data is correctly and completely received.

TCP Socket -- A socket is an endpoint of a TCP connection, identified with an IP address and a port number. A port number is a semi-arbitrary way to divide up different connections to the same IP address. A useful analogy: if an IP address is like a telephone number, the port number is the phone's extension.

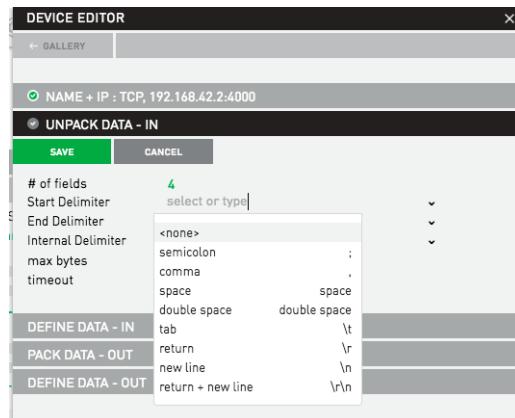


Intera TCP/IP Communications

There are two ways to connect using TCP/IP: Either Sawyer is the server and the other device is the client, or vice versa.

Note: The server is not required to give an IP address, but it must give a port number for devices to connect to.

TCP sockets in Intera communicate with strings of text only. The text can be any valid character. The text strings are separated by special characters, or delimiters.



Types of Delimiters

- Internal delimiter -- Separates fields within the text string. Example: comma.
- End delimiter -- Marks the end of the data being sent. Example: /r/n (carriage return or line feed).
- Starting delimiter -- Indicates the start of the message. Example: RETHINK. Starting delimiters are optional.

Note: When messages are accepted, all delimiters are stripped from the message and are therefore not seen as part of the data.

Data Types

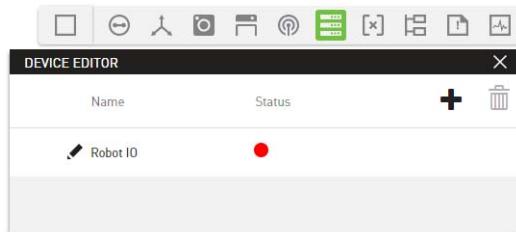
- Float -- A number with a decimal point. (Example: 5.5)
- Integer -- A number. same as float without a decimal point. (Example: 10)



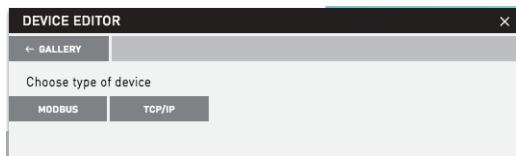
- Boolean -- True/False or 1/0. (Intera recognizes both.)
- Max. Bytes -- Defines maximum number of bytes that constitute a received message, i.e., when 7 bytes are received, that's considered a complete message.
- Timeout -- If a full message is not received in x seconds, it's dropped; wait for another message.

To Create a Device for TCP/IP

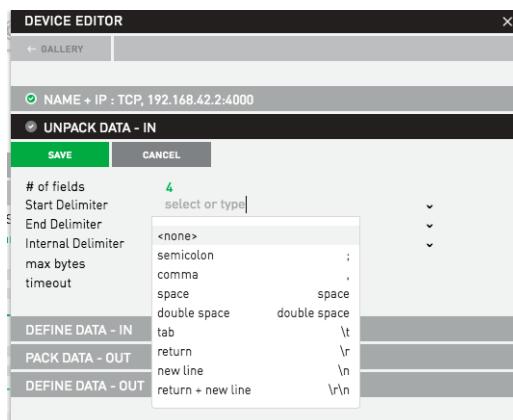
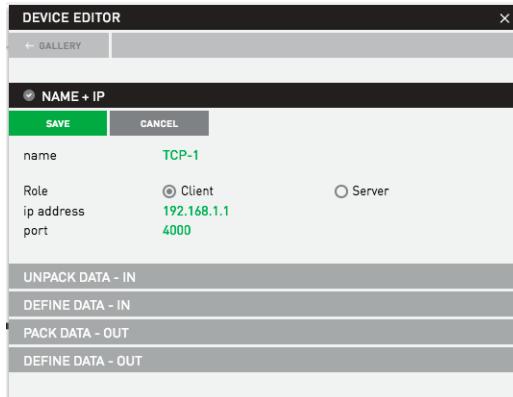
1. Select Devices icon from task bar to display the Device Editor panel.



2. Click on +.



3. Select the TCP/IP option to display a panel where you can enter connection parameters, as in the following examples.



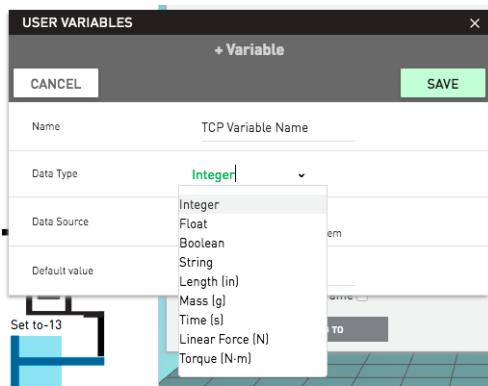
The Set To node in the Behavior Editor is used to output information:





NOTE: You cannot send any “unit-ed” data from Sawyer, that is, any data defined in units. So, force newtons, newton meters, millimeters, position over time, etc. -- none of that data can be sent over TCP.

Input information is through the Variables panel:





Fieldbus Devices

For the latest and most detailed information on Sawyer and Intera 5, please refer to the Online User Guide at: mfg.rethinkrobotics.com/intera. The Rethink Robotics support page is here: [Rethink Support](#).

The Industrial Fieldbus Protocols available on the Sawyer robot include:

- PROFINET
- EtherNet/IP

DISCLAIMER

Any advice provided to you relating to the integration of a Rethink Robotics product with any third party product into to your facility is provided “as is.” Because Rethink Robotics does not have access to the systems you are using, nor does Rethink Robotics have any control over how you may implement any integration with third party products, Rethink Robotics assumes no liability for this limited advice.

Setup Notes

Depending on which Fieldbus protocol is used, additional files for the master device may be required. Please review the following:

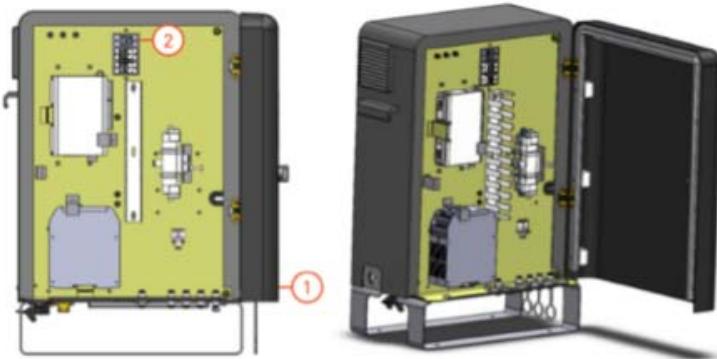
- “Appendix G1: Intera PROFINET Reference” on page 178
- “Appendix G2: Intera EtherNet/IP Reference” on page 193

The Fieldbus protocol should be enabled on the controller, which can be properly configured from the Field-Service-Menu (FSM) on the robot.



The Fieldbus network cable **must** be connected to the inside port of the Controller, identified by the number 2 in the diagram.

- The **Inside Port (2)** may be used for Fieldbus Protocols, TCP/IP, Modbus, and Studio Access.
- The **Outside Port (1)** does not allow access to Industrial Fieldbus Networks but can be used for all other purposes.



Note: Both ports **cannot** be connected to the same network at the same time.

Enabling the Fieldbus Protocol

REQUIRED TOOLS

USB Keyboard

1. With the robot powered off, attach a USB keyboard to a USB port located inside or outside the Controller and power on the robot.
2. When Sawyer's eyes first appear, continually press and release "F" on the keyboard until the FSM menu appears (this process may take up to 4 minutes). The robot's GUI has started when Sawyer's eyes appear on the screen.

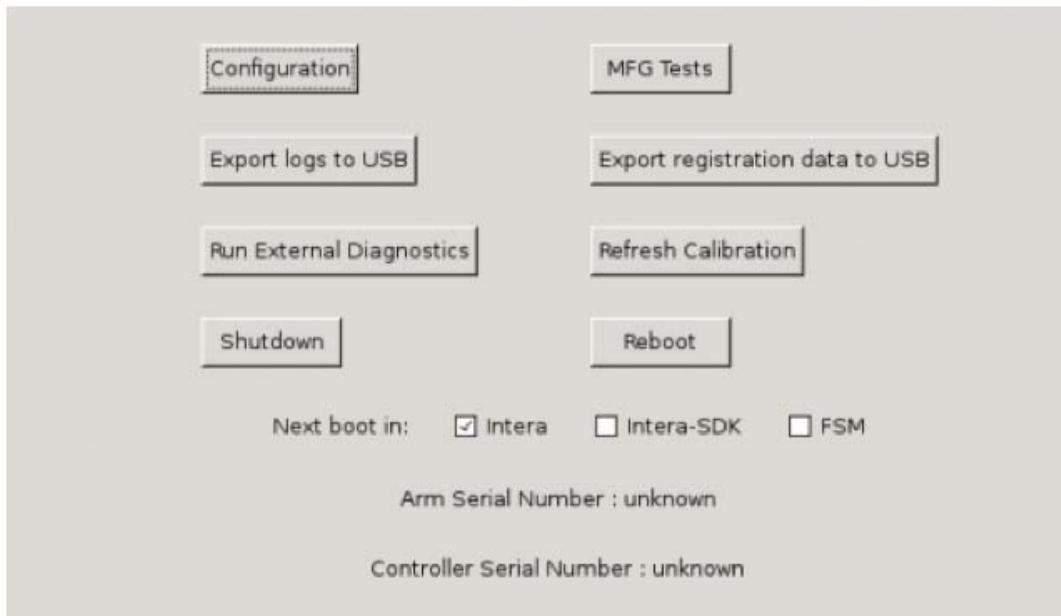
For the latest and most detailed information on the FSM, please review the Online User Guide at:
http://mfg.rethinkrobotics.com/intera/Field_Service_Menu



Preparing to boot Intera...



3. Using a keyboard, navigate to CONFIGURATION and press ENTER.





4. In the CONFIGURATION menu, enable the inside port and select which industrial Fieldbus protocol to use.

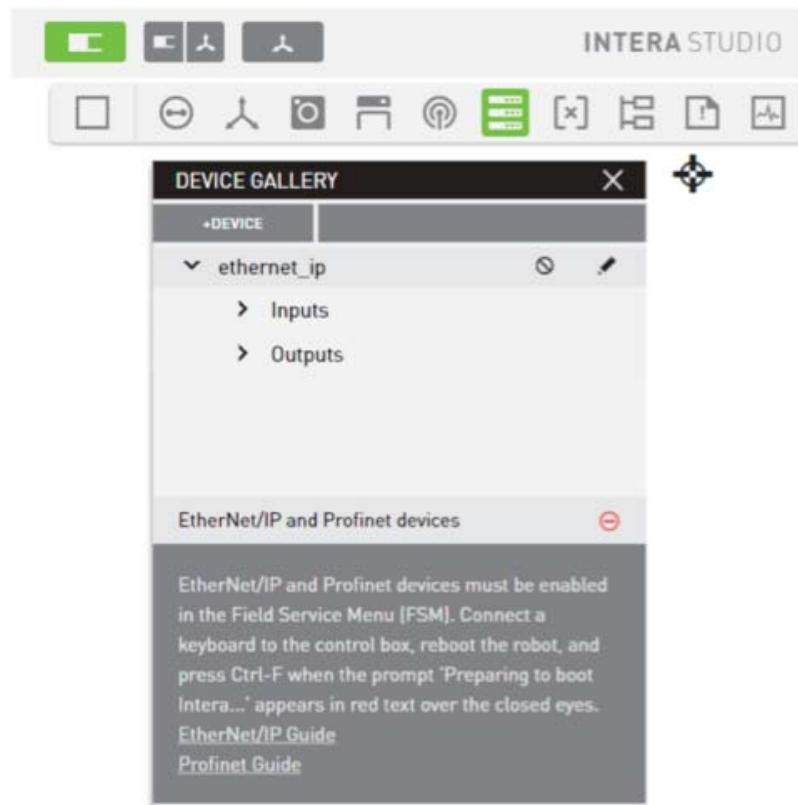
The screenshot shows the Intera configuration interface. On the left, there is a main configuration screen with fields for Hostname (set to 'herne'), Outside Port (checkbox checked, 'enabled' button), Inside Port (checkbox checked, 'config' button), Industrial Protocol Enabled (radio buttons for ETHERNET/IP, PROFINET, and PROFINET selected), Profinet Name (empty input), DNS (empty input), NTP Servers (empty input), ROS Naming Type (radio buttons for ROS_IP, ROS_HOSTNAME, ROS_HOSTNAME.local, ROS_HOSTNAME.local selected), Timezone (dropdown set to America/New_York), and buttons for Save, Revert changes, and Cancel. On the right, a modal window titled 'Industrial Protocol Enabled' displays the 'Enable protocol' section with three options: DISABLED (disabled), ETHERNET/IP (selected and highlighted in orange), and PROFINET.

5. Then press the “config” button for the Inside Port to configure the network parameters.

The screenshot shows the 'Inside Port' configuration dialog. It includes a header stating 'Used for Industrial Ethernet, located on inside of control box'. Below are fields for IP Type (Static IP), MAC Address (00:0e:95:9d:48:11), Current IP Address (192.168.4.4), IP Address* (empty input), IP Netmask* (empty input), IP Gateway* (empty input), and Route + Bit Prefix (empty input). At the bottom are 'Revert changes' and 'Back' buttons.

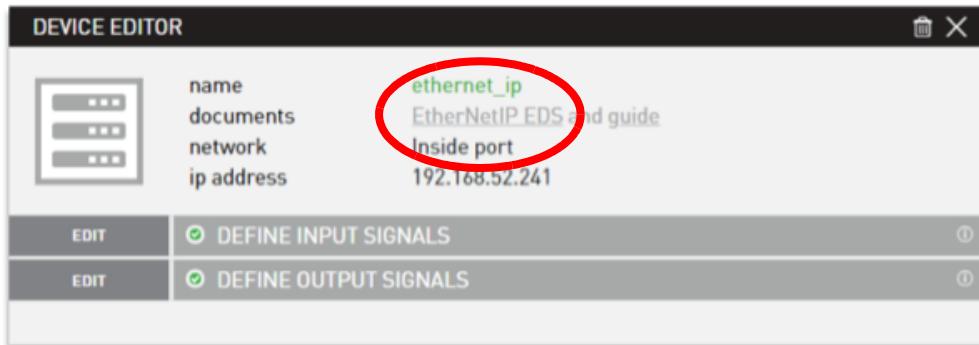


6. Save the settings and reboot into Intera.
7. In the task bar in Intera Studio, the Industrial Network Device is in the Device Editor panel.

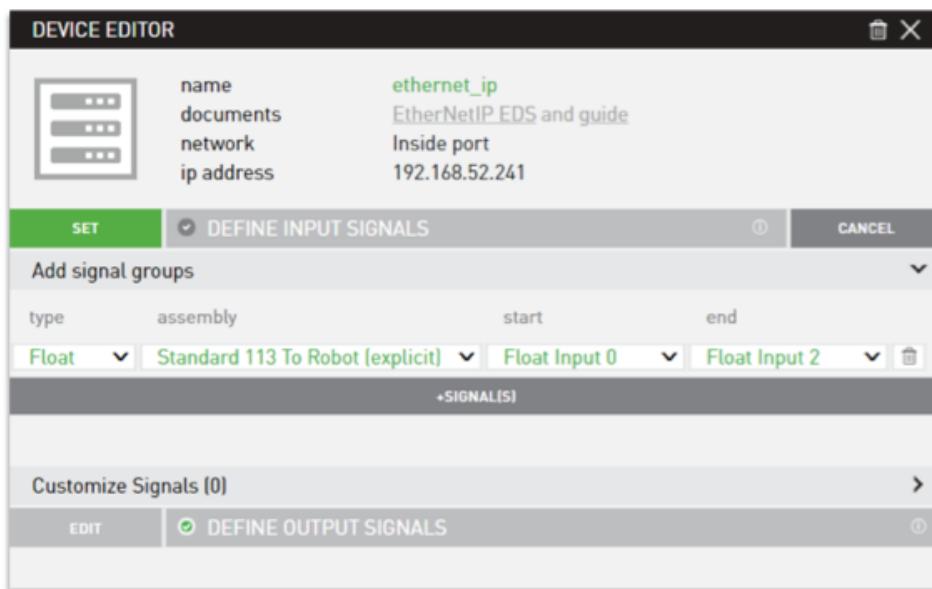


8. Configure the Master Device (e.g. PLC) to look for the Sawyer Device.
9. Install the relevant files (EDS/GSDML) on the Master Device.

These files can be directly downloaded from Intera.



10. Verify Sawyer is visible from the Industrial Device Master.
11. In Intera, configure signals by selecting the appropriate Modules/Assemblies on the Device Editor.



12. The Fieldbus is set up and the device configuration is complete. The robot should be able to communicate with the devices.



Sawyer and Safety

For the latest and most detailed information on Sawyer and Intera 5, we always recommend you see the Online User Guide at: mfg.rethinkrobotics.com/intera. The Rethink Robotics support page is here: [Rethink Support](#).

Safety Statement

Complying with ISO 10218-2 requires performing a risk assessment of each application to determine the needed safety performance and safeguarding. ANSI RIA R15.06-2012 is a U.S.-national adoption of ISO 10218-1 & 2.

Users should exercise caution while training the robot and practicing motions. The risk of injury is increased when using custom end-effectors, movements that lead with the end effector, and potentially hazardous work pieces.

Rethink Robotics recommends the use of safety glasses when interacting with robots, as is common with other equipment used in industrial environments.

The safety of any system incorporating Sawyer is the responsibility of the assembler of the system.

Important: Customers should perform a risk assessment before using Sawyer.

While Rethink Robotics believes Sawyer is capable of being used safely without additional safeguards, it is the responsibility of the customer to conduct a risk assessment to determine if the planned applications using Sawyer are going to meet safety requirements.

The risk assessment should identify all possible hazards, and the risks associated with those hazards. The customer should then perform adequate risk elimination or reduction to meet overall goals in terms of residual risk.

For more information, see “Appendix C: Certifications and Information for Integrators” on page 147 and “Appendix F: Safety Subsystem” on page 171.



Also refer to the Banner Safety Controller documentation (SC26-2evm) and, for guidance on how to perform risk assessments for collaborative robots applications, refer to ISO TS 15066:2016.

How these unique collaborative robots safely manage operational risks

Unlike typical industrial robots that operate behind safeguarding, Sawyer(TM), the collaborative robot from Rethink Robotics, is designed to work effectively directly alongside people in a factory setting, making it possible to deploy in environments which have historically been off-limits to robotic automation. Rethink's Collaborative Robots combine a number of unique technologies designed to allow deployment without some of the traditional safeguarding described in ANSI, ISO, or other safety standards, based on the application's risk assessment. Sawyer(TM) is designed for:

- Physical interaction between a worker and the robot.
- Avoiding accidental contact.
- Minimizing forces and stopping on human contact.

Rethink's Collaborative Robots meet the requirements of a collaborative robot that is Power and Force Limited by Inherent Design as described in ISO 10218-1: 2011, section 5.10.5. The most recent edition of ISO 10218-1 does not include these power and force limiting collaborative requirements, but instead points to the requirement in ISO 10218-2 requiring a risk assessment of the entire robotic application, and refers readers to Technical Specification ISO TS 15066:2016 for further guidance. ANSI RIA R15.06-2012 is a U.S.-national adoption of ISO 10218-1 & 2.

Rethink's Collaborative Robot Safety Features

1. Safety by Design: Mechanical design and human-like cadence inherently reduces risks and injuries.

- Series Elastic Actuators (SEAs): Flexures at all joints provide passive compliance to minimize the force of any contact or impact.
- Smooth and Impact-Absorbing Surfaces: Sawyer has smooth, rounded arms with padding in key areas, such as the elbows and wrists.
- Backdrivable Joints: Sawyer has backdrivable joints allowing manual repositioning of the arm and avoiding clamping hazards common with traditional industrial robots, whether the arm actuators are powered up or not.



- Moderate velocity: Sawyer operates at human-equivalent speeds which are limited by the power limits of the inherent design, which makes it easier for nearby people to avoid any unintended contact with the robot.

2. Machine Safety: Rethink's Collaborative Robots are designed with many protective features which govern operation and protect those working around them.

- E-Stop: When actuated, the emergency stop function directly removes power to actuators and applies brakes (Category 0 protective stop per IEC 60204-1).
- Brake Applied at Joints on Power Loss: When experiencing a power loss, Sawyer will brake using residual power to slow to a stop. Sawyer's small joints will slowly return to a gravity-neutral position. Sawyer also has physical brakes that hold the position of the shoulder and elbow joints, yet can be released simply by pressing a button to allow manual re-positioning of the robot arm.
- Over-Temperature Shutdown: Operating temperatures are internally monitored and Sawyer(TM) will shut down if overheating is detected.

3. Contact Detection: Sawyer has Series Elastic Actuators that directly measure torque at every joint, allowing the robots to detect and respond to contact.

- Clamping Detection: Monitors torque at all joints for a steady obstruction or resistance and pauses robot motion, preventing Sawyer from applying continuous or excessive force.
- Impact Detection: Monitors torque at all joints to sense sharp contact with a hard surface and pauses motion.
- End Effector Force/Torque Detection: If excess force or torque is detected at the tool tip, the robot will pause motion.
- Over-Torque Detection: If torques in excess of joint limits are detected, the arms disable and apply brakes to prevent damage.

4. Diverse Checking Subsystems: Diverse subsystems leverage and control the “heartbeat” signals to enable joint brakes, and disable motor power if a control error or failure is detected.

- Heartbeats:
 - Commanded Stop via “Heartbeat” Signal: Hardware “Heartbeat” signal that can be interrupted by external control, an internal failure, or by any internal subsystem resulting in stopping all joints, engaging brakes and disabling motor power.
 - Communications Heartbeat: A second “heartbeat” stops all joints, engages brakes, and disables motor power in response to detecting internal communication issues.



- Subsystems:
 - Distributed Joint Controllers: Provide local “heartbeat” monitoring at each joint, local joint disabling and braking capability.
 - Global Joint Disable/Braking: Implemented by the disruption of the heartbeat signal.
 - Joint Position and Force Sensing Redundancy: Multiple sensors and feedback mechanisms at each joint enable correlation of results to detect failure.
 - Joint Controller Watchdog Timer: Self-monitoring disables motors and applies brakes if an internal issue is detected with any joint or sensor.

5. Sensing and Behavior

- Head Motion and Screen: Sawyer provides feedback on their status and intentions, using their eyes during operation to signal intent by looking in the direction of the next motion. This cue is intuitively picked up by nearby workers, signaling what the robot will do next.
- Motion Deactivated: Sawyer can be quickly and easily stopped by touching any button, as if tapping a coworker on the shoulder.
- Head-Mounted Lights: Sawyer has lights to signal status at a glance.

Rethink's Collaborative Robot Regulatory Certifications

An application risk assessment, performed by the integrator and/or user, is a critical requirement to ensure the proper use of Rethink's Collaborative Robots and the safety of personnel associated with the robot's application. The end effector and part must be evaluated as part of the application's task-based risk assessment. If either presents a hazard, safeguarding can be required. For example, a risk assessment for an application where Sawyer would be handling “knives” or sharp-edged objects would result in excluding collaborative operation and using Sawyer as a typical machine that is safeguarded.

Sawyer complies with applicable requirements in ISO 10218-1:2011 as supplemented by ISO/TS 15066 for collaborative robots and provides E-stop and protective stop functions meeting requirements in ISO 13849-1:2006, Cat. 3 / PL d. Sawyer meets applicable requirements for electrical, fire & mechanical hazards in IEC 61010-1:2010 (including all country deviations in the CB Scheme), and EMC requirements in IEC 61326-1:2013.



IEC 6100-4-2

Sawyer has been tested to IEC 61000-4-2, electrostatic discharge immunity, with the following limits: air discharges +/-8kV, contact discharges +/-4kV. See the results below:

- CISPR 11 Radiated Emissions - PASSED - Class A
- CISPR 11 Conducted Emissions - PASSED - Class A
- IEC 61000-4-2 Electrostatic Discharge Immunity - PASSED
- IEC 61000-4-3 Radiated Electric Field Immunity - PASSED - Levels 1, 2 & 3 (10V/m)
- IEC 61000-4-4 Electric Fast Transient Burst Immunity - PASSED - Level 2 (1kv) & 3 (2kv)
- IEC 61000-4-5 Surge Immunity - PASSED - Level 2 (1kv) & 3 (2kv)
- IEC 61000-4-6 Radio-Frequency Common Mode Immunity - PASSED - 150kHz - 80MHz @ 3V
- IEC 61000-4-8 Power Frequency Magnetic Field Immunity - PASSED - 0 Amps/m
- IEC 61000-4-11 Interrupt Immunity - PASSED - Dropout # 1, 2, 3 & 4

North America

UNITED STATES

- Meets applicable requirements in ANSI/RIA R15.06-2012 (equivalent to ISO 10218:2011)
- Meets FCC Part 15 emissions requirements (Class A limits)
- Suitable for installations in accordance with requirements of ANSI/NFPA 70 (NEC)
- NRTL approval (UL 61010-1)

Canada

- Meets applicable requirements in CAN/CSA-Z434-14, 3rd ed (equivalent to ISO 10218:2011)
- Meets ICES-003 emissions requirements (Class A limits)
- Complies with general requirements of CAN/CSA C22.2 No. 0 for installations in accordance with the Canadian Electrical Code (CEC), Part 1, CSA C22.1
- NRTL approval (CAN/CSA-C22.2 NO. 61010-1-12)



Mexico

- No mandatory NOM standards or import restrictions apply to industrial robots, however, IEC 61010-1 CB certificate covers general electrical & fire safety requirements, and ISO 10218-1:2011 compliance addresses requirements relating to use of machinery and equipment under Mexico's occupational health and safety regulations [RFSHT].

EU

OVERVIEW

Sawyer conforms to the applicable requirements in relevant EU Directives including those under Machinery, EMC, Low Voltage and RoHS, and is placed on the market in the EU as partly completed machinery under a Declaration of Incorporation. The robot must not be put into service until the final installation has been declared in conformity with the Machinery Directive.

MACHINERY (2006/42/EC)

- Meets applicable requirements in ISO 10218:2011, supplemented by ISO/TS 15066
- E-stop and protective stop functions meet ISO 13849-1:2006, Cat 3 / PL d
- Meets immunity requirements in IEC 61326-1:2013 (industrial limits)
- Meets applicable requirements of IEC 60204-1
- Designed in accordance with ISO 12100:2010

EMC (2004/108/EC)

- Meets emissions requirements in IEC 61326-1:2013 (as per EN 55011:2009, Class A limits)
- Low Voltage (2006/95/EC)
- Complies with requirements of EN 61010-1:2010
- CB certified to IEC 61010-1:2010 including EN country deviations.

ROHS (2011/65/EU)

- Meets requirements for the restriction of hazardous substances.

China

- No CCC requirements or import restrictions apply to industrial robots



Japan

- Meets applicable requirements of JIS B 8433-1:2015 (equivalent to ISO 10218-1:2011)
- Industrial robots are not listed under DENAN regulations (electrical safety), however, IEC 61010-1 CB certificate covers general electrical & fire safety requirements

Learn More

To learn more about Sawyer's safety and regulatory compliance, contact your authorized Rethink Robotics Distributor Partner or visit www.rethinkrobotics.com.



Maintaining and Supporting Sawyer

Powering Down Sawyer Properly

1. Clear the area around the robot.
2. If performing maintenance, grab the training cuff or turn the knob to cause the head to move to the side. If the robot does not have power, carefully move the head manually.
3. Press the white power button on the robot pedestal.

The shutdown process is complete when all lights and the LCD screen have completely powered down.

Unplug the power cord from the wall outlet/power source. Make sure there is no sound coming from the control box before removing power.

Maintaining Sawyer

Dust filters installed in the controller air inlet and fan exhaust ports require periodic inspection to ensure proper ventilation of the controller.

Cleaning Sawyer

To clean Sawyer, you may periodically wipe it down with a clean, damp cloth. Do not use abrasives or solvents.

Check the fan filter in the controller box periodically and clean if necessary.

On behalf of the entire team at Rethink Robotics, we wish you great success with your Sawyer robot, and hope you find it to be a valuable solution for your business.



Calibrating Sawyer

In order to Calibrate Sawyer, you must access the CALIBRATE routine on Sawyer's Head Screen:

On the main screen, press the Rethink Button, then go to SYSTEM, and then click on CALIBRATE.

Use this feature to calibrate each of Sawyer's 7 joints. The calibration routine takes about 5 minutes.

- Please remove any external payload from the robot arm prior to calibrating (EOAT, Tool Plate, 3rd party gripper)
- Clear space around the robot so the arm can move freely without obstruction during calibration.
- Reboot robot after successful calibration in order for calibration parameters to be saved.

What is actually being calibrated?

This process calibrates the Joint Torque Sensors. Having better calibrated torques sensors may have some secondary affects on position accuracy, primarily for mid-motion tracking with heavy payloads, but it's just a second order affect.

Could calibrating the robot have a negative impact or are there situations when I shouldn't calibrate? For example, if my task is running well, could the endpoints shift after calibrating?

- Any change to the SDS sensor could cause small changes to the endpoint accuracy. If the task is running well, don't touch it.

When should a calibration be performed?

- When setting up for the first time.
- Any time the robot has been shipped and is coming out of a box, it is recommended to run a calibration right after booting it up.
- When the robot gets upgraded.
- A re-calibration should not be required when updating, unless something specific to the release requires it (bug fixes to calibration or to the model that the calibration uses). The release notes will make reference to the calibration requirements if they are needed.
- When one or more joints are pulling in one direction in zero-G. This is a sign that something may be off with the calibration and the robot should be calibrated.



Appendix A: Glossary

For the latest and most detailed information on Sawyer and Intera 5, we always recommend you see the Online User Guide at: mfg.rethinkrobotics.com/intera. The Rethink Robotics support page is here: [Rethink Support](#).

Glossary

- Approach Point - The pose that immediately precedes an action.
- Behavior Editor - Used to create, view, and edit all nodes in the Task. Organized in a tree-like structure, and made up of parent and child nodes, it grows and branches out from the left side of the screen.
- Condition Node - Used where you want to perform a sequence of actions, but only if some condition is true, for example, a signal being true.
- End Effector - The external device attached to the end of Sawyer's arm, used to perform a task or interact with the robot's environment. A Rethink vacuum gripper is a type of end effector. There are also 3rd party end effectors designed and created for specific tasks. In many cases, the end effector will behave based on a signal out.
- Frame - A way to orient the world in which you're working. A frame is a 3D point in space, with x, y, and z coordinates as well as x, y, and z rotation information. Its purpose is to make other 3D objects relative to it by using its coordinate system. A frame is a container that can also have children, which reference the frame as their 0,0 point. As the frame moves, so do the children that reference it. Frames are rendered in the Intera User Interface as planes.
- Frame: Base Frame - The absolute 0,0 point at the base of the robot. All other frames are relative to the base frame in some way. It is a constant that never moves and is the parent of every item in the task.
- Frame: End Effector Frame - Its 0,0 point is at the end of the robot arm. Its precise location is dependent upon the specific end effector being used.
- Head Screen - The head display User Interface on the Sawyer robot itself.
- Homing screen - The screen displayed after Sawyer has booted up. The arm then performs a Homing Sequence so the robot can recognize where each joint is in real space. During this sequence, each joint will move approximately 5 degrees.



- Intera Studio - The Intera 5 software on the Chrome browser, used to create the programming logic for Sawyer tasks. It features a behavior editor of the task and a simulated Sawyer robot. The second screen may be connected to an actual Sawyer robot.
- IP address - Unique identifier for every workstation in the world.
- Node - The basic component of the behavior editor. It is an instruction for the robot to perform a specific function.
- Path - The arm movement between two actions.
- Port Number - A semi-arbitrary way to divide up different connections to the same IP address.
- Pose - A position and orientation of the robot's arm at a location.
- Primitive - Nodes with no children. Analogous to the leaf of a branch of the behavior editor. They affect the state of the world (as opposed to Composite nodes, which determine what's appropriate to do when, and in what order). Examples of primitive nodes: Move To, Wait, Set Values, Alert, Camera node.
- Retract Point - The pose that immediately follows an action.
- Sequence Node - Use a Sequence Node if you want to perform a series of actions, one after another.
- Signal Variable - Represent signals the robot sends to other devices or other devices send to the robot. Inputs are read only. Outputs are read and write.
- TCP/IP - Transmission Control Protocol/Internet Protocol. The suite of communications protocols used to connect hosts on the Internet, over Ethernet or wifi.
- TCP Socket - Endpoint of a TCP connection, identified with an IP address and a port number.
- Template - A basic, or "skeleton" subtree behavior that can be inserted into a task as needed. Once inserted, it becomes part of the task as if it had been copied and pasted there. Templates do not contain unique properties of the nodes, for example, references to poses, signals, or other variables.
- Tool Center Point - The precise location of a pose as identified by the Intera software. Also called the TCP. Important for jogging, especially for rotating around the TCP.
- UI - User Interface. The means by which you interact with the robot's software, for example, by entering values, scrolling through screens, making selections, etc.
- Waypoint - A location in space that the arm will move to along a path.



Appendix B: Support & Warranty

For the latest and most detailed information on Sawyer and Intera 5, we always recommend you see the Online User Guide at: mfg.rethinkrobotics.com/intera. The Rethink Robotics support page is here: [Rethink Support](#).

The Sawyer robot comes with a one (1) year limited warranty.

If there is a problem with your robot and you are unable to resolve it, try shutting down and restarting the robot. If the problem persists, contact your authorized Rethink Robotics service provider for technical support. You will need to provide the model and serial number of the robot experiencing the problem. These can be found on the back of the robot near the power button.

If the product is no longer within the warranty period, the authorized Rethink Robotics service provider will provide an estimate of the technical support or repair costs.



Appendix C: Certifications and Information for Integrators

For the latest and most detailed information on Sawyer and Intera 5, we always recommend you see the Online User Guide at: mfg.rethinkrobotics.com/intera. The Rethink Robotics support page is here: [Rethink Support](#).

Third Party Certifications

To provide the best service to our customers, Rethink Robotics has chosen to certify the Sawyer robot at the following recognized test institute:



TUV Rheinland of North America
295 Foster Street, Suite 100
Littleton, MA 01460

Validation of the Robot Risk Assessment was performed according to Table F.1 of EN ISO 10218-1 by TUV Rheinland, report No. 31771701.001.

The Safety system is in compliance to meet PLd Category 3 per EN ISO 13849-1:2006.



TUV Rheinland of North America
Commercial Division



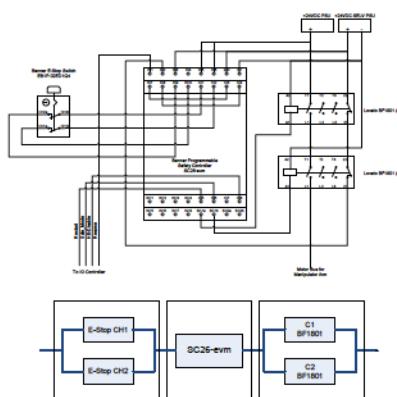
Letter of Attestation

Rethink Robotics, Inc.
27-43 Wormwood St
Boston, MA 02210

June 15, 2017

This letter serves to show that the Rethink Robotics, Inc. robot, model No. Sawyer has been investigated to determine the structure category and performance level for compliance with EN ISO 10218-1 (ANSI/RIA R15.06). Note that the standards require a design of PL=d with structure category 3 as described in ISO 13849-1:2006

The following circuit below was analyzed:



As a result of the investigation, the safety controller circuit provided can meet PLd Cat. 3 if a proper protective stop or E-Stop input device is used and implemented in accordance with EN ISO 13849. Both the logic and output devices of this circuit meet the requirements (The E-stop provided with Sawyer meets this requirement for a full circuit).

Test Engineer:

Ryan Braman
Senior Test Engineer
TUV Rheinland of North America
295 Foster St., Suite 100
Littleton, MA 01460
Cell: 978-760-5262
rbraman@us.tuv.com



Certificate



Certificate no.

T 72172308 01

License Holder:
Rethink Robotics
27 Wormwood Street
Boston MA 02210
USA

Manufacturing Plant:
Benchmark Electronics, Inc
100 Innovative Way
Nashua NH 03062
USA

Test report no.: USA-RB 31771701 003
Tested to: EN ISO 10218-1:2011

Client Reference: Paul Notari

Certified Product: Robot Manipulator and Controller

License Fee - Units

Model Designation: Sawyer

7

Rated Voltage: AC 100-240V, 47-63Hz
Rated Current: 4A
Protection Class: I

Special Remarks: Solely assessed per standard listed above.
The robot is only a component in a final collaborative robot system and alone is not sufficient for a safe collaborative operation. The collaborative operation application shall be determined by the risk assessment performed during the application system design.

7

Appendix: 1, 1-5

Licensed Test mark:



EN ISO 10218-1
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Date of Issue
(day/mo/yr)
15/09/2017

TUV Rheinland of North America, Inc., 12 Commerce Road, Newtown, CT 06470, Tel (203) 426-0888 Fax (203) 426-4009



Declaration of Incorporation



EC Declaration of Incorporation (Original)

We, Rethink Robotics, Inc. of 27-43 Wormwood St, Boston, MA, U.S.A, declare under our sole responsibility that the product described below

Type: Collaborative Robot

Model: Sawyer

Robot Arm Serial Number_____

Controller Serial Number_____

to which this declaration relates, conforms as partly completed machinery to the applicable requirements of Directive 2006/42/EC (Machinery), and conforms to the applicable requirements of relevant Directives 2014/30/EU (EMC), 2014/35/EU (Low Voltage), and 2011/65/EU (RoHS).

The product is in conformity with the applicable requirements of the following harmonized standards,

EN 60204-1	Safety of machinery - Electrical equipment of machines - Part 1: General requirements
EN 61010-1	Safety requirements for electrical equipment for measurement, control and laboratory use - Part 1: General requirements
EN ISO 10218-1	Robots and robotic devices - Safety requirements - Part 1: Industrial robots [as supplemented by ISO TS 15066 for PFL collaborative robots]
EN ISO 12100	Safety of machinery - General principles for design - Risk assessment and risk reduction
EN ISO 13849-1	Safety of machinery - Safety-related parts of control systems - Part 1: General principles for design
EN 55011	Industrial, scientific and medical equipment. Radio-frequency disturbance characteristics. Limits and methods of measurement
EN 61326-1	Electrical equipment for measurement, control and laboratory use - EMC requirements - Part 1: General requirements

This partly completed machinery must not be put into service until the final machinery into which it is to be incorporated has been declared in conformity with the provisions of Directive 2006/42/EC, where appropriate.

Rethink Robotics, Inc. undertakes to transmit, in response to a reasoned request by the national authorities, relevant information on the partly completed machinery. The person authorized to compile the technical documentation is Darius Wilke at Dalienweg 10, 82319 Starnberg, Germany.

Refer to Annex A of this document for a description of the essential requirements in Annex I of 2006/42/EC that are applied and fulfilled for the scope of the incomplete machine as per Annex II 1 B.

Date of issue: March 26, 2018 Place of issue: Boston, Massachusetts, U.S.A.
Name: Scott Eckert
President and CEO

Signature:

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Information for Integrators

Risk assessment

Sawyer is supplied for assembly with other equipment to form a complete machine and is not itself a complete machine. Integrators must therefore perform an application risk assessment based on general shop safety rules and safety standards that considers the installation, surroundings, work-force training and competence, and the general safety culture. The purpose of the risk assessment is to ensure that hazards posed to users are eliminated or minimized in accordance with occupational health & safety requirements established by local regulatory authorities. Guidance on the risk assessment process may be found in the following standards (non-exhaustive):

- ISO 10218-2:2011 Robots and robotic devices - Safety requirements - Part 2: Industrial robot systems and integration
- RIA TR R15.306-2014 Technical Report for Industrial Robots and Robot Systems - Safety Requirements, Task-based Risk Assessment Methodology.
- ISO 12100:2010 Safety of machinery - General principles for design - Risk assessment and risk reduction
- ANSI B11.0-2010 Safety of Machinery; General Requirements & Risk Assessment.

The risk assessment shall take into account all potential contact between an operator and the robot during normal use and foreseeable misuse. The operator's neck, face and head shall not be exposed to contact.

The risks associated with collaborative operation of Sawyer are reduced to levels as low as reasonably practicable through a combination of inherently safe design measures employed by Rethink Robotics and safe practices/risk assessments carried out by integrators and end users. Any residual risks remaining with the robot prior to installation are communicated to integrators and end users through this document. If the integrator's risk assessment for the specific application determines there is an unacceptable level of risk, additional risk reduction measures must be applied.



Sawyer offers additional features to support further risk reduction if necessary, e.g. operation at reduced speed, Category 0 E-stop and protective stop functions, however, the integrator is responsible for ensuring that:

- All hazards have been eliminated or minimized in the final installation using appropriate means,
- Risks have been reduced to levels as low as reasonably practicable, and
- Residual risks have been communicated to end users.

The sections below offer guidance on best practices for a number of topics relating to risk assessment and use of Sawyer.

Use considerations

Collaborative use of Sawyer presumes that there is no safeguarding or presence sensing used, and as such, expected or unexpected contact between personnel and Sawyer or its end-effectors/parts will not pose unacceptable risks. Expected or unexpected contact with other objects in the work-space (equipment, surfaces, conveyors, etc.) will likewise not pose unacceptable risks. If the integrator's risk assessment determines hazards are present in their specific application that pose unacceptable risks to users, then the integrator must use appropriate risk reduction measures to eliminate or minimize those hazards until risks are reduced to an acceptable level. Any use of Sawyer prior to appropriate risk reduction (if required) is considered unsafe.

Safe use of Sawyer requires that integrators and users follow Rethink's installation and mounting instructions for Sawyer.

Sawyer is not intended for use in explosive atmospheres or any environment designated as a hazardous location under relevant electrical codes.

Use of Sawyer without perimeter safeguarding requires risk assessment to determine whether or not associated hazards pose unacceptable risks, for example, hazards could be present with the use of sharp end-effectors/parts or with the handling of toxic or other hazardous substances. The integrator must take into account such hazards and their associated risk levels through risk assessment and identify and implement appropriate measures to reduce risks to acceptable levels.



End-effectors

Integrators are responsible for selecting end-effectors for use with Sawyer that reduce and/or eliminate hazards.

Installation

Integrators must install Sawyer following guidelines prescribed by ISO TS 15066 and by Rethink installation materials.

Sawyer's arm must always be securely mounted upright on its pedestal or securely mounted upright on a suitably stable surface.

Sawyer must be positioned to ensure separation from other workstations and traffic aisles (to limit opportunities for passersby to enter the workspace).

If personnel are working close to Sawyer they must have an unobstructed view of Sawyer at all times.

PPE

As is common practice with other industrial equipment personnel interacting with Sawyer are required to wear safety glasses (wrap-around type).

General safety

Personnel interacting with Sawyer must not wear loose jewelry nor wear loose clothing and long hair must be secured.

Sawyer must not be operated if damaged or operating abnormally.

SOPs & training

Integrators must develop training & procedures and manage the use of Sawyer.

Integrators must provide power off instructions and training to operators.

Integrators must develop SOPs and train personnel on use and interaction with Sawyer. Training must be provided to both personnel working directly with the robot and those within proximity of the robot workspace. It is recommended that access to the cell be limited to trained individuals.



Integrators and users must provide power on instructions and training to personnel who will operate and interact with Sawyer. Instructions and training will include a description of Sawyer's behavior during power up. Personnel must be made aware of any hazards posed by arm movements and instructed to stand clear of Sawyer during user initiated sequences.

Integrators must develop training & procedures on the operation of Sawyer's brake release feature.

Integrators must follow lockout and tagout (LOTO) guidelines and provide training on LOTO to personnel who will operate and interact with Sawyer, as determined by risk assessment.

User documentation, manuals and safety information must be made available to personnel at the time it is needed in either printed or electronic form.

Awareness

Integrators may provide a status lamp to indicate to personnel that Sawyer is operating at normal speed.

Users must be made aware that a potential pinch hazard is present when either of the lower corners of the head display is near to the arm when the second link (L1) is rotating upwards and that they should avoid placing their hands or fingers in the gap created between the arm and the corner of the display.

Integrators and users must install signage and awareness means regarding potential hazards associated with the use of Sawyer, and train personnel as to their meaning.

Integrators and users must install signage and awareness means to make clear to passersby that the workspace is for authorized personnel only, and train personnel as to their meaning.

Integrators must mark the collaborative area.

Useful References

ANSI B11.0: 2010, Safety of Machinery; General Requirements & Risk Assessment

EN 60204-1:2005, Safety of machinery - Electrical equipment of machines - Part 1: General requirements.

IEC 61010-1: 2010, Safety requirements for electrical equipment for measurement, control, and laboratory use - Part 1: General requirements.



ISO 10218-1: 2011, Robotics and robotic devices - Safety requirements - Part 1: Industrial robots.

ISO 10218-2: 2011, Robots and robotic devices - Safety requirements - Part 2: Industrial robot systems and integration.

ISO 12100: 2010, Safety of machinery - General principles for design - Risk assessment and risk reduction.

ISO 13849-1: 2006, Safety of machinery - Safety-related parts of control systems - Part 1: General principles for design.

ISO 13849-1: 2012, Safety of machinery - Safety-related parts of control systems - Part 2: Validation.

RIA TR R15.306: 2014, Technical report for Industrial Robots and Robot Systems - Safety Requirements, Task-based Risk Assessment Methodology.



Appendix D: Ratings and Performance Specs

For the latest and most detailed information on Sawyer and Intera 5, we always recommend you see the Online User Guide at: mfg.rethinkrobotics.com/intera. The Rethink Robotics support page is here: [Rethink Support](#).

Supply Ratings

Supply	Rating
Controller Box	
Supply Input	
Voltage	100VAC – 240VAC
Frequency	47 – 63 Hz
Current	4 A

I/O Ratings

I/O	Rating
SMC Series SY5000 Solenoid Valves (Controller box)	
Max pressure	90 Psi
End-effector Connection	
Supply Output	
Voltage	24VDC
Current	1A max
	5VDC
	1A max



Environmental Ratings:

Parameter	Rating
Environment	Indoor use
Noise	Sawyer's weighted emission sound pressure level at workstation does not exceed 70 dB(A)
Altitude	Up to 2000 meters
Operating Temperature	5°C to 40°C
Relative Humidity	80% for temperatures up to 31°C, decreasing linearly to 50% relative humidity at 40°C
Mains Supply Voltage Fluctuations	Up to ±10% nominal voltage
Transient Overvoltage	Overvoltage Category II
Pollution Degree	2



Tool Tip Speed

The tool tip speed is measured at Sawyer's tool plate when it is moving through space. There is an unlimited number of variables that contribute to the measured tip speed, including pose of the arm, end of arm tooling specs (weight, moment load, part presence, etc.), and speed settings in the software. Here we show the measured tip speed under three conditions.

Task 1: Pick and Place task with joint acceleration set to Medium

A typical Pick and Place task where we simulate the robot is picking an object from a table, moving approximately 120 degrees around J0, placing the object, and starting again. The joint acceleration setting in the software is set to *medium* and the move is defined as a *joint* move. The payload is zero. In this scenario, the maximum measured tip speed is 0.84 m/s as seen in the graph below.

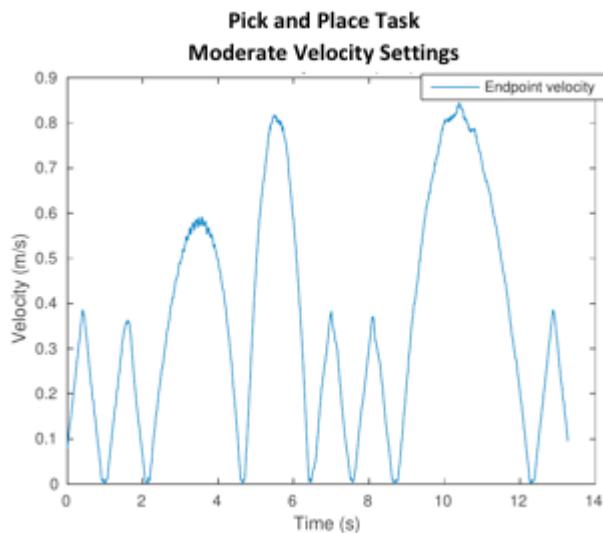


Figure D-1: Chart showing the endpoint velocity for a specific task. This task is a standard pick and place where the robot is rotating about 120 degrees around its base. The joint acceleration setting is set to *medium* in the Intera software.



Task 2: Pick and Place task with joint acceleration set to Express

A typical Pick and Place task where the robot is picking an object from a table, moving approximately 120 degrees around J0, placing the object, and starting again. The joint acceleration setting in the software is set to *express* and the move is defined as a *joint* move. The payload is zero. In this scenario, the maximum measured tip speed is 1.46 m/s as seen in the graph below.

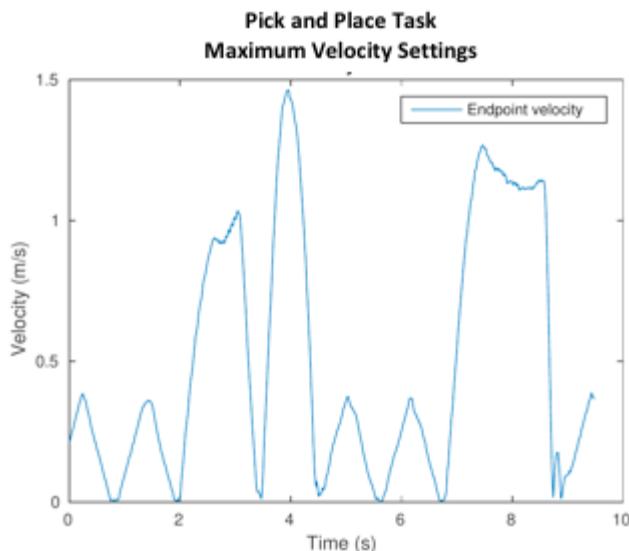


Figure D- 2: Chart showing the endpoint velocity for a specific task. This task is a standard pick and place where the robot is rotating about 120 degrees around its base. The joint acceleration setting is set to *express* in the Intera software.

Task 3: Improbable task with joint acceleration set to Express

An improbable task where the robot is extended vertically, and is trained to move 180 degrees between two poses. The arm is trained to maximize velocity at the tool tip by moving in J0 and J2. The joint acceleration setting in the software is set to *express* and the move is defined as a *joint* move. The payload is zero. In this scenario, the maximum measured tip speed is 2.82 m/s as seen in the graph below.

Important Note – This graph is meant to show the theoretical maximum for tool tip speed. Under normal operating conditions for standard tasks the robot is designed for, the max tip speeds will



typically fall between 0.8 and 1.5 m/s. That said, the speed for an individual movement can be set in the software, and can be tailored to the specific task.

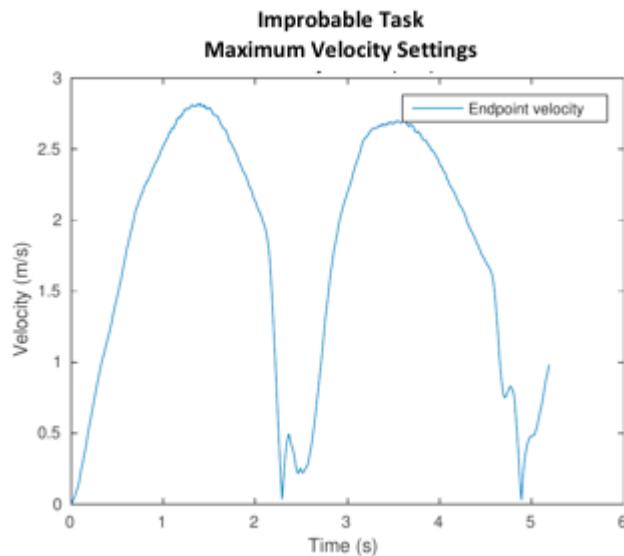


Figure D-3: Chart showing the endpoint velocity for a specific task. This task is designed for maximizing speed at the endpoint. J0 and J2 are set to rotate around the base for a 180 degree movement. The joint acceleration setting is set to *express* in the Intera software.

For more information regarding speed as it relates to safety standards, please see *Sawyer Safety Overview: Safety by Design*.

E-Stop Performance

When an emergency stop is performed, the power is cut to the arm at the motor level, and the robot stops wherever it is in the task. To assess the performance of the E-Stop, two metrics have been analyzed, settling time and overshoot.

Settling Time - The settling time is defined to be the steady state time minus the time at which the E-Stop was triggered.



Overshoot - The overshoot is calculated as the difference in position of the end-effector measured at the E-Stop time and the steady state time.

We also tested under multiple scenarios, and varied payload and voltage mode. The table below summarizes the data from these runs.

MODE	SETTLING TIME (sec)	OVERSHOOT (mm)
Low velocity mode/0 kg payload	0.3	50
Low velocity mode/3.85 kg payload	0.5	80
Normal velocity mode/0 kg payload	0.2	80
Normal velocity mode/3.85 kg payload	0.2	110

Table D-1: E-Stop performance data for eight different conditions, varying the velocity mode and the payload. The joint acceleration setting is set to *express* and the speed ratio is set to 1.0 in the Intera software.

More information about low velocity mode can be found in the document titled *Sawyer Safety Overview: Low Power Mode*.

Payload vs. Reach

Depending on where Sawyer is in the workspace and how the end-effector is designed, the combination of speed, acceleration, reach and payload can have an impact on overall performance of the robot. We can use Figure D-4 to represent the workspace in terms of speed ratio, acceleration, reach and payload, unless one of the following conditions is met:

- The reach of the robot during a task is greater than 1 m;
- The center of mass of the payload is offset from the J6 axis by more than 10 cm;
- The payload offset from the J6 axis is greater than 2 kg.



The reach is defined as the straight-line distance between Sawyer's center point mounting location and the center of mass of the payload. The payload includes the end-effector and object weights. The speed ratio and acceleration can be set in the software.

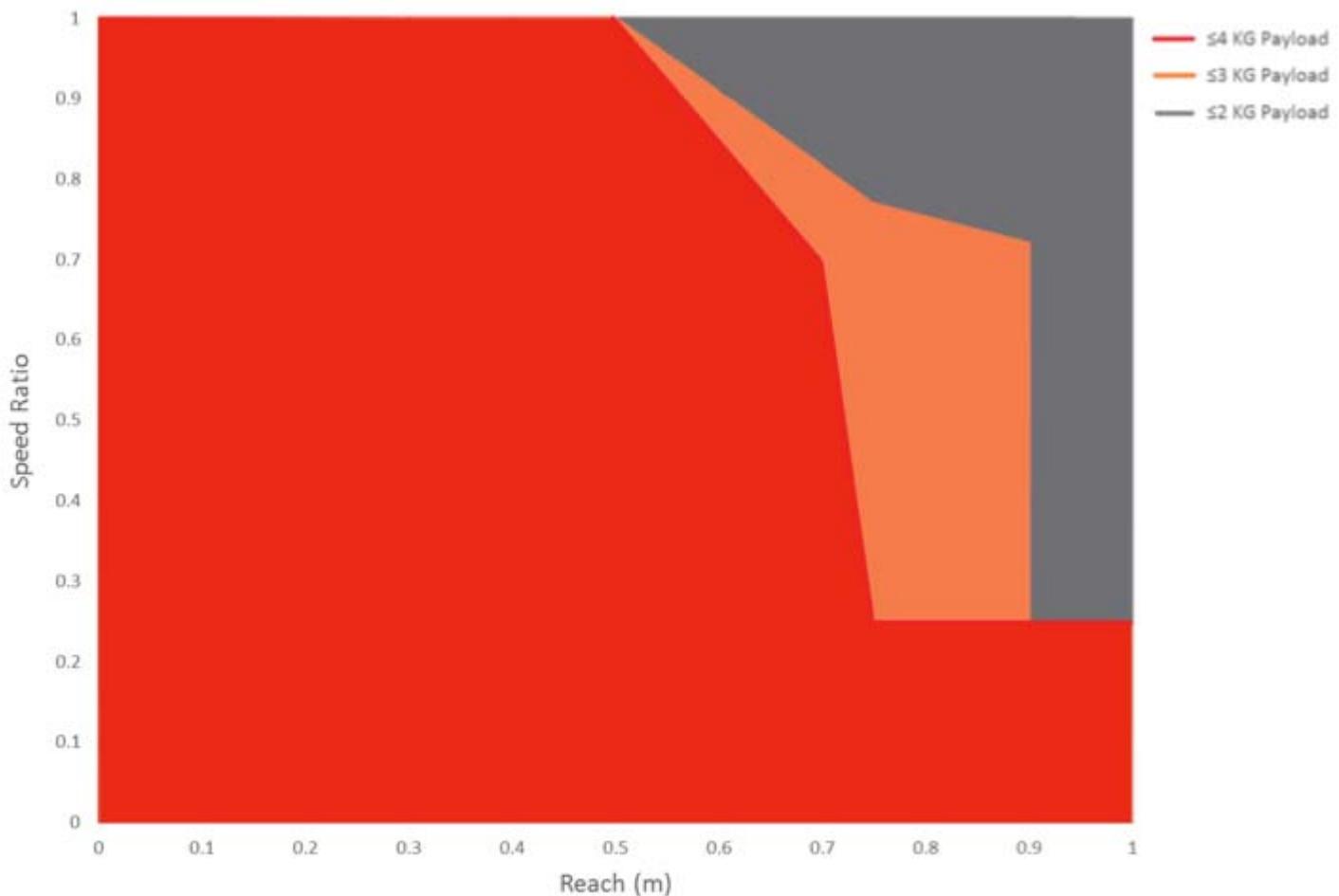


Figure D-4: Recommended speed ratios as a function of payload and reach for optimal performance.

Experiments showed that when none of the three criteria listed at the beginning of this section is met, speed ratio is the primary factor impacting robot performance. Therefore, acceleration is not shown as a variable in Figure D-4.



The *express* acceleration setting should not be used for any payload greater than 3 kg. Typically, *fast* is the maximum acceleration setting and can be applied to any point in the red region. If you would like to use *express* in the red region, the payload cannot exceed 3 kg. For any payload under 3 kg, *express* is the maximum acceleration setting and can be applied to any point in Figure 4.

The red region is suitable for all payloads, including those less than 2 or 3 kg; the orange region is suitable for all payloads less than 3 kg, including those less than 2 kg. When payload is under 3 kg, the valid workspace covers both the orange region as well as the red region. The regions are not mutually exclusive.

To interpret the data, find the appropriate reach and payload you are looking for. For example:

- If you have a reach of 0.6 m and a payload of 3.5 kg, you fall into the red region. The maximum speed ratio should not exceed 0.85. Since the payload is greater than 3 kg, the maximum acceleration setting that can be used is *fast*.
- If you have a reach of 0.8 m and a payload of 2.5 kg, you fall into the orange region. The maximum speed ratio should not exceed 0.74. Since the payload is under 3 kg, there is no restriction on acceleration.

If your task requires an end-effector or task settings beyond our recommendation, please perform additional risk assessment to ensure the robot joints do not experience excessive torque during operation. Please be aware operating the robot out of the recommended ranges may negatively impact the robot performance and increase the risk of hardware damage, which may not be covered by warranty. Please consult Rethink Robotics' Support Team or Channel Partners if you need assistance.

When you perform risk assessment, please make sure the joint torque limits are not exceeded during operation:

- J0 and J1: 85 Nm;
- J2 and J3: 40 Nm;
- J4, J5 and J6: 9 Nm.



Performance with Advanced End-effectors

If one of the three conditions stated at the beginning of the previous section is true, the user should refer to a separate set of payload vs. acceleration plots for end-effector design. It is unnecessary to use the following charts when the reach is less than 1 m, the payload is under 2 kg and the offset from the J6 axis is less than 10 cm.

First, let's define the on-axis and off-axis distances with respect to Sawyer's cuff according to Figure D-5.

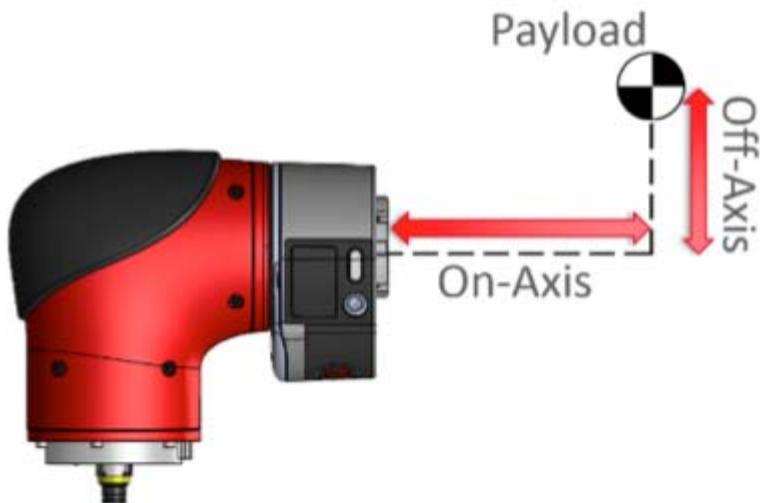


Figure D-5: Illustration of on-axis and off-axis payload positions. The payload includes the end-effector and object weight and is represented as a point mass at its center of mass.

The recommended combinations of payload, center-of-mass position and joint acceleration setting are shown in Figures D-6 and D-7.

Similar to Figure D-4, the regions with different colors are not mutually exclusive. For example, when acceleration setting is set to *fast*, the valid workspace covers the dark blue region and the yellow region.

Unlike Figure 4, the *x*-axis in Figure D-6 and D-7 represents payload, and the *y*-axis represents the offset payload position (not *reach*).



Any end-effector should operate within both the on-axis and off-axis boundaries. If the maximum reach of the robot is greater than 1 m or for regions where *express* is not recommended, the speed ratio should not be set to greater than 0.6. You are free to set the speed ratio up to 1 in any other regions. In the experiments that Figures 6 and 7 are based upon, acceleration affects the robot performance more significantly than speed ratio. That is why speed ratio is not used as a variable.

We do not recommend users to attach exceptionally long end-effectors to the end of the arm. If the offset distance is too large, the actuators are more susceptible to physical damage when the robot is powered off or when it accidentally hits an obstacle while running a task. For example, if you have an end-effector that reaches 50 cm from the J6 axis, you can over-torque the J4 actuator and physically damage it by applying 13 N of force to the tip of the end-effector.

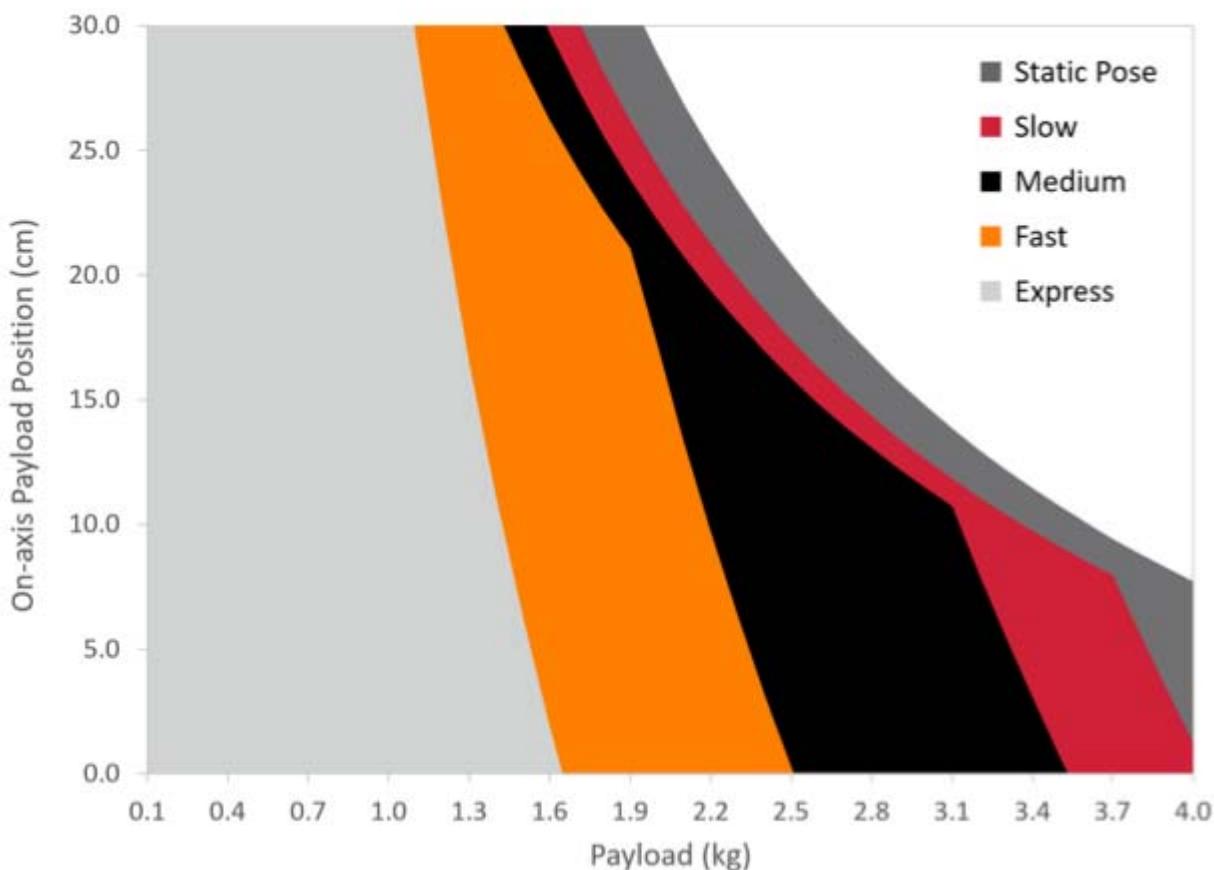




Figure D-6: Recommended acceleration setting as a function of on-axis payload position (defined in Figure D-5) and payload.

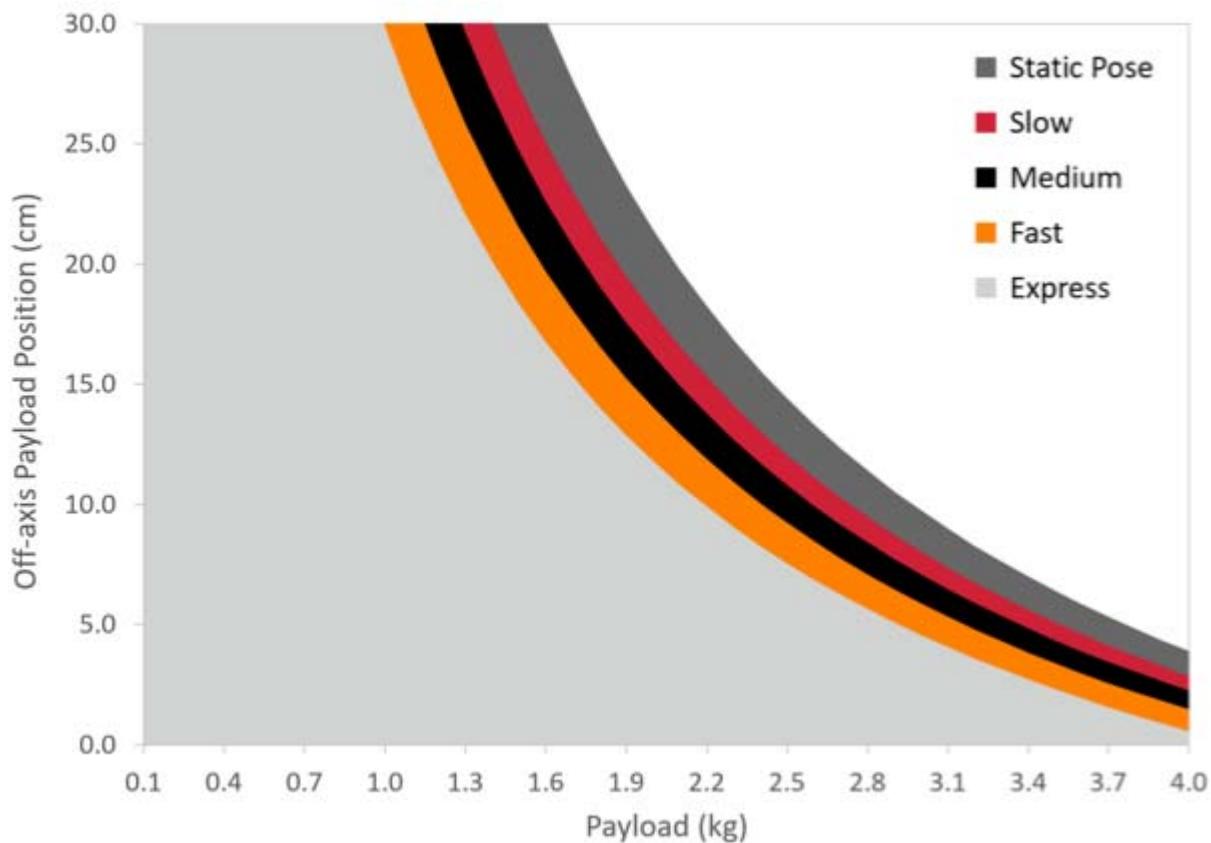


Figure D-7: Recommended acceleration setting as a function of off-axis payload position (defined in Figure D-5) and payload.

To interpret the data, find the appropriate on-axis and/or off-axis distance and payload you are looking for. For example, let's consider a 1 kg end-effector that needs to pick up a 1.5 kg object. In this case the payload is 2.5 kg in total. Measure the center of mass of the end-effector while it holds the object to get the on-axis and off-axis distances according to Figure D-5. Suppose the on-axis and off-axis distances are 10 cm and 6 cm, respectively. According to Figure D-6, you fall into the black zone, which corresponds to *medium* acceleration setting or less. According to Figure D-7, you fall into the light grey zone, which corresponds to *express* acceleration setting or less. Based



on these two results, the acceleration setting should not exceed *medium*. Suppose the maximum reach is 0.8 m. The maximum recommended speed ratio is 1.

However, if the maximum reach is 0.8 m and the payload is reduced to 1.5 kg, Figure D-4 should be used instead. Though there is an off-axis distance, it does not exceed 10 cm, and the payload is under 2 kg. None of the three conditions stated in the previous section is met. According to Figure D-4, this case falls into the grey zone. Therefore, the maximum speed ratio is 1 and the maximum acceleration setting is *express*.

If your task requires an end-effector or task settings beyond our recommendation, please perform additional risk assessment to ensure the robot joints do not experience excessive torque during operation. Please be aware operating the robot out of the recommended range may negatively impact the robot performance and increase the risk of hardware damage, which may not be covered by warranty. Please consult Rethink Robotics' Support Team or Channel Partners if you need assistance.

Below is a flow chart that you can refer to when deciding which figures to use.

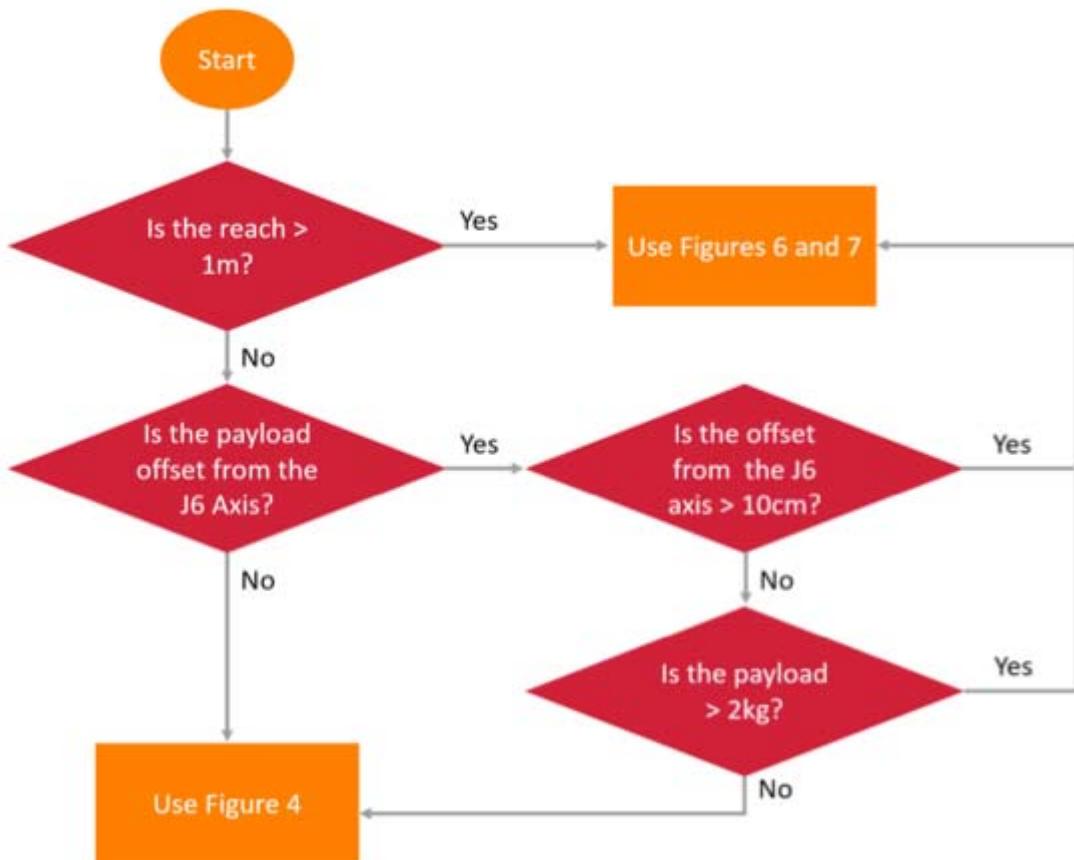


Figure D-8: Flow chart for determining when to use (1) Figure D-4 or (2) Figures D-6 and D-7.



Appendix E: Warnings & Notices

For the latest and most detailed information on Sawyer and Intera 5, we always recommend you see the Online User Guide at: mfg.rethinkrobotics.com/intera. The Rethink Robotics support page is here: [Rethink Support](#).



Warnings & Notices

If Sawyer is used in a manner not specified by Rethink Robotics, the protection provided by the equipment may be impaired.



FCC Part 15 Notice:

This equipment complies with part 15 of the FCC Rules. Operation is subject to the following two conditions:

- (1) This device may not cause harmful interference, and
- (2) this device must accept any interference received, including interference that may cause undesired operation.



This equipment complies with Industry Canada ICES-003 standard. Operation is subject to the following two conditions:

- (1) this device may not cause interference, and
- (2) this device must accept any interference, including interference that may cause undesired operation of the device.

CAN ICES-3 (A)/NMB-3(A)



Sawyer is considered ‘Electrical and Electronic Equipment’ (EEE) under EU Council Directive 2012/19/EU on waste electrical and electronic equipment (recast) [WEEE] and contains an internal non-rechargeable coin cell battery. Do not dispose of the equipment with general waste at the end of its life. Users are encouraged to discard WEEE separately from other waste and may obtain guidance on disposal from their local electronic equipment waste management authority.



This icon identifies the location of the controller cable plug. The controller cable houses both power and I/O.



Appendix F: Safety Subsystem

For the latest and most detailed information on Sawyer and Intera 5, we always recommend you see the Online User Guide at: mfg.rethinkrobotics.com/intera. The Rethink Robotics support page is here: [Rethink Support](#).

The Safety Subsystem

The main function of the safety subsystem is to control the motor bus power relays and to report the status of the safety subsystem. This functionality includes:

- Motor Bus Power Relays
- *Alternate Relays*
- Emergency Stop Button
- *Safety Mat*
- *Optical Sensor*
- *Enabling Device*
- Software Input Switches
- Bus Monitoring
- *Access Switch*
- I/O Controller Interface

The functions in italics are optional and these devices are available from third party manufacturers. They are not included with the Sawyer robot.

The Banner Safety Controller itself is rated to PLe CAT 4 per ISO 13849-1:2006, and the motor safety relays are rated to PLd Cat3. The combined safety function comprised by these safety devices meets PLd Cat 3.

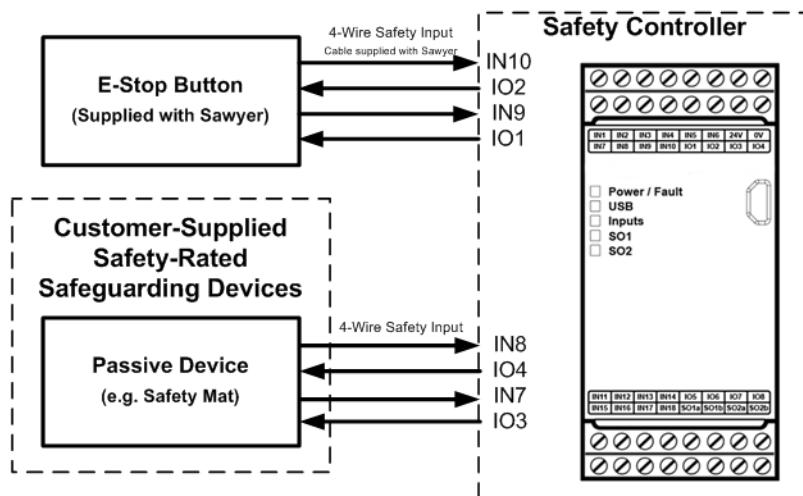


The Banner Safety Controller

Sawyer uses a Banner Safety Controller (SC26-2evm), which is housed in Sawyer's controller box, as the controller of its safety subsystem.

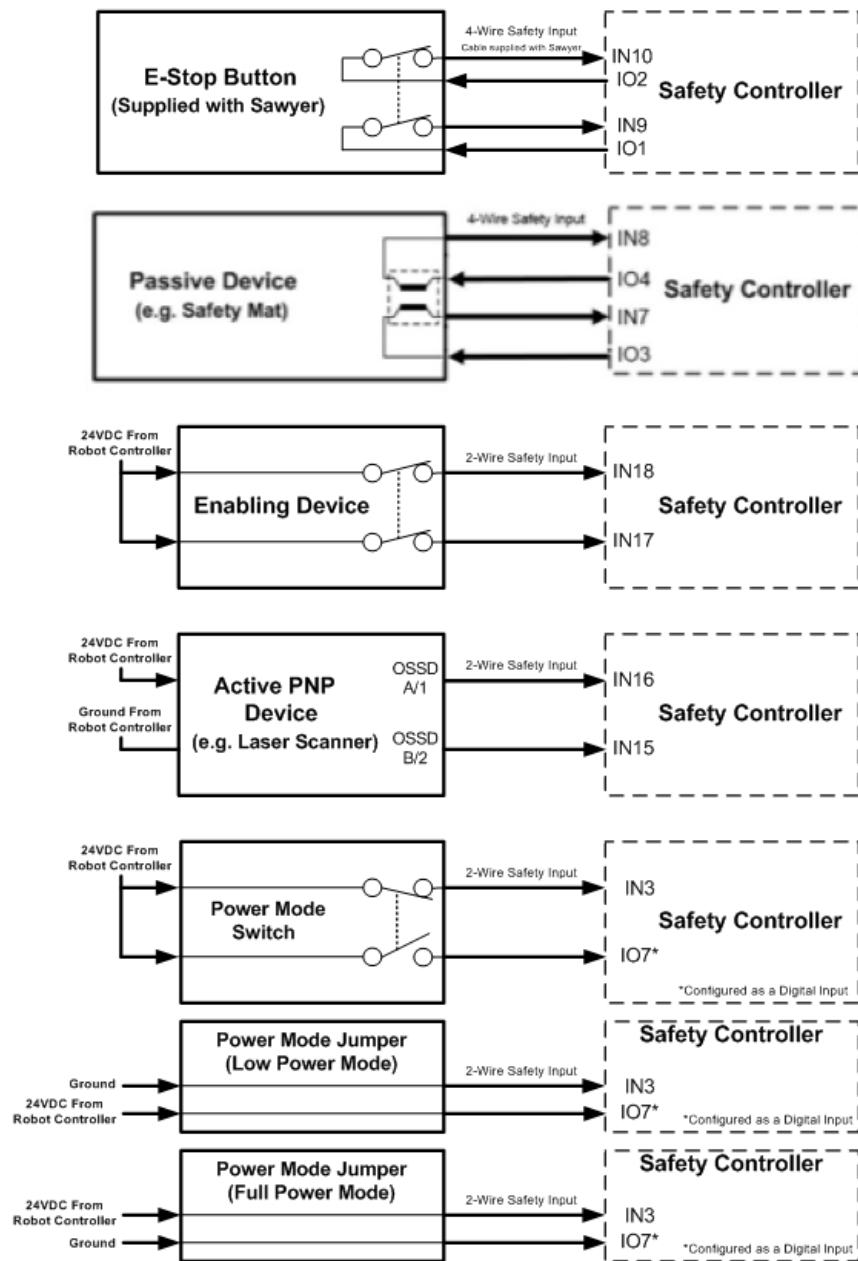
Here is a block diagram illustrating how the subsystem is wired:

How to Connect Safety-Related Devices to Sawyer's Safety System



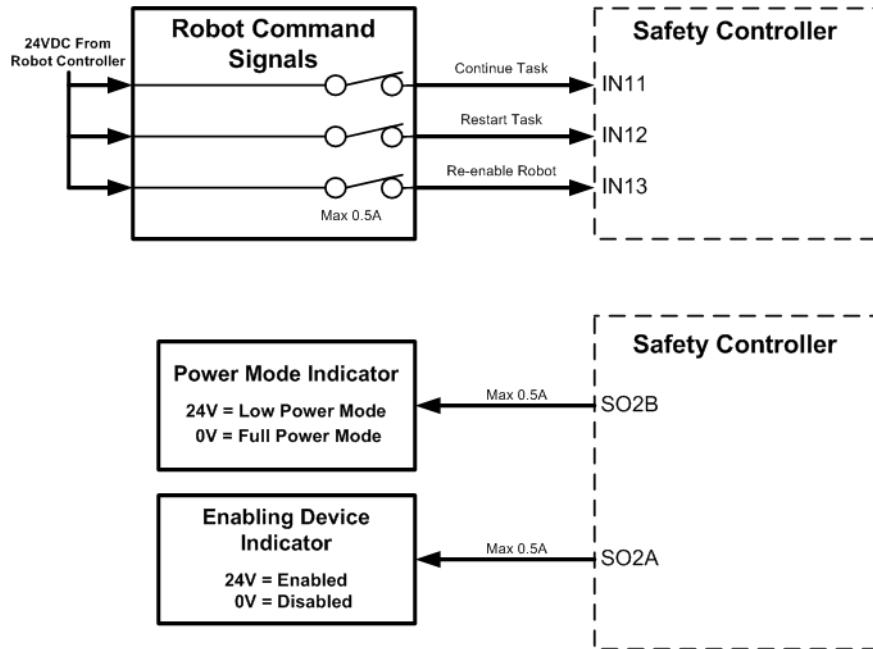


Safety-Related Device Connection Details





Non Safety-Related Device Connection Details



The Banner Safety Controller is an extremely reliable, self-monitoring, redundant device. It monitors all safety conditions and controls the Motor Bus Power relays (there are two of them, making for a failsafe architecture.) If the Banner Safety Controller senses a safety input signal, it shuts the motor power down. It can be restarted based on inputs from the user. If the Safety Controller senses an internal or external failure in its safety functions, it shuts itself and the robot motor power down.

The Banner Safety Controller is customer-accessible for customers who may want to attach other safety devices. It is also configurable, so customers can configure the desired behavior, if not already supported via the standard configuration provided by Rethink Robotics and documented here.



Note: With Intera 3 software, the default Banner Safety Controller configuration supports only the Emergency Stop Switch. With Intera 5 software and the default wiring and configuration settings, the Safety Controller will also support common safeguarding devices such as laser scanners, light curtains, and safety mats.

LOW POWER MODE

Sawyer is designed as a power and force limited robot by inherent design, but customers can choose to further limit the capabilities of the robot by further limiting the power available to the robot in such a way that limits the maximum speed at which it can run. This is done by operating Sawyer in Low Power Mode .

The Banner Safety Controller has been customized to monitor the voltage of the power going to Sawyer's arm. To place Sawyer in Low Power mode, jumper the Low Voltage Enable signal before powering up the robot. The robot's maximum speed will be limited to approximately half that of normal operation.

If, at some point, the Banner Safety Controller senses the robot operating at normal power mode when the wiring is configured for low power mode, the motor power relay will be opened, cutting power to the motors in the arm, and a safety violation error will be reported.

WHAT HAPPENS WHEN A SAFETY DEVICE IS TRIGGERED

When there is a category 0 stop signal, for example, the E-stop is pressed or a light curtain is obstructed, the Banner Safety Controller Interface signals the robot's I/O Controller Interface to inform the robot controller that it will be losing power, and signals the motor bus relays, opening the switch, and cutting power to the actuators in the arm.

In the meantime, the joint controller boards in the arm receive notification of the category 0 stop, and decelerate the actuators using regenerative braking, leveraging the residual power generated from the spinning motors to stop them. The arm rapidly slows to a stop. Brakes in three of the large joints lock in place to prevent the arm from falling under gravity, while the three small joints at the end of the arm gently coast to a gravity-neutral position.

EMERGENCY STOP SWITCH

Sawyer ships with an E-stop device (Emergency Stop button), which can be used in the event of an emergency to remove power from Sawyer's arm. The E-Stop button is a safety-rated safety device that meets functional safety performance level PLd CAT3.



If an operator presses down on the E-stop button, the Banner Safety Controller signals the robot's I/O Controller Interface that it has seen an E-stop. The Banner Safety Controller signals the motor bus relays, which open, cutting the power.

The E-stop button locks in position, and must be physically rotated to release the button, which ends the E-Stop condition. However, the robot is not allowed to power up again until the operator resumes power to the robot arm, either using the navigator user interface on the robot, or via a button connected to the software signal inputs on the Safety Controller. The motor bus relays remain open until the Safety Controller receives the message that resumption of power has been requested. At that point, power is returned to the arm, and servo's become active and take over holding the arm position. The mechanical brakes are then released. Note that there may be a noise and slight motion when power is restored as the robot controller takes over holding the robot stationary.

OPTIONAL SAFETY DEVICES

For differing levels of risk reduction, customers may add one or more safety-rated safeguarding devices to create a monitored space in proximity to the robot.

For example, if a customer has an application where the robot must not move when a human is required to approach within reach of the robot due to a hazard present in the work cell, and the customer doesn't want to surround Sawyer with a safety cage, there are several other devices that can be employed instead.

An optical sensor, like a laser scanner, usually placed at ankle height, senses people approaching, and can act like an e-stop. When triggered, the device sends a signal to the Banner Safety Controller, which triggers a category 0 stop.

Other devices in this category are light curtains and pressure-sensitive safety mats.

Support for Software Signals has been added for situations where the operator should leave the work cell before resetting the robot. A three-button device positioned outside the safety space is connected to the Banner Safety Controller by a cable. Its buttons are wired to correspond to the software signals: Run From Here, Run From Start, and Re-Enable.

When the operator leaves the safety space and presses the Re-Enable button, for example, the Banner Safety Controller receives that signal and closes the motor bus relays, making bus power available to Sawyer's arm again. (This is the same effect as pressing OK on the Sawyer navigator to



recover from triggering E-stop.) The operator also has the option of running the task from the beginning or from where the robot left off.

This safety configuration creates a fully safeguarded work cell: the robot cannot run if someone is in the robot work space; and the robot can be safely restarted by someone outside the work space.

There are situations where an operator needs to be close to the robot to restart it. For example, the operator may need to restart the flow of power to the arm to be able to reposition it before leaving the work space. Or the operator may need power in order to take a part that was still in the robot's gripper when the power was cut. That requires overriding the outputs of triggered safety devices like the safety mat or optical sensor.

In these instances, a handheld Enabling Device is connected to the Banner Safety Controller. The Enabling Device is a three-position switch, sometimes called a "live man switch."

This positions are:

- not pressed
- half-pressed (center position)
- pressed (panic position)

When not pressed or pressed, the output voltage is 0 VDC: no power flows to the robot. When half-pressed, the output voltage is 24 VDC and the other safety measures are bypassed. In other words, the operator is controlling his/her own safety. If something unexpected happens with the robot, the operator presses the device or drops it, and power to the robot is cut.

Note that when pressed all the way (panic position), the device needs to be released completely in order to be reset.

Access Switch - If Sawyer is housed in a cage or behind a door whose lock is wired to the Banner Safety Controller, the owner of the key has access and will be able to override the other safety devices. When the door is unlocked and the owner of the key enters the work area, the robot is stopped.

STOPPING DISTANCE

The stopping distance of the robot is dependent upon several factors including the application for which it is being used, the load the robot is carrying, etc. Customers should study the behavior of the robot under application-specific working conditions to determine stopping distance.



Appendix G1: Intera PROFINET Reference

For the latest and most detailed information on Sawyer and Intera 5, we always recommend you see the Online User Guide at: mfg.rethinkrobotics.com/intera. The Rethink Robotics support page is here: [Rethink Support](#).

This document describes the data structures and connections of Intera's PROFINET implementation and GSDML.

Overview

The data tables in this document describe the format and byte addressing of the PROFINET Modules defined in the GSDML (General Station Description Markup Language) for Intera. Multiple data configuration options are possible using the various Modules, with each including a different type and number of variables that can be mixed and matched to best suit the application.

Default Connection - Standard Modules

The default PROFINET configuration loads a set of 'Standard' Modules for input and output, which give a fixed number of general purpose variables of each data type (Booleans, Integers, Floats, and Strings). There is an additional module sent from the robot ('Fixed Data') that includes a set of automatically filled-in data fields related to the robot status, task status, and the state of the safety signals. More information on these status fields can be found under the State Flags Definitions section of this document.



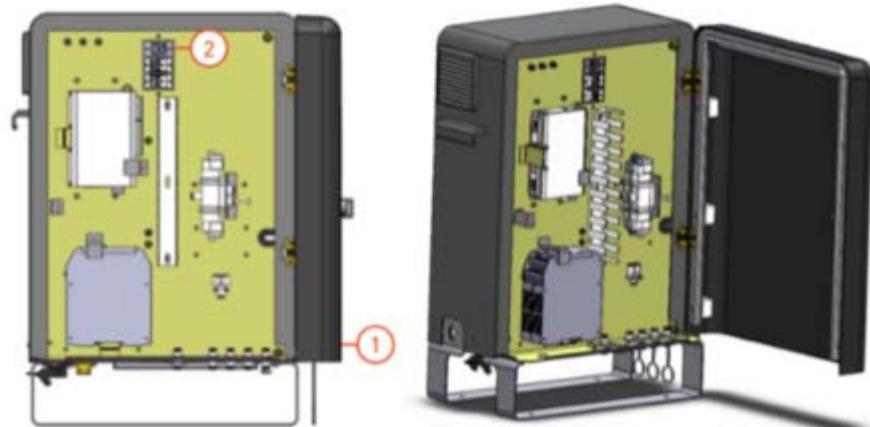
Setup Resources

The Rethink Intera GSDML will be necessary to setup the Intera PROFINET IO Device on the PLC.

- The GSDML and corresponding image icon can be downloaded directly from the robot via a link in the 'Device Editor' window, found in Intera Studio.
- The 'Device Editor' also provides helpful address lookups when creating signals.

PROFINET will also need to be enabled on the controller and the network properly configured from the Field-Service-Menu (FSM) on the robot.

The Fieldbus network cable **must** be connected to the Inside Port of the Controller, identified by the number 2 in the diagram.





Summary of Modules

From-Robot Modules Summary

Module Name	ID	Contents	Size** (bytes)
* Fixed Data 112 From-Robot	112	Robot data Version Status Flags {Robot, Arm, Task, and Safety} Times	40
* Standard Bools 114 From-Robot	114	64 Booleans	8
* Standard Ints 116 From-Robot	116	24 Integers (32-bit)	96
* Standard Floats 118 From-Robot	118	24 Floats (32-bit)	96
Small Bools 120 From-Robot	120	32 Booleans	4
Small Ints 122 From-Robot	122	6 Integers	24
Small Floats 124 From-Robot	124	6 Floats	24
* Small Strings 126 From-Robot	126	1 String***	88
Large Bools 128 From-Robot	128	1024 Booleans	128
Large Ints 130 From-Robot	130	100 Integers	400
Large Floats 132 From-Robot	132	100 Floats	400
Large Strings 134 From-Robot	134	4 Strings***	352
<i>Generic Bytes 136 From-Robot****</i>	136	N/A	400

* Loaded in default configuration.

** All sizes are in Bytes.

*** Format of 'String' variables is: 4-byte 'Length' header, followed by 82-character 'Data' string (82



bytes), followed by a 2 byte spacer (88 bytes total).

**** Reserved for future use.

To-Robot Modules Summary

Module Name	ID	Contents	Size** (bytes)
* Standard Bools 113 To-Robot	113	64 Booleans	8
* Standard Ints 115 To-Robot	115	24 Integers (32-bit)	96
* Standard Floats 117 To-Robot	117	24 Floats (32-bit)	96
Small Bools 119 To-Robot	119	32 Booleans	4
Small Ints 121 To-Robot	121	6 Integers	24
Small Floats 123 To-Robot	123	6 Floats	24
* Small Strings 125 To-Robot	125	1 String***	88
Large Bools 127 To-Robot	127	1024 Booleans	128
Large Ints 129 To-Robot	129	100 Integers	400
Large Floats 131 To-Robot	131	100 Floats	400
Large Strings 133 To-Robot	133	4 Strings***	352
<i>Generic Bytes 135 To-Robot****</i>	<i>135</i>	<i>N/A</i>	<i>400</i>

* Loaded in default configuration.

** All sizes are in Bytes.

*** Format of 'String' variables is: 4-byte 'Length' header, followed by 82-character 'Data' string (82 bytes), followed by a 2 byte spacer (88 bytes total).

**** Reserved for future use.



Modules Data Tables

- Robot Output data modules (from Robot to PLC) are formatted with the byte offsets shown in the following tables (per module).
- Robot Input data modules (from PLC to Robot) do not include a 'Fixed Data' module, but are otherwise formatted the same, with each To-Robot module mirroring a corresponding From-Robot module in the opposite direction.

Definitions of the State Flags fields shown in the first module can be found under the 'State Flags Definitions' section of this document.



Fixed Data 112 From Robot

Labels	Byte #	Data table (4 bytes in each row)					
		+0	+1	+2	+3		
Intera Version	0	Intera Major # (uint16)		Intera Minor # (uint16)			
	4	Intera Micro # (uint16)		Intera Build # (uint16)			
Robot State Flags, Arm State Flags	8	[Robot State Flags] (16 bits array)		[Arm State Flags] (16 bits array)			
Task State Flags, Safety Flags	12	[Task State Flags] (16 bits array)		[Safety Flags] (16 bits array)			
Controller Timestamp	16	Timestamp (s) (uint32)					
	20	Timestamp (ns) (uint32)					
Task Run Time	24	Total Task Time (s) (uint32)					
	28	Current Task Time (s) (uint32)					
Uptime	32	Total Uptime (s) (uint32)					
	36	Current Uptime (s) (uint32)					



Standard Booleans (113: To-Robot | 114: From-Robot)

Labels	Byte #	Data table (4 bytes in each row)			
		+0	+1	+2	+3
Booleans 0-63	0	[Booleans 0-7] (8 bits)	[Booleans 8-15] (8 bits)	[Booleans 16-23] (8 bits)	[Booleans 24-31] (8 bits)
	4	[Booleans 32-39] (8 bits)	[Booleans 40-47] (8 bits)	[Booleans 48-55] (8 bits)	[Booleans 56-63] (8 bits)

Standard Integers (115: To-Robot | 116: From-Robot)

Labels	Byte #	Data table (4 bytes in each row)			
		+0	+1	+2	+3
Integers 0-23	0		Integer 0 (int32)		
	4		Integer 1 (int32)		
	8		Integer 2 (int32)		
	12		Integer 3 (int32)		
	16		Integer 4 (int32)		
	20		Integer 5 (int32)		
	24		Integer 6 (int32)		
		
	88		Integer 22 (int32)		
	92		Integer 23 (int32)		



Standard Floats (117: To-Robot | 118: From-Robot)

Labels	Byte #	Data table (4 bytes in each row)			
		+0	+1	+2	+3
Floats 0-23	0		Float 0 (float32)		
	4		Float 1 (float32)		
	8		Float 2 (float32)		
	12		Float 3 (float32)		
	16		Float 4 (float32)		
	20		Float 5 (float32)		
	24		Float 6 (float32)		
		
	88		Float 22 (float32)		
	92		Float 23 (float32)		

Small Booleans (119: To-Robot | 120: From-Robot)

Labels	Byte #	Data table (4 bytes in each row)			
		+0	+1	+2	+3
Booleans 64-95	0	[Booleans 64-71] (8 bits)	[Booleans 72-79] (8 bits)	[Booleans 80-87] (8 bits)	[Booleans 88-95] (8 bits)



Small Integers (121: To-Robot | 122: From-Robot)

Labels	Byte #	Data table (4 bytes in each row)			
		+0	+1	+2	+3
Integers 24-29	0		Integer 24 (int32)		
	4		Integer 25 (int32)		
	8		Integer 26 (int32)		
	12		Integer 27 (int32)		
	16		Integer 28 (int32)		
	20		Integer 29 (int32)		

Small Floats (123: To-Robot | 124: From-Robot)

Labels	Byte #	Data table (4 bytes in each row)			
		+0	+1	+2	+3
Floats 24-29	0		Float 24 (float32)		
	4		Float 25 (float32)		
	8		Float 26 (float32)		
	12		Float 27 (float32)		
	16		Float 28 (float32)		
	20		Float 29 (float32)		



Small Strings (125: To-Robot | 126: From-Robot)

Labels		Data table (4 bytes in each row)				
	Byte #	+0	+1	+2	+3	
String 0	0	String 0 Length (uint32)		...		
	4	String 0 Data (82 bytes + 2 byte spacer)		...		
		
	84	...		...

Large Bools (127: To-Robot | 128: From-Robot)

Labels		Data table (4 bytes in each row)				
	Byte #	+0	+1	+2	+3	
Booleans 96-1119	0	[Booleans 96-103] (8 bits)	[Booleans 104-111] (8 bits)	...	...
	
	124	...	...	...	[ Booleans 1112-1119] (8 bits)

Large Integers (129: To-Robot | 130: From-Robot)

Labels		Data table (4 bytes in each row)				
	Byte #	+0	+1	+2	+3	
Integers 30-129	0	Integer 30 (int32)		...		
	4	Integer 31 (int32)		...		
		
	396	Integer 129 (int32)		...		



Large Floats (131: To-Robot | 132: From-Robot)

Labels	Byte #	Data table (4 bytes in each row)			
		+0	+1	+2	+3
Floats 30-129	0		Float 30 (float32)		
	4		Float 31 (float32)		
		
	396		Float 129 (float32)		

Large Strings (133: To-Robot | 134: From-Robot)

Labels	Byte #	Data table (4 bytes in each row)			
		+0	+1	+2	+3
String 1-4	0	String 1 Length (uint32)			
	4	String 1 Data (82 bytes + 2 byte spacer)			
			
	84		...		
	88	String 2 Length (uint32)			
	...	String 2 Data (82 bytes + 2 byte spacer)			
			
	176	String 3 Length (uint32)			
	...	String 3 Data (82 bytes + 2 byte spacer)			
			
	264	String 4 Length (uint32)			
	...	String 4 Data (82 bytes + 2 byte spacer)			
			
	348		...		



State Flags Definitions

Bit Definitions for State Flags

Below are the bit positions for the various State Flag fields within the predefined data from the robot.

Robot State Flags	
0	Ready
1	Enabled
2	Error
...	
15	

Arm State Flags	
0	Arm Moving
1	Zero-G Active
...	
15	

Task State Flags	
0	Task Running
1	Task Paused
2	Task Error
...	
15	

Safety Flags	
0	Safety Contactor Closed
1	Low Power Mode
2	Enabling Device Pressed
3	E-Stop Released



4	Safety Mat Released
5	Protected Stop Released
6	
7	
8	Continue Task Released
9	Restart Task Released
10	Re-Enable Button Released
11	
12	
13	
14	
15	

Robot State Flags Meaning

Ready	Enabled	Error	State	Action
1	1	0	OK - Ready	None
0	1	0	Not Ready - Most likely not Homed (e.g. after initial boot)	Home Robot
0	0	1	Error/Stopped - Hardware Error or Safety Stop	Clear Safeguard & Re-Enable; Or diagnose Robot Hardware Error with Intera
0	0	0	Off	Power on and Enable robot



Data Addressing and Format

Notes:

- Numeric data is by default sent/received in Big-Endian byte-order.
- Boolean and String Variables are arrays of bytes, and may be treated as Little-Endian byte-order.
- However, the order of **bits** *inside each byte* is still largest **bit** first.

EXAMPLE: BOOLEAN VARIABLES ADDRESSING

Using example offset addresses Byte 40 - Byte 47

(Adjust for the memory offsets of the Intera Modules in your PLC program).

"Boolean Variable 10" == **Byte 41, Bit 2**

== %IB41.2 (Byte addressing)
== %IW40.2 (16-bit Word addressing)
== %ID40.18 (32-bit Double Word addressing)

Offset addresses Byte 40 - Byte 43

Byte 40	Byte 41								Byte 42								Byte 43														
7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	23	22	21	20	19	18	17	16	31	30	29	28	27	26	25	24

Offset addresses Byte 44 - Byte 47

Byte 44	Byte 45				Byte 46				Byte 47										
39	38	...	32	47	46	...	40	55	54	...	48	63	62	61	60	59	58	57	56

**Address by Byte (8-bit):**

%IB40.0= Boolean Variable 0
%IB40.1= Boolean Variable 1

%IB41.0= Boolean Variable 8
%IB41.1= Boolean Variable 9

%IB42.0= Boolean Variable 16
%IB43.0= Boolean Variable 24

Addressing by Double Word (32-bit):

%ID40.0= Boolean Variable 24
%ID40.1= Boolean Variable 25
%ID40.2= Boolean Variable 26

%ID40.7= Boolean Variable 31
%ID40.8= Boolean Variable 16
%ID40.9= Boolean Variable 17



Appendix G2: Intera EtherNet/IP Reference

For the latest and most detailed information on Sawyer and Intera 5, we always recommend you see the Online User Guide at: mfg.rethinkrobotics.com/intera. The Rethink Robotics support page is here: [Rethink Support](#).

Overview

The data tables in this document describe the format and byte addressing of the EtherNet/IP Assemblies defined in the EDS (Electronic Data Sheet) for Intera. Multiple connection options are available with the various Assemblies including a different mix of variable types and numbers, so the best option can be chosen for each application.

Default Connection - Standard Assemblies

The default EtherNet/IP connection defines a 'Standard To-Robot Assembly' and a 'Standard From-Robot Assembly', each of which include a fixed number of general purpose variables of each data type (Booleans, Integers, Floats, and Strings). For the Assembly sent from the robot, there are additional, automatically filled-in data fields related to the robot status, task status, and the state of the safety signals. More information on these status fields can be found under the State Flags Definitions section of this document.

Setup Resources

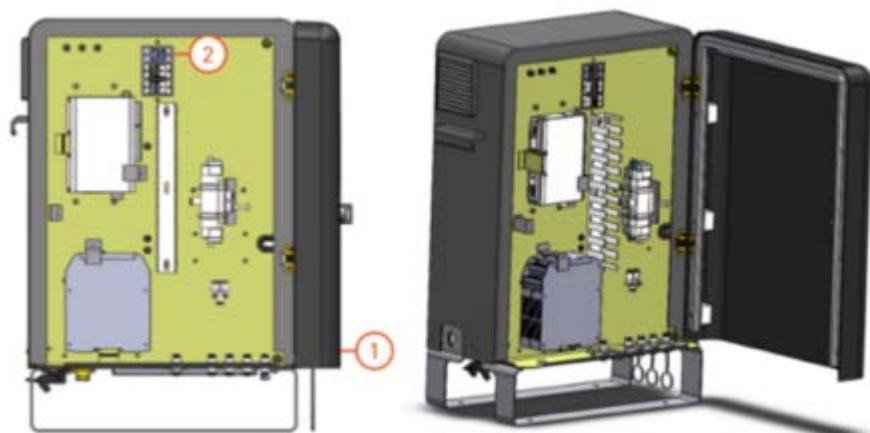
The Rethink Intera EDS will be necessary to setup the Intera Adapter Device on the PLC.



- The EDS can be downloaded directly from the robot via a link in the 'Device Editor' window, found in Intera Studio.
- The 'Device Editor' also provides helpful address lookups when creating signals.

EtherNet/IP will also need to be enabled on the controller and the network properly configured from the Field-Service-Menu (FSM) on the robot.

The Fieldbus network cable **must** be connected to the Inside Port of the Controller, identified by the number 2 in the diagram.





Summary of Assemblies

From-Robot Assemblies Summary

Assembly Name	ID	Size** (bytes)	Contents	Section Sizes**	Offset **
* Standard From-Robot Assembly	112	328	Robot data Version Status Flags {Robot, Arm, Task, and Safety} Times 64 Booleans 24 Integers (32-bit) 24 Floats (32-bit) 1 String***	40 8 96 96 88	+0 +40 +48 +144 +240
Small Assembly	114	40	32 Booleans 3 Integers 6 Floats	4 12 24	+0 +4 +16
Large Assembly	116	488	512 Booleans 42 Integers 42 Floats 1 String***	64 168 168 88	+0 +64 +232 +400
FLOATS +	118	272	32 Booleans 3 Integers 64 Floats	4 12 256	+0 +4 +16
Strings +	120	368	32 Booleans 3 Integers 4 Strings***	4 12 352	+0 +4 +16

* Loaded in default configuration.

** All sizes are in Bytes.

*** Format of 'String' variables is: 4-byte 'Length' header, followed by 82-character 'Data' string (82 bytes), followed by a 2 byte spacer (88 bytes total).



To-Robot Assemblies Summary

Assembly Name	ID	Size** (bytes)	Contents	Section Sizes**	Offset **
* Standard To-Robot Assembly	113	288	64 Booleans 24 Integers (32-bit) 24 Floats (32-bit) 1 String***	8 96 96 88	+0 +8 +104 +200
Small Assembly	115	40	32 Booleans 3 Integers 6 Floats	4 12 24	+0 +4 +16
Large Assembly	117	488	512 Booleans 42 Integers 42 Floats 1 String***	64 168 168 88	+0 +64 +232 +400
FLOATS +	119	272	32 Booleans 3 Integers 64 Floats	4 12 256	+0 +4 +16
STRINGS +	121	368	32 Booleans 3 Integers 4 Strings***	4 12 352	+0 +4 +16

* Loaded in default configuration.

** All sizes are in Bytes.

*** Format of 'String' variables is: 4-byte 'Length' header, followed by 82-character 'Data' string (82 bytes), followed by a 2 byte spacer (88 bytes total).



Assembly Data Tables

From-Robot Standard Assembly (112)

Robot Output data (from Intera to PLC) is formatted with the following byte offsets

Labels	Byte #	Data table (4 bytes in each row)			
		+0	+1	+2	+3
Intera Version	0	Intera Major # (uint16)		Intera Minor # (uint16)	
	4	Intera Micro # (uint16)		Intera Build # (uint16)	
Robot State Flags, Arm State Flags	8	[Robot State Flags] (16 bits array)		[Arm State Flags] (16 bits array)	
Task State Flags, Safety Flags	12	[Task State Flags] (16 bits array)		[Safety Flags] (16 bits array)	
Controller Timestamp	16		Timestamp (s) (uint32)		
	20		Timestamp (ns) (uint32)		
Task Run Time	24		Total Task Time (s) (uint32)		
	28		Current Task Time (s) (uint32)		
Uptime	32		Total Uptime (s) (uint32)		
	36		Current Uptime (s) (uint32)		
Booleans 0-63	40	[Booleans 0-7] (8 bits)	[Booleans 8-15] (8 bits)	[Booleans 16-23] (8 bits)	[Booleans 24-31] (8 bits)
	44	[Booleans 32-39] (8 bits)	[Booleans 40-47] (8 bits)	[Booleans 48-55] (8 bits)	[Booleans 56-63] (8 bits)
Integers 0-23	48		Integer 0 (int32)		
	52		Integer 1 (int32)		
		
	140		Integer 23 (int32)		
Floats 0-23	144		Float 0 (float32)		
	148		Float 1 (float32)		
		
	236		Float 23 (float32)		
String 0	240		String 0 Length (uint32)		
	244		String 0 Data (82 bytes + 2 byte spacer)		
		
	324		...		



To-Robot Standard Assembly (113)

Robot Input data (from PLC to Intera) is formatted with the following byte offsets

Labels	Byte #	Data table (4 bytes in each row)			
		+0	+1	+2	+3
Booleans 0-63	0	[Booleans 0-7] (8 bits)	[Booleans 8-15] (8 bits)	[Booleans 16-23] (8 bits)	[Booleans 24-31] (8 bits)
	4	[Booleans 32-39] (8 bits)	[Booleans 40-47] (8 bits)	[Booleans 48-55] (8 bits)	[Booleans 56-63] (8 bits)
Integers 0-23	8		Integer 0 (int32)		
	12		Integer 1 (int32)		
		
	100		Integer 23 (int32)		
Floats 0-23	104		Float 0 (float32)		
	108		Float 1 (float32)		
		
	196		Float 23 (float32)		
String 0	200		String 0 Length (uint32)		
	204		String 0 Data (82 bytes + 2 byte spacer)		
		
	384		...		



Small Assembly (114: From-Robot | 115: To-Robot)

Labels	Byte #	Data table (4 bytes in each row)			
		+0	+1	+2	+3
Booleans 64-95	0	[Booleans 64-71] (8 bits)	[Booleans 72-79] (8 bits)	[Booleans 80-87] (8 bits)	[Booleans 88-95] (8 bits)
Integers 24-26	4		Integer 24 (int32)		
	8		Integer 25 (int32)		
	12		Integer 26 (int32)		
Floats 24-29	16		Float 24 (float32)		
	20		Float 25 (float32)		
	24		Float 26 (float32)		
	28		Float 27 (float32)		
	32		Float 28 (float32)		
	36		Float 29 (float32)		



Large Assembly (116: From-Robot | 117: To-Robot)

Labels		Data table (4 bytes in each row)			
	Byte #	+0	+1	+2	+3
Booleans 96-607	0	[Booleans 96-103] (8 bits)	[Booleans 104-111] (8 bits)	...	...

	60	...	...	...	[ Booleans 600-607] (8 bits)
Integers 27-68	64	Integer 27 (int32)			
	68	Integer 28 (int32)			
			
	228	Integer 68 (int32)			
Floats 30-71	232	Float 30 (float32)			
	236	Float 31 (float32)			
			
	396	Float 71 (float32)			
String 1	400	String 1 Length (uint32)			
	404	String 1 Data (82 bytes + 2 byte spacer)			
			
	484	...			



Floats+ (118: From-Robot | 119: To-Robot)

Labels	Byte #	Data table (4 bytes in each row)			
		+0	+1	+2	+3
Booleans 608-639	0	[Booleans 608-615] (8 bits)	[Booleans 616-623] (8 bits)	[Booleans 624-631] (8 bits)	[Booleans 632-639] (8 bits)
Integers 69-71	4		Integer 69 (int32)		
	8		Integer 70 (int32)		
	12		Integer 71 (int32)		
Floats 72-135	16		Float 72 (float32)		
	20		Float 73 (float32)		
		
	268		Float 135 (float32)		



Strings+ (120: From-Robot | 121: To-Robot)

Labels	Byte #	Data table (4 bytes in each row)			
		+0	+1	+2	+3
Booleans 640-671	0	[Booleans 640-647] (8 bits)	[Booleans 648-655] (8 bits)	[Booleans 656-663] (8 bits)	[Booleans 664-671] (8 bits)
Integers 72-74	4		Integer 72 (int32)		
	8		Integer 73 (int32)		
	12		Integer 74 (int32)		
String 2-5	16		String 2 Length (uint32)		
	20		String 2 Data (82 bytes + 2 byte spacer)		
		
	100		...		
	104		String 3 Length (uint32)		
	...		String 3 Data (82 bytes + 2 byte spacer)		
		
	192		String 4 Length (uint32)		
	...		String 4 Data (82 bytes + 2 byte spacer)		
		
	280		String 5 Length (uint32)		
	...		String 5 Data (82 bytes + 2 byte spacer)		
		
	364		...		



State Flags Definitions

Bit Definitions for State Flags

Below are the bit positions for the various State Flag fields within the predefined data from the robot.

Robot State Flags	
0	Ready
1	Enabled
2	Error
...	
15	

Arm State Flags	
0	Arm Moving
1	Zero-G Active
...	
15	

Task State Flags	
0	Task Running
1	Task Paused
2	Task Error
...	
15	

Safety Flags	
0	Safety Contactor Closed
1	Low Power Mode
2	Enabling Device Pressed



3	E-Stop Released
4	Safety Mat Released
5	Protected Stop Released
6	
7	
8	Continue Task Released
9	Restart Task Released
10	Re-Enable Button Released
11	
12	
13	
14	
15	

Robot State Flags Meaning

Ready	Enabled	Error	State	Action
1	1	0	OK - Ready	None
0	1	0	Not Ready - Most likely not Homed (e.g. after initial boot)	Home Robot
0	0	1	Error/Stopped - Hardware Error or Safety Stop	Clear Safeguard & Re-Enable; Or diagnose Robot Hardware Error with Intera
0	0	0	Off	Power on and Enable robot



Data Addressing and Format

Notes:

- Data is sent/received in Little-Endian byte-order between Intera and the PLC.
- Boolean and String Variables are considered arrays of bytes.

EXAMPLE: BOOLEAN VARIABLES ADDRESSING

Using example offset addresses Byte 40 - Byte 47

(Adjust for the memory offsets of the Intera Assemblies in your PLC program).

"Boolean Variable 10" == **Byte 41, Bit 2**

Offset addresses Byte 40 - Byte 43

Byte 40	Byte 41												Byte 42								Byte 43										
7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	23	22	21	20	19	18	17	16	31	30	29	28	27	26	25	24

Offset addresses Byte 44 - Byte 47

Byte 44				Byte 45				Byte 46				Byte 47							
39	38	...	32	47	46	...	40	55	54	...	48	63	62	61	60	59	58	57	56

Index

Numerics

3D controller 52
3D View 28, 49

A

About pane 27
action button 15, 17
Active Collision Avoidance 18
Actuation time 59
Advanced End-effectors 164
Approach Point 144
arm
 stiffness 106, 124
Assembly Data 197
Assigning a Signal 71
Awareness 154

B

Back button 16
Banner Safety Controller 15, 172
 current configuration of 175
Banner Safety Controller documentation 136
Base Frame 144
Behavior Editor 28, 31, 38, 144
 branch 31
 defined 31
Boolean 126
Brakes 17
branch 31
browser 28
 Google Chrome 27, 31
button
 Go To 52

C

cable

 networking 26
Calibrate 65
Calibrating Sawyer 143
Cartesian view 53
Charts List 99
cleaning Sawyer 142
ClickSmart Gripper 56
ClickSmart Robot Side Adapter 19
collision avoidance 12
Compliance 108
compliance
 how to define 109
Condition Node 144
Configure End Effectors 54
Controller 13
controller 26
controller box 21

D

Data Addressing 191
Declaration of Incorporation 150
Delimiters 125
Devices Panel 45
Dimensions 9
Disclaimer 7
Disconnecting power 22
display options 36
Dual Tools 67

E

emergency stop 160
Emergency Stop Switch 175
End Effector 144
End Effector Frame 144
End Effectors
 configuring 54
End of Arm Tooling 54
Error Log 49
E-Stop 175
E-stop 19
E-Stop device 23
E-Stop Performance 160
Ethernet Port 13, 15
EtherNet/IP 129, 193
Export Current Task 33
Export Logs 35

F

Fieldbus 45
Fieldbus Devices 129
Fieldbus Protocol 130
Float 125
force
 sensing 106, 124
force data
 how to access, modify 108
force limit 110
Force Mode 108, 110
Force Sensing 106, 124
Frame 144
Frames 43

G

Getting Started 22
getting started 26
Getting Started with Intera 5 26
Getting Started with Sawyer 22
Glossary 144
Go To button 52
Google Chrome 27
Google Chrome browser 31
Graphical User Interface (GUI) 12
Grasp button 17

H

head 12
 Sawyer 12
Head Screen 30, 144
Head Screen Menu 27
Help 35
Homing screen 144
Homing Sequence 23

hot keys 42, 51

I

IEC 6100-4-2 139
Impedance Mode 108
Import Task 33
Installation
 risk guidelines 153
Integer 125
Integrators
 information for 147
 Risk assessment 151
Intended use 4
Intera 5
 Getting Started 26
Intera Insights 98
Intera Insights Panel 99
Intera Studio 31, 145
 3D View 49
 components 32
Intera Terms 30
Internet Explorer 28
IP address 27, 47, 145

J

joint limit indicators 24
Joint Limits 11
Joints Tab 12, 43

L

Landmarks 19
list view 74
Lock Robot 35
Low Power Mode 175

M

maintenance 142
Max. Bytes 126
menu
 Head Screen 27
Modbus 45
Motor Bus Power relays 174
Moving the Arm 24
Moxa I/O device 70

N

Navigator 15, 24
networking cable 26
Node 145
node
 defined 31
 disable 41
 Node Palette 37
Node Colors, meaning of 38
Node Inspector 42
 defined 42
node move hot keys 42
Node Palette 37, 39
nodes
 parent and child 31
 sibling 38
Nomenclature 11

O

OK button 15

P

Path 145
Patterns 80
payload 161
Payload vs. Reach 161
pick and place
 create without Studio 72
Port Number 145
Pose 145
pose 25
Power 22
power down Sawyer
 how to 142
Primitive 145
Primitive Node
 defined 39
PROFINET 129, 178

R

Ratings 156
reach 161, 162
Redo 41
repairs 21
Reset Zoom 42
residual risks 151
Rethink button 16
Retract Point 145
risk
 End-effectors 153
Risk assessment
 integrators to perform 151
risk assessment
 necessity of 135
Robot Runtime Visuals 99

S

Safety 135
safety
 general 153
Safety Controller
 Banner 136, 172
Safety Device
 when triggered 175
Safety Devices
 optional 176
safety glasses 153
Safety Rated Controller 15
Safety Statement 3, 135
Safety Subsystem 171
Safety Symbols 21
Sawyer
 simulated 31
 turning on 23
selective arm stiffness 106, 124
selector knob 15, 16
Sequence Node 145
service
 how to acquire 21
Setting Up Sawyer 22
Settings 34
Shared Data 48

Shared Data tab 48
sibling nodes 38
Signal Variable 145
Signals 45
Signals tab 45
Simulated Robot
 change view of 51
 how to move 52
simulated Sawyer robot 31
Snapshot Editor 45
SOPs & training 153
Square button 16
start, how to 26
State Flags 189, 203
stiffness 110
 arm 106, 124
Stopping Distance 177
Studio Menu 33
Studio Menu Button 32
SVG file 42

T

Task 33, 38
task
 defined 31
Task Bar 42
Task name 32
TCP Socket 145
TCP sockets 125
TCP/IP 45, 125, 145
Template 34, 145
terms
 Intera 30
Third Party Certifications 147
Third Party End Effectors 70
Timeout 126
Tool Center Point 58, 145
Tool Plate 19
Tool Selection Panel 38
Tool Tip Speed 158
Tooling Gallery 45, 57
Top Bar 32
Tracking Cycle Time 103
Training Cuff 17
training cuff 24
tree view 74

U

UI 145
Undo 41
USB ports 13, 15
Use considerations 152
User Variables tab 48

V

Variables 48

W

Warnings 4
Warnings & Notices 169
Waypoint 145

X

X button 16

Z

Zero G button 16, 17

Zero G mode 24

Zero Gravity mode 17

zoom

reset 42

