KINOVA MICO™ *Robotic arm*

User Guide

KINOVA

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About this document

⚠ Read all instructions before using this product.

⚠ Keep these instructions for future reference.

⚠ Read all warnings on the product and in this guide.

⚠ Follow all instructions.

This document contains information regarding product setup and the operation. It is intended for:

- Field service, customer support and sales employees of authorized Kinova distributors
- Kinova product end users

Symbols, definitions, and acronyms

 Important information regarding the safety related to the product and the user.

 Tip on the maintenance, operation and manipulation of Kinova's products.

 Refer to accompanying documents.

 Direct current.

 Alternating current.

 Operating temperature range.

 Compliance with WEEE2 directive.

 Compliance with ROHS3 directive.

 Type BF Applied Part device.

Warranty

This section describes the Kinova warranty terms.

Subject to the terms of this clause, Kinova warrants to End User that the Products are free of defects in materials and workmanship that materially affect their performance for a period of two (2) years from the date Kinova ships the Products to the End User ("Delivery Date").

Kinova agrees to repair or replace (at Kinova's option) all Products which fail to conform to the relevant warranty provided that:

1. Notification of the defect is received by Kinova within the warranty period specified above.
2. Allegedly defective Products are returned to Kinova, at the End User's expense, with Kinova's prior authorization within thirty (30) days of the defect becoming apparent.
3. The Products have not been altered, modified or subject to misuse, incorrect installation, maintenance, neglect, accident or damage by excessive current or used with incompatible parts
4. The End User is not in default under any of its obligations under this Agreement.
5. Replacement Products must have the benefit of the applicable warranty for the remainder of the applicable warranty period.

If Kinova diligently repairs or replace the Products in accordance with this section, it will have no further liability for a breach of the relevant warranty.

Allegedly defective Products returned to Kinova in accordance with this contract will, if found by Kinova on examination not to be defective, be returned to End User and Kinova may a charge a fee for examination and testing.

The warranty cannot be assigned or transferred and is to the sole benefit of the End User.

Where the Products have been manufactured and supplied to Kinova by a third party, any warranty granted to Kinova in respect of the Products may be passed on to the End User.

Kinova is entitled in its absolute discretion to refund the price of the defective Products in the event that such price has already been paid.

Warnings

This section summaries important warnings and cautions related to use of the robotic arm.

⚠ It is not recommended to use the arm under heavy rain or snow.

⚠ Never use the HOME/RETRACTED function when carrying liquid. The HOME position is preset and the wrist may rotate and drop the liquid.

⚠ Do not manipulate cutting, very sharp or any dangerous tools or objects with the arm.

⚠ When the power is turned off, the arm will fall down and may cause damage to itself, depending on its position at the time of disconnection. Be sure to support its wrist before turning the power off.

⚠ Do not force the fingers beyond their maximal opening. This could damage some internal components.

⚠ Do not immerse any part of the arm under water or snow.

⚠ When lifting weight near the maximum load and reach, if the red lights of the controller blink, put down the object in the gripper, bring back the arm to HOME or RETRACTED position and wait until the warning goes away before using it again.

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Address any questions or comments concerning this document, the information it contains or the product it describes to:

support@kinovarobotics.com

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General Information

The KINOVA MICO™ Robotic arm is a light-weight robot composed of four or six inter-linked segments. Through the controller or through a computer, the user can move the robot in three-dimensional space and grasp or release objects with the gripper (if a gripper is installed).

⚠ Do not modify this equipment without authorization of the manufacturer.

⚠ The Normal Use Definition contains some fundamental information to the proper operation of the robotic arm. arm.

⚠ It is not recommended to use the arm under heavy rain or snow.

MICO innovation configurations

This section describes the different configurations available for MICO robotic arms.

For Innovation applications, the MICO robotic arm is available in two configurations:

- 4 degrees of freedom (DOF)
- 6 degrees of freedom (DOF) curved wrist

Figure 1: MICO 4 DOF

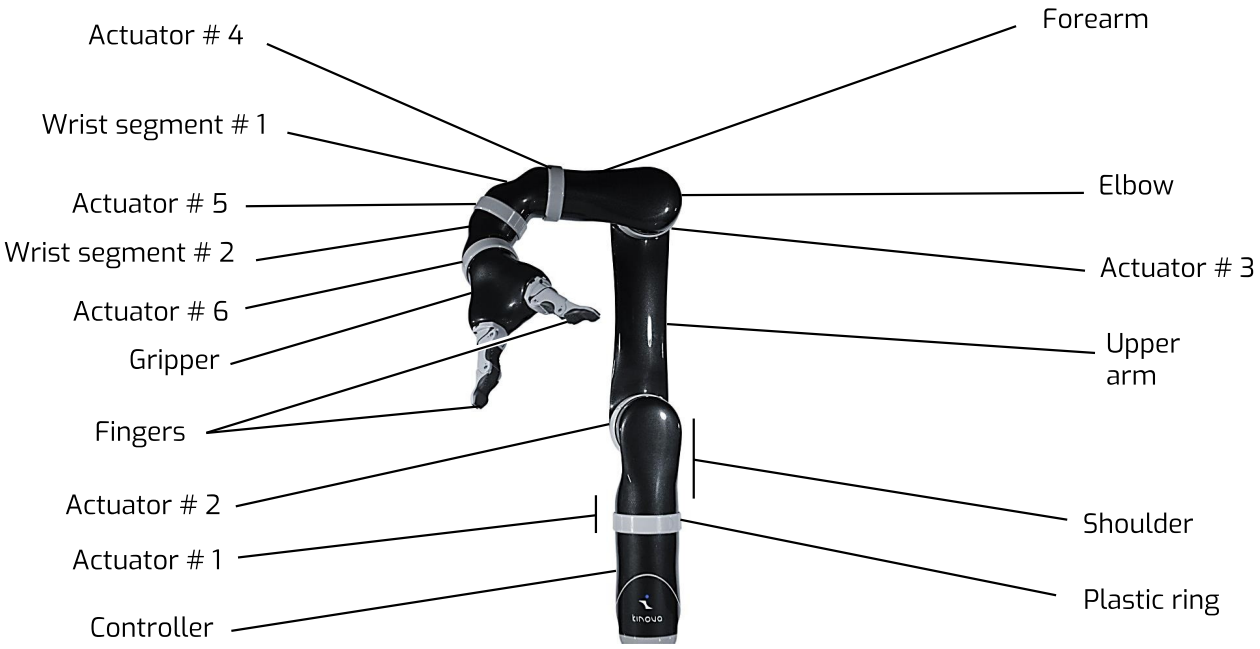
Figure 2: MICO 6 DOF curved wrist

MICO 4 DOF components

This section shows the components of the MICO 4 DOF robotic arm.

MICO 6 DOF curved wrist components

This section shows the components of the MICO 6 DOF curved wrist robotic arm.



Comparing MICO configurations

This section compares the different configurations of MICO.

Each of the two MICO configurations have their particular strengths. The best option depends on the needs of the specific users / group. The following table compares the options.

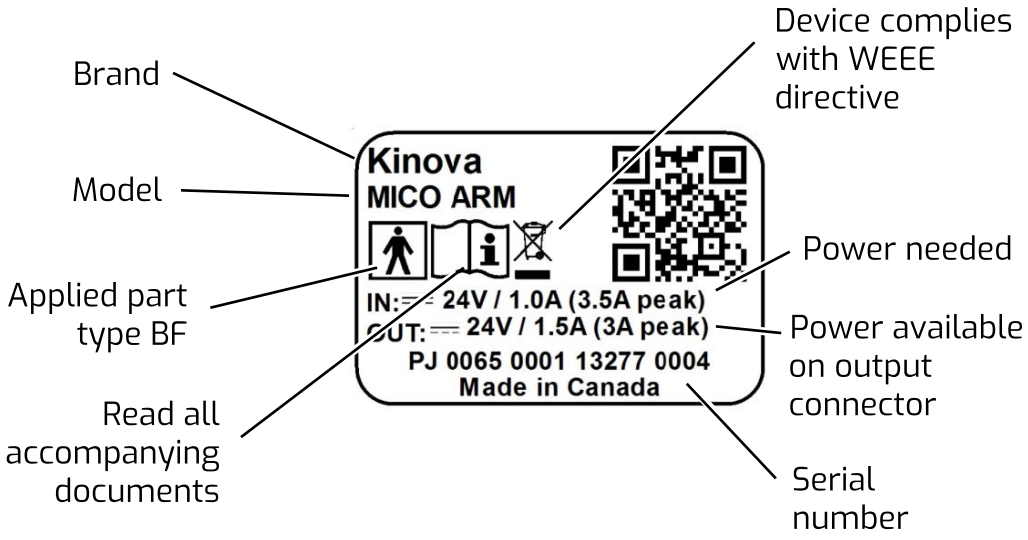
Table 1: MICO2 configurations

	4 DOF	6 DOF
		
Total weight	3.8 kg	4.6 kg
Reach	55 cm	70 cm
Maximum payload	• 5.2 kg (mid-range continuous) • 2.7 kg (full-reach peak / temporary)	• 2.1 kg (mid-range continuous) • 1.5 kg (full-reach peak / temporary)
Materials	Reinforced plastic (links), aluminum (actuators)	
Joint range (software limitation)	± 27.7 turns	
Maximum linear arm speed	20 cm / s	
Power supply voltage	18 to 29 VDC	
Average power	25 W (5 W in standby)	
Peak power	100W	
Communication protocol	RS485	
Communication cables	20 pins flat flex cable	
Water resistance	IPX2	
Operating temperature	-10 °C to 40 °C	

Markings and Labels

This section describes markings and labels on the robotic arm.

Please note that these labels may slightly differ from the ones accompanying your device depending of your country. The following figure depicts the information about the label affixed on the robotic arm controller.



Installation of the robotic arm

This section describes the main high level steps of the installation process.

The robotic arm's installation consists of four high-level steps:

1. Mechanical integration
2. Electrical integration
3. End-effector electrical integration (optional)
4. Control integration

Mechanical mounting of the robotic arm

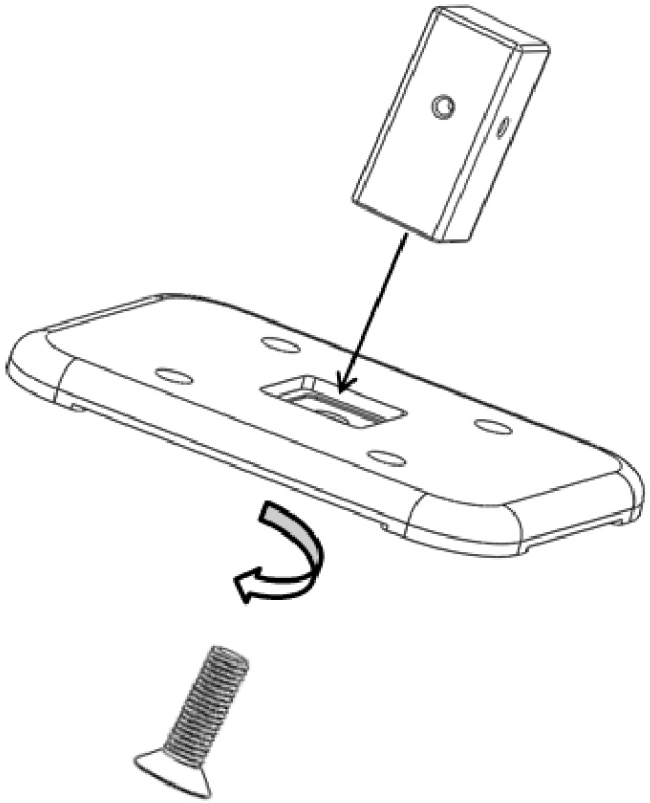
This section describes the steps for mechanical mounting of the robotic arm.

About this task

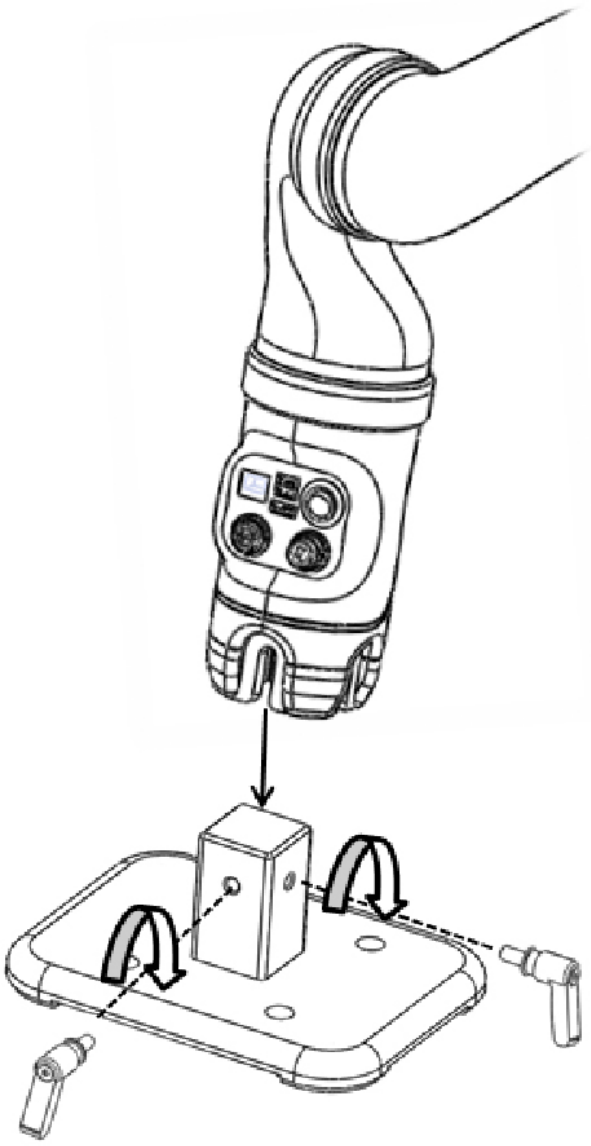
The arm is designed to be installed on a fixed surface or mobile platform. Please make sure the arm is fixed in such a way that its base cannot fall or break during operations involving maximum reach of the arm. Here is a guide on how to install the arm on the mounting kit (XK 0000 0014) supplied with your robotic arm.

Procedure

1. Assemble the mounting kit. Insert the mounting post into the square cavity on the top of the mounting plate and use an 8 mm hex key to attach from the bottom of the mounting plate.



2. Affix the mounting kit to a flat surface. You can either place the larger side of the mounting kit on the edge of a solid flat surface and clamp it as firmly as possible by placing the two clamps supplied with the package on each side of the mounting post or secure four M12 screws through the holes in the mounting plate.
3. Insert the robot arm on the top of the mounting post. Screw the two M8 lever screws into the mounting post, one in the back of the controller and the other on one of the sides of the robot.



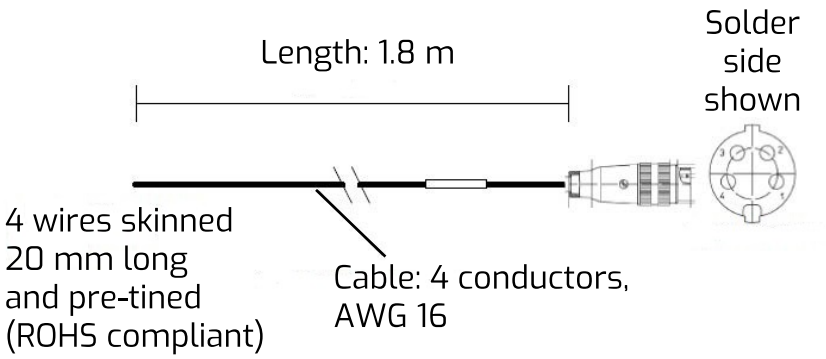
Electrical integration

This section describes how to connect the robotic arm to an electrical power source.

There are two ways of powering the robotic arm:

- Wall electrical outlet
- Battery power

Electrical outlet - You can power your robotic arm using a standard 110/220 V power outlet by plugging the power cord (EH 0300 0001 (USA), EH 2500 0001 (EUR), EH 2500 0002 (AUS), EH 2500 0003 (UK)) into the Power Supply Unit (PSU - AE 0000 0029) on one end and into a power outlet on the other. Then plug the PSU into the base controller power connector.



Battery power - You can use the battery power cord (EH 01M8 0003) by plugging one end into the base controller power connector and connecting the four wires at the other end to a 24V battery. The following table shows the relationships between power connector pinout, the signal, and the wire color.

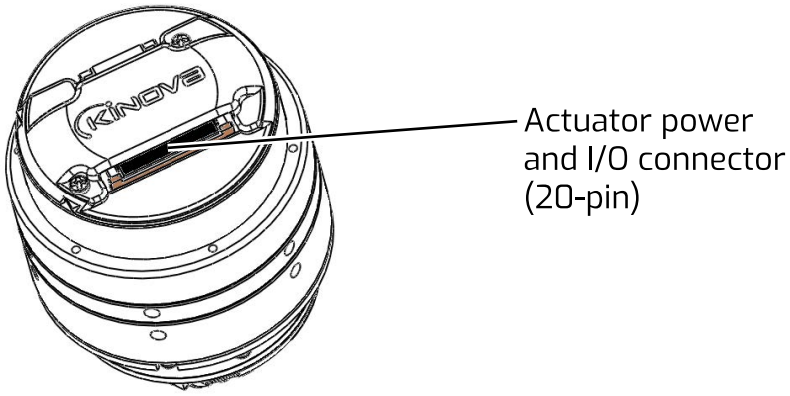
Pinout table		
Pin #	**Signal**	**Wire color**
1	24V	Red
2	24V	Brown
3	GND	Black
4	GND	Orange

⚠ Make sure that your battery respects the electrical specifications of the robotic arm.

Integrating a new end effector (optional)

This section describes how to integrate a new end effector with Kinova actuators, whether in a Kinova robotic arm or custom application.

Kinova actuators, whether as part of a Kinova robotic arm, or as part of a reseacher's custom-built robotics application, have the ability to be connected to end effectors. The output end of each actuator has a 20-pin power and I/O connector. Two of these pins are set aside as dedicated expansion communication and power lines. This allows you the option to connect an additional device to the end of a robotic arm or the end of a chain of actuators in a custom-built set-up.

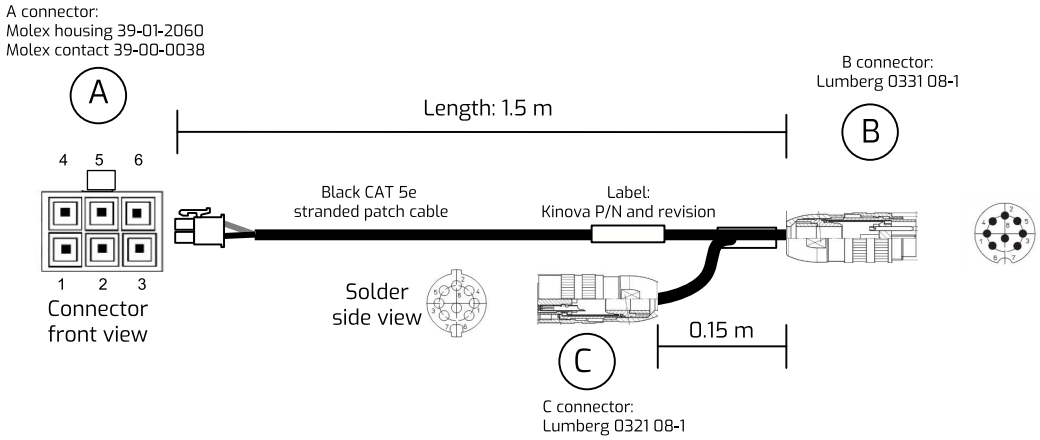


The pins and their function are described in the table below:

Table 2: K-58 actuator pinout

Pin #	Signal
1 to 8	24V input
9 to 16	GND
17	RS485 low
18	RS485 high
19	Expansion 0
20	Expansion 1

⚠ Make sure to connect your end effector using only pins 19 and/or 20. Using other pins could severely damage your robot. These two expansion lines are accessible for power and controls purposes via pins at the joystick port. The A “Y” cable is supplied with the robot to allow you to access both the joystick and the expansion lines.



The output pinout of the two expansion lines is indicated in the table below.

Table 3: EH 01M5 0001 pinouts

Connector A		
Pin #	**Signal**	**Function**
1	COM1	RS485_low
2	GND	GND
3	COM3	Expansion 0
4	COM2	RS485_high
5	24V (max current: 1.5A)	24V
6	COM4	Expansion 1

Control integration

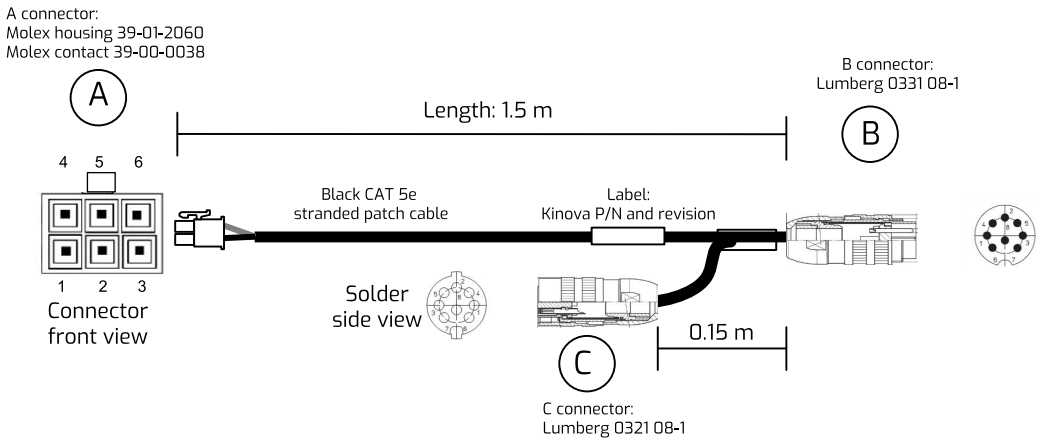
This section describes the controls integration for Kinova robotic applications, whether for Kinova robotic arms or custom-built applications.

Once the mechanical and electrical integration are completed are completed (as well as the end effector integration if applicable), you can power on the robot by flipping the power switch on the back of the controller to ON. To control the robot, you can use either the Kinova API or Kinova's joystick.

API - Connect the USB cable supplied with your package. Connect one end to the controller USB port, and the other to a USB port on the development computer. Install and open the Kinova SDK Development Center on the development computer and follow the procedure and documentation included in the SDK.

Note: Refer to the Development Center user guide and the Kinova API documentation for more guidance on controlling the robotic arm via the API.

Kinova Joystick - Connect the joystick to the joystick port or to the C connector if you are using a "Y" cable. Refer to Kinova's Joystick section in the user guide for all the details regarding the use of the joystick.



Control modes overview

This section explains how to operate the robotic arm with factory configuraton.

Kinova robot actuators can be controlled by end effector position, actuators' angular position or actuators' torque. Kinova robots offer the following control mode options:

Table 4: Control modes

Control mode	Description
Cartesian position	Specifies end-effector's position and end-effector's orientation (Euler angles, X-Y'-Z'' convention) in the base frame.
Cartesian velocity	Specifies end-effector's translation velocities in the base frame and end-effector's rotation velocities in the effector's frame.
Angular position	Specifies each actuator's angle.
Angular velocity	Specifies each actuator's angular (rotational) velocity.
Cartesian admittance (Reactive Force control in Cartesian space)	Applies forces and torques on the end-effector and get a Cartesian motion (translation/rotation) in the appropriate direction.
Angular admittance (Reactive Force control in joint space)	Applies torques on actuators and get an angular motion (joint rotation) in the appropriate direction.
Direct torque control	Specifies each actuator's torque. By default, each actuator receives its corresponding gravity torque so the robot compensates its own weight.
Force control	Specifies forces and torques at the end-effector. The robot automatically computes the torque at each actuator required to generate the appropriate forces/torques at the end-effector.

Control peripheral options overview

Three options are available to control Kinova robotic arms. Two of these options use the API. The

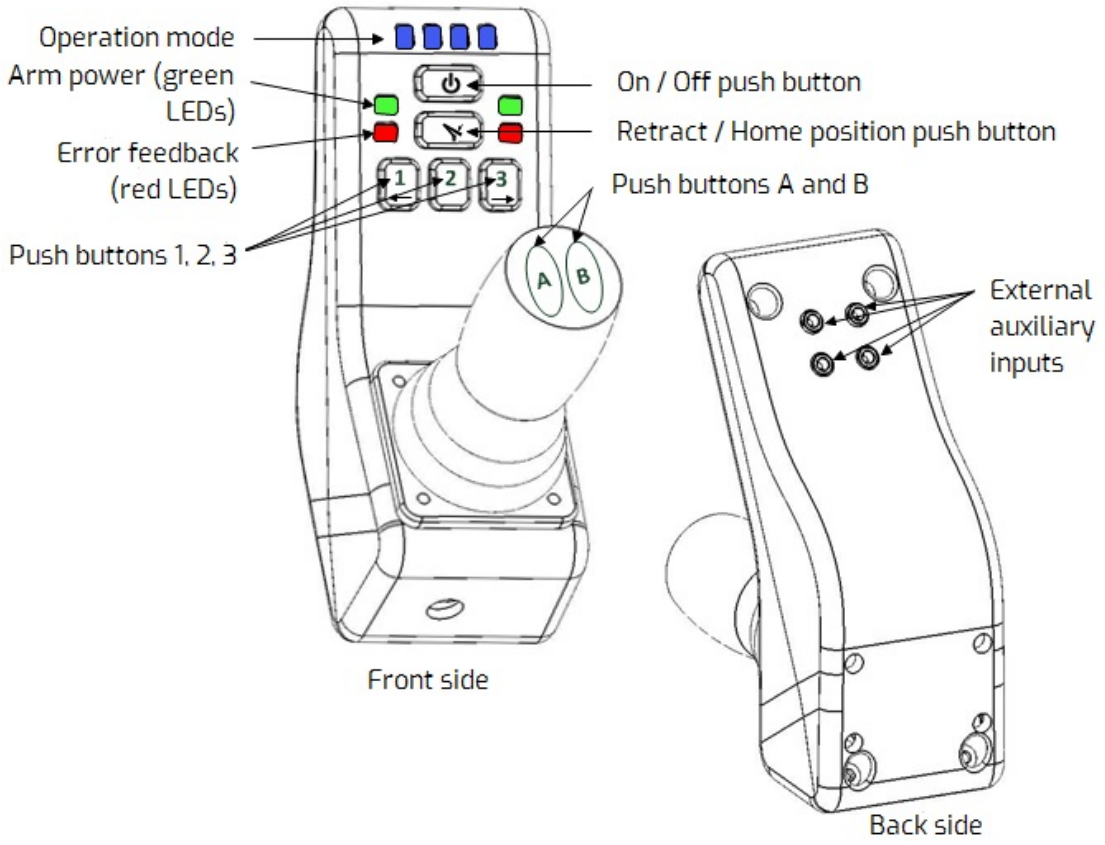
third option is the joystick control. The three options are:

- **(Kinova) joystick control**: This controls the arm in Cartesian velocity (by default as soon as the robot reaches its READY position) or in Angular velocity (if angular control is activated). Joystick control in Cartesian mode is the only control peripheral option Assistive users should be familiar with.
- **Kinova software control:** Kinova provides two different software control panels that allow you to control the arm via a graphical user interface.: the Development Center and the Torque Console. These two software panels allow users to command the arm in position, velocity, and trajectories. It also allows users to activate admittance control (inside the Development Center) and direct torque control/force control (inside the Torque Console). For more details on Kinova software, please see the Development Center User guide (downloadable from Kinova website).
- **API control:** Kinova has a library of C++ functions to control its robotic arms. This library of functions is referred to as the Kinova API. The API (.dll files and .h files) is downloadable from Kinova's website as part of the Kinova software development kit (SDK). The SDK is supplemented by HTML-based documentation detailing all the available functions. The Kinova API is supported on both Windows and Ubuntu. Kinova also offers developers the possibility for developers to control the robotic arm through a ROS interface (ROS Indigo on Ubuntu 14.04 currently supported). For more information, see the Kinova ROS Github page at https://github.com/Kinovarobotics/kinova-ros.

A fourth option is to control the arm by directly interacting with it (pushing/pulling on some link or at the end-effector). The robot becomes reactive to direct interaction in admittance control and direct torque/force control.

Kinova joystick controller

The Kinova standard controller is a three-axis joystick mounted on a support. The controller iincludes five independent push buttons and four external auxiliary inputs (on the back side).



Joystick movements and modes

The Kinova joystick allows to control the arm in a “2-axis” or “3-axis” mode. The “2-axis” mode will disable the joystick twist rotation.

The following table shows the button default factory settings for using the joystick in a 2-axis and 3-axis modes.

Table 5: Default joystick button settings

Buttons	One click	Hold 2 sec (Hold until position is reached)
⏻	Deactivate / Activate Joystick	Change joystick operating mode (2-axis Vs 3-axis)
	---	Home / Retracted function
	3-Axis	
1	Deactivate / Activate Drinking mode	---
2	---	Set Position
3	---	Go to pre-set position
A	Reach Finger mode	Decrease speed
B	Reach Translation & Wrist mode	Increase speed
Ext1	Reach Finger mode	Decrease speed
Ext2	Reach Translation and Wrist mode	Increase speed
Ext3	--	Home / Retracted function
Ext4	Deactivate / Activate Drinking mode	--
	2-Axis	
1	Deactivate / Activate Drinking mode	---
2	Reach Wrist orientation & Finger mode	Decrease speed
3	Reach Translation-X/Y & Translation-Z / Wrist rotation mode	Increase speed
A	---	---
B	---	---
Ext1	Reach Wrist orientation & Finger mode	Decrease speed
Ext2	Reach Translation-X/Y & Translation-Z / Wrist rotation mode	Increase speed
Ext3	--	Home / Retracted function
Ext4	Deactivate / Activate Drinking mode	--

Kinova Joystick LED feedback

The Kinova joystick offers visual feedback:

- Blue lights : Feedback on control mode
- Green lights : Feedback on arm power
- Red lights : Feedback on error

Kinova joystick Blue LEDs feedback

This section describes the blue LED feedback on the Kinova controller.

The blue LEDs on the controller give feedback on the current control mode. The interpretation of the blue mode LED indicators is described in the following table.

Table 6: Control mode feedback

Blue LED indication		Control Mode
3-Axis		Translation (X-Y-Z)
		Wrist
		Fingers
		Drinking mode (to be used with wrist rotation mode)
		Disabled controller
2-Axis		Translation (X-Y)
		Translation (Z) / Wrist Rotation
		Wrist Orientation
		Fingers
		Drinking mode (to be used with wrist rotation mode)
		Disabled controller

When no blue lights are visible, the controller is disabled. To enable the controller, you must either proceed with the following options:

- The On/Off button must be pushed
- The arm must be set in its HOME position by holding the HOME/RETRACTED function until the arm stops moving.

Kinova joystick Green LEDs feedback

This section describes the green LED feedback on the Kinova controller.

The green lights offer visual feedback on the power status of the arm.

Table 7: Power status feedback

Green LED indication	Power Status
Flashing	The arm has just been turned on and the internal communication is synchronizing. The arm is not yet ready to use.
Solid	The arm is powered and ready to use.

Kinova joystick Red LEDs feedback

This section describes the red LED feedback on the Kinova controller.

The red lights offer visual feedback on possible errors that may occur while operating the arm:

Table 8: Error status feedback

Red LED indication	Cause of the Error Status	Action to resolve the situation
Flashing	The weight that is being lifted is too heavy or too much force is applied on the arm.	Safely put down the object, or release force applied on the arm, and wait until red lights turn off.
	The temperature of a section of the arm is too high.	The usage of the arm is excessive and doesn't respect the normal use definition. Safely put down any object that is in the gripper, bring back the arm to its RETRACTED position, and wait until red lights turn off.
	The input voltage to the arm (or batteries) is too low or too high.	Safely put down any object that is in the gripper, bring back the arm to its RETRACTED position. Ensure the power supply is appropriate, connections are secure and batteries are charged properly before using the arm again.
Solid	The arm is in fault	Turn off the arm and turn it back on. If the problem remains, contact your distributor or Kinova.

Operating principles and Cartesian mode

This section describes at a high level the control of the arm using the joystick in Cartesian mode.

Operating principles

The operating principles are very simple and intuitive. The robotic arm may be operated through several controllers. The following sections present the general control principles through Kinova's joystick.

Basic movements

The normal control of the robotic arm with the joystick is said to be Cartesian. The user commands the end-effector's translations (position variations) with respect to the base and the rotations (orientation variations) around the end-effector's reference point. The different joints are piloted automatically following the given command.

In "Translation mode", the user controls the position of the gripper in space. The gripper will always keep its parallelism with the arm's base. Translation X refers to left/right movements of the gripper. Translation Y refers to front/back movements of the gripper. Translation Z refers to up/down movements of the gripper.

In the "Wrist mode", the user controls the position of the gripper around its center point (reference point) which will not move (or move slightly) when operating in this mode. Lateral orientation refers to a thumb/index circular movement of the wrist around the reference point. Vertical orientation refers to a top/bottom circular movement of the wrist around the reference point. Wrist rotation refers to a circular movement of the gripper around itself.

The "Drinking mode" is to be used with the wrist rotation only. While operating the Jaco² arm in "Drinking mode", the reference point (normally set in the middle of the gripper), is offset in height and length to produce a rotation around another point in the space of the arm.

In the "Finger mode", the user controls the opening and closing of the fingers.

Note: The arm will sometimes respond differently to a given command than described in this section. This may be due to the singularity and collision avoidance algorithms embedded in the kinematics. It is a normal protective behaviour of the arm and is position dependent. Both these avoidance algorithms can be deactivated by the user.

Home / Retracted positions

This section describes the Home and Retracted positions of the robotic arm.

The arm comes with two factory default pre-set positions that may be configured in the Kinova Development Center:

- Home position and
- Retracted position.

The Home position refers to the position of the arm when it is ready to be used. In the Home position, the arm is awaiting a commands from the joystick.

The Retracted position refers to the position of the arm when it is not used. The user should always place the arm in the Retracted position when it is unused as it decreases the physical volume occupied by the arm. In the Retracted position, the arm is in standby mode; the joystick features are disabled and power consumption is much lower.

⚠ Never use the Home / Retracted function when carrying liquid. The Home position is pre-set and the wrist may have to rotate and will drop the liquid.

Operating the arm via joystick

This section describes operation of the arm using the joystick.

This section explains how to operate the arm with factory configuration. Contact your reseller for operation instructions in the case of an adapted configuration.

⚠ Before operating the arm, please make sure it is properly installed.

⚠ Do not manipulate cutting, very sharp or any dangerous tools or objects with the arm.

⚠ This equipment is not designed to act as a lift.

⚠ This equipment is not designed to be used in presence of flammable mixture. (Not AP or APG rated).

⚠ Do not install the arm near any heat sources, such as radiators. Do not use it to directly manipulate hot objects.

Joystick control quick start

This section describes how to get started using the Kinova joystick to control the arm in the default configuration.

About this task

Procedure

1. Turn ON the device by pushing the ON/OFF switch located on the arm base.
2. Wait until the green lights on the controller stop flashing.
3. Put the arm in its Home position by holding down the HOME/RETRACTED button. until the arm stops moving. The arm will slowly reach the Home position.

   Note: When starting the arm, you are in 3-Axis operation mode, "Translation control mode", meaning that any movement of the joystick will move the center of the gripper parallel to the floor.
4. You may move the 3 axes of the joystick to experience the Translation control mode.

   Note: To change the operating mode of the Joystick, hold the ON/OFF button for 2 seconds. At this point, you are in 2-axis mode and the stick rotation is deactivated.
5. One press of Button B will bring you in Wrist control mode meaning that any movement of the joystick will result in a rotation of the gripper around its center.

   Note: Another press of Button B will bring you back in Translation control mode.
6. One press of Button 1 will activate the Drinking mode which may be used only in Wrist mode. When rotating the joystick lever, you will see that the arm's wrist rotation now compensates for the height and radius of a virtual glass. This movement is ideal when trying to drink directly from a glass.

   Note: Another press of Button 1 will disable Drinking mode.
7. One press of Button A will bring you in Finger control mode. The fingers will move per a left/right inclination of the joystick.

   Note: At any time, you may use the Home / Retracted button until the arm stops moving to bring it back to its Home position.

   Note: If you hold the Home / Retracted button again, the arm will start to move toward the Retracted position.
8. Hold the On/Off Button for 2 seconds to change the operating mode. This will disable the stick rotation. You are now in a 2-Axis Translation control mode. Stick rotation won't have any effect and you will only be able to control the horizontal translation of the arm (X- and Y- axis).
9. One press of Button 3 will bring you to control the vertical translation of the gripper (Translation-Z) and Wrist rotation.

   Note: Another hit on Button 3 will bring you back in Translation-X and Translation-Y control mode.
10. One press of Button 1 will activate the Drinking mode which may be used only in Wrist mode. When rotating the joystick lever, you will see that the arm's wrist rotation now compensates for the height and radius of a virtual glass. This movement is ideal when drinking directly from a glass.
11. One press of Button 2 will bring you to control the wrist orientation (Lateral orientation and Vertical orientation).
12. Another press of Button 2 will bring you to Finger control mode. The fingers will move according to a left/right inclination of the joystick.

Note: Another press of Button 2 will bring you back in Lateral orientation and Vertical orientation control mode.

Default joystick motion settings - Cartesian three-axis mode

This section describes default motion settings in Cartesian three-axis mode.

Table 9:

Joystick movement	Arm movement	Availability
	Translation Mode	
Incline FRONT	Gripper moves forward	4 / 6 / 6 -S / 7 DOF-S
Incline BACK	Gripper moves backward	4 / 6 / 6 -S / 7 DOF-S
Incline LEFT	Gripper moves left	4 / 6 / 6 -S / 7 DOF-S
Incline RIGHT	Gripper moves right	4 / 6 / 6 -S / 7 DOF-S
Rotate stick CLOCKWISE	Gripper moves up	4 / 6 / 6 -S / 7 DOF-S
Rotate stick COUNTERCLOCKWISE	Gripper moves down	4 / 6 / 6 -S / 7 DOF-S
	Wrist Mode	
Incline FRONT	Vertical orientation – Top side	6 / 6 -S / 7 DOF-S
Incline BACK	Vertical orientation – Bottom side	6 / 6 -S / 7 DOF-S
Incline LEFT	Lateral orientation – Thumb side	6 / 6 -S / 7 DOF-S
Incline RIGHT	Lateral orientation – Index side	6 / 6 -S / 7 DOF-S
Rotate stick CLOCKWISE	Wrist rotation clockwise	4 / 6 / 6 -S / 7 DOF-S
Rotate stick COUNTERCLOCKWISE	Wrist rotation counterclockwise	4 / 6 / 6 DOF-S / 7 DOF-S
	Finger Mode	
Incline LEFT	Close Fingers (3 finger mode)	4 / 6 / 6 -S / 7 DOF-S
Incline RIGHT	Open Fingers (3 finger mode)	4 / 6 / 6 -S / 7 DOF-S
Incline FRONT	Open Fingers (2 finger mode)	6 -S/ 7 DOF-S
Incline BACK	Close Fingers (2 finger mode)	6 -S / 7 DOF-S

Default joystick motion settings - Cartesian two-axis mode

This section describes default motion settings in Cartesian two-axis mode.

Table 10:

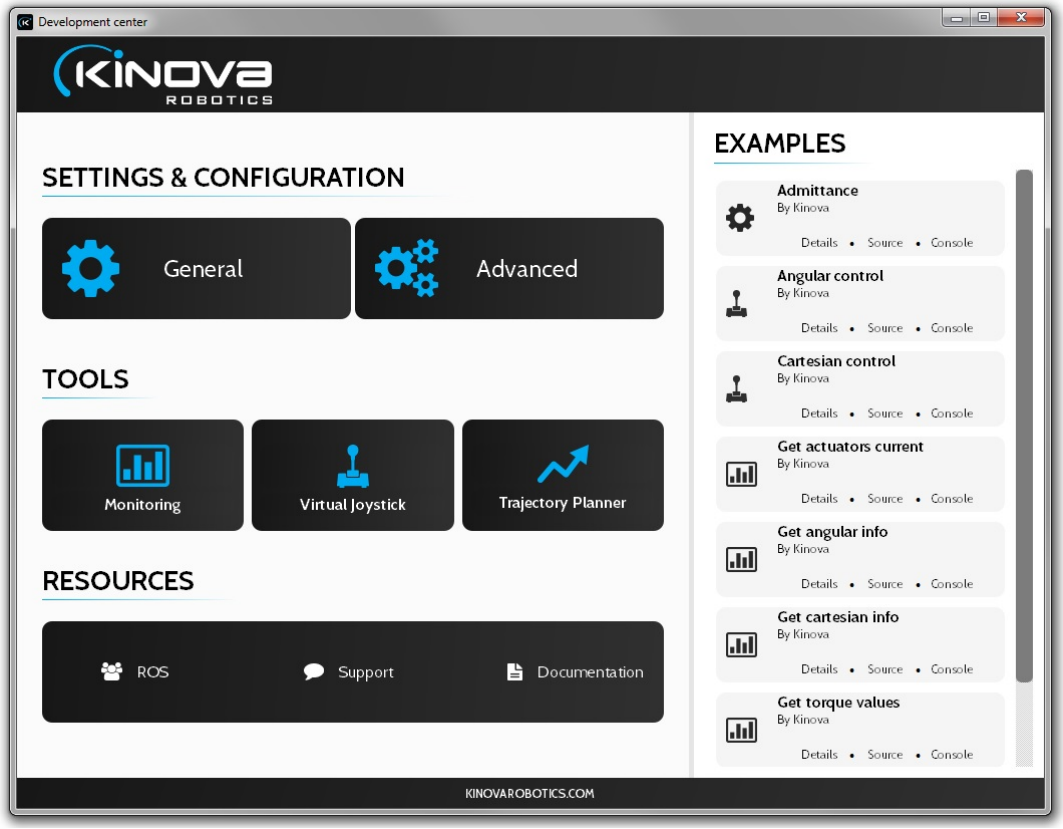
Joystick movement	JACO arm movement	Availability
	Translation-X and Translation-Y	
Incline FRONT	Gripper moves forward	4 /6 / 6S / 7S DOF
Incline BACK	Gripper moves backward	4 /6 / 6S / 7S DOF
Incline LEFT	Gripper moves left	4 /6 / 6S / 7S DOF
Incline RIGHT	Gripper moves right	4 /6 / 6S / 7S DOF
	Translation-Z and Wrist Rotation	
Incline FRONT	Gripper moves up	4 /6 / 6S / 7S DOF
Incline BACK	Gripper moves down	4 /6 / 6S / 7S DOF
Incline LEFT	Wrist rotation clockwise	4 /6 / 6S / 7S DOF
Incline RIGHT	Wrist rotation counter-clockwise	4 /6 / 6S / 7S DOF
	Wrist Orientation	
Incline FRONT	Vertical orientation – Top side	6 / 6S /7S DOF
Incline BACK	Vertical orientation – Bottom side	6 / 6S /7S DOF
Incline LEFT	Lateral orientation – Thumb side	6 / 6S /7S DOF
Incline RIGHT	Lateral orientation – Index side	6 / 6S /7S DOF
	Finger Mode	
Incline LEFT	Close Fingers (3 finger mode)	4 /6 / 6S / 7S DOF
Incline RIGHT	Open Fingers (3 finger mode)	4 /6 / 6S / 7S DOF
Incline FRONT	Open Fingers (2 finger mode)	6S / 7S DOF
Incline BACK	Close Fingers (2 finger mode)	6S / 7S DOF

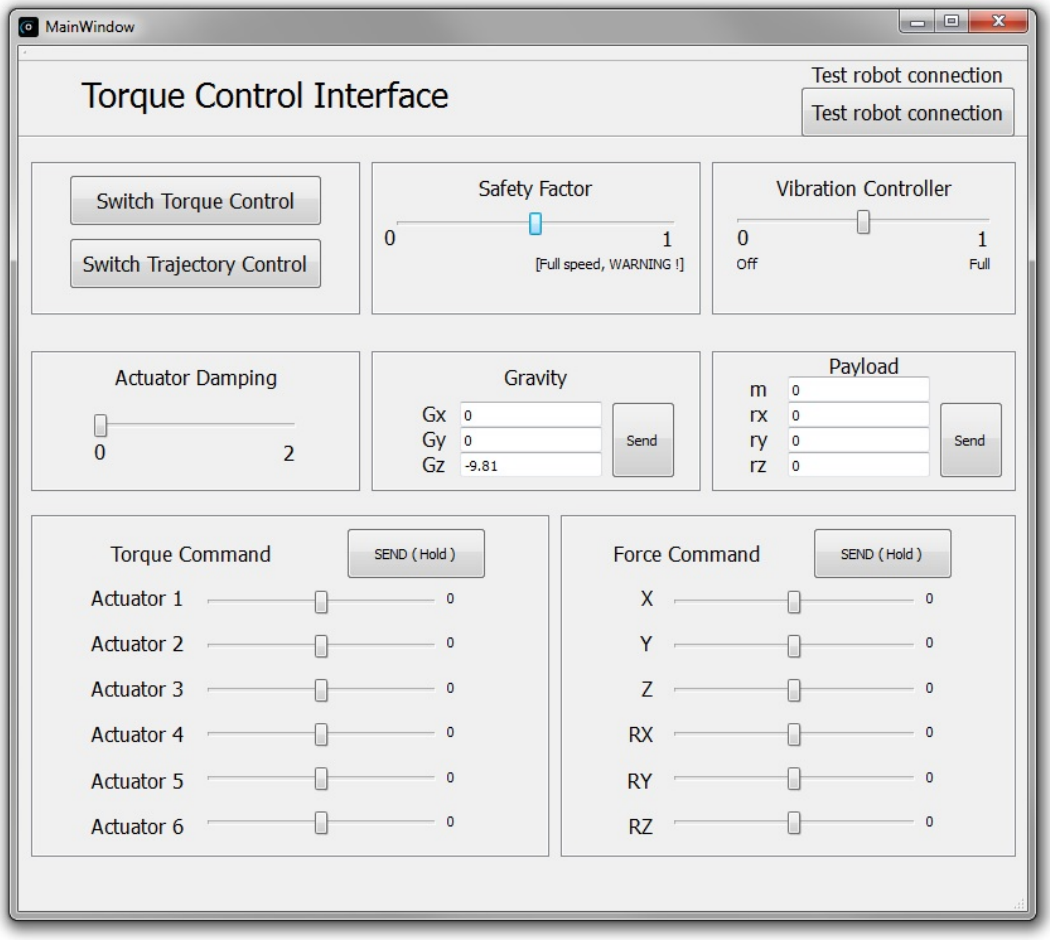
Controlling the arm using Kinova software

This section describes at a high level control of the arm using Kinova software.

Multiple functionalities are offered by Kinova software. Using the Development Center and the Torque Console, users can (among other things) send trajectories, monitor their robot's state, activate admittance and switch between Cartesian and angular control. Kinova software is also useful to update the robot's firmware and to diagnose different problems.

The Development Center and Torque Console are available for download on the Kinova website. For a complete list of Kinova software functionalities and use instructions, please see the separate Kinova Development Center User Guide.





Controlling the arm using the Kinova API

This section describes at a high level control of the arm using Kinova API.

As with the Development Center and the Torque Console, information about the API is downloadable from Kinova's website. The Development Center comes with HTML documentation describing the C++ programming functions that can be used to access the API. A good way to start with the API is to look at the examples provided with the Kinova Development Center. For more details, please see the Kinova Development Center User Guide and the HTML-based API documentation.

Specific Utilization Limitations

The robotic arm has certain utilization limitations that research users should be cautious of. This includes:

- Recommended maximum actuators utilization
- Software position limitations of actuators
- Software position limitations of fingers

Recommended maximum actuators utilization

	Big actuators (75mm)	Small actuators (58mm)	Fingers actuators
Maximum RPM	6 RPM	8 RPM	600 RPM
Maximum command / sec	36° / sec	48° / sec	300 mm / sec 10800° / sec
Maximum repetitive current	1.5A	1.6A	1.4
Maximum temperature	80°C	80°C	80°C

Utilization over these maximum recommended parameters may affect lifetime of the arm and its modules. Please refer to the specification sheet information for your particular arm configuration for additional information

Software position limitations of actuators

This section provides a reference of software position limitations of various robotic arm configurations.

The following limitations indicate the software limitations that are presents in the robotic arm controller base to ensure safety of the robot. These limitations are there to protect the arm and its environment.

When moving the actuators, the following minimum and maximum positions should be followed. If the command sent to any of these actuators goes further than these values, the actuators will stop moving.

Table 11: 4 DOF software limitations

Actuator	Min(°)	Max(°)
1	-10 000	10 000
2	50	310
3	35	325
4	-10 000	10 000

Table 12: 6 DOF curved wrist software limitations

Actuator	Min(°)	Max(°)
1	-10 000	10 000
2	50	310
3	35	325
4	-10 000	10 000
5	-10 000	10 000
6	-10 000	10 000

Software position limitations of fingers

When moving the robotic arm fingers, the following minimum and maximum positions should be respected. If the command sent to any of these fingers goes further than these values, the fingers will stop moving.

Finger #	Minimum	Maximum
1	0 mm (0°)	18.9 mm (6800°)
2	0 mm (0°)	18.9 mm (6800°)

Advanced Configurations

Position indexation of the arm

The set zero positions of the MICO robotic arm configurations are as follows:

Table 13:

Config	Joint #1 angle	Joint #2 angle	Joint #3 angle	Joint #4 angle	Joint #5 angle	Joint #6 angle	Joint #7 angle
4 DOF	180	180	180	180	N/A	N/A	N/A
6 DOF curved	180	180	180	180	180	180	180

4 DOF

6 DOF curved wrist

Resetting torque sensors

In order to reset the torque sensors zero, you must first place the arm in a position where gravity does not influence the joint torques. The set zero position is good but it is suggested to use the positions as indicated in the table below since this position also limits perpendicular torques on the actuators.

Table 14:

Config	Joint #1 angle	Joint #2 angle	Joint #3 angle	Joint #4 angle	Joint #5 angle	Joint #6 angle
4 DOF	*	180	180	0	N/A	N/A

Config	Joint #1 angle	Joint #2 angle	Joint #3 angle	Joint #4 angle	Joint #5 angle	Joint #6 angle
6 DOF curved wrist	*	180	180	0	0	180

* Any angle

Kinematics Parameters

There are several sets of useful kinematic parameters:

- Basic geometric parameters of the arm
- Classic Denavit-Hartenberg (DH) parameters
- Directions of joints in angular space
- Inertial parameters

Basic geometric parameters - MICO 4 DOF

This section describes the basic geometric parameters of the MICO 4 DOF arm..

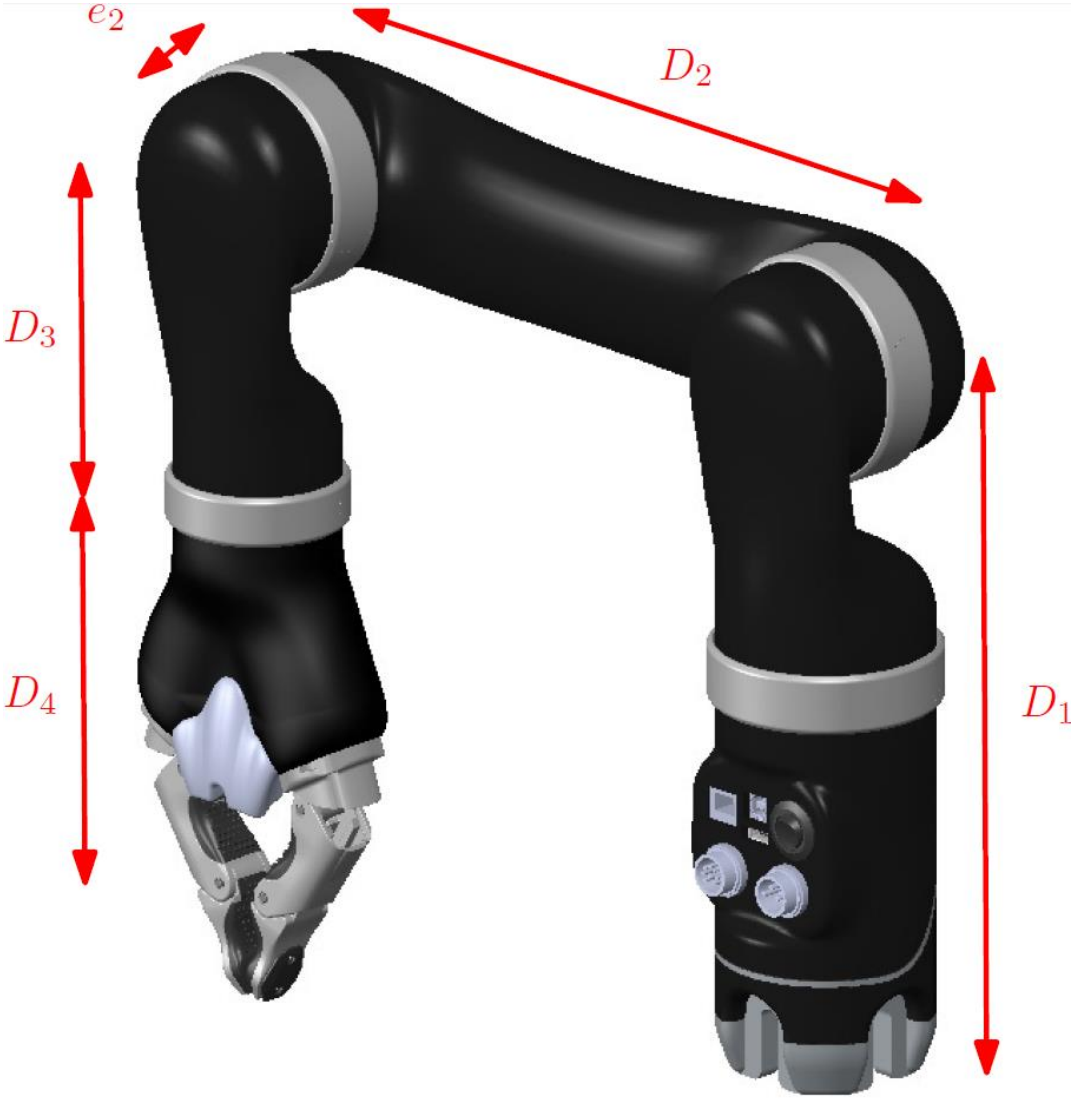


Table 15: MICO 4 DOF basic geometric parameters

Parameter	Description	Length (m)
D1	Base to shoulder	0.2755
D2	Upper arm length	0.2900
D3	Forearm length	0.1233
D4	Wrist to center of hand	0.1600
e2	Joint 3-4 lateral offset	0.0070

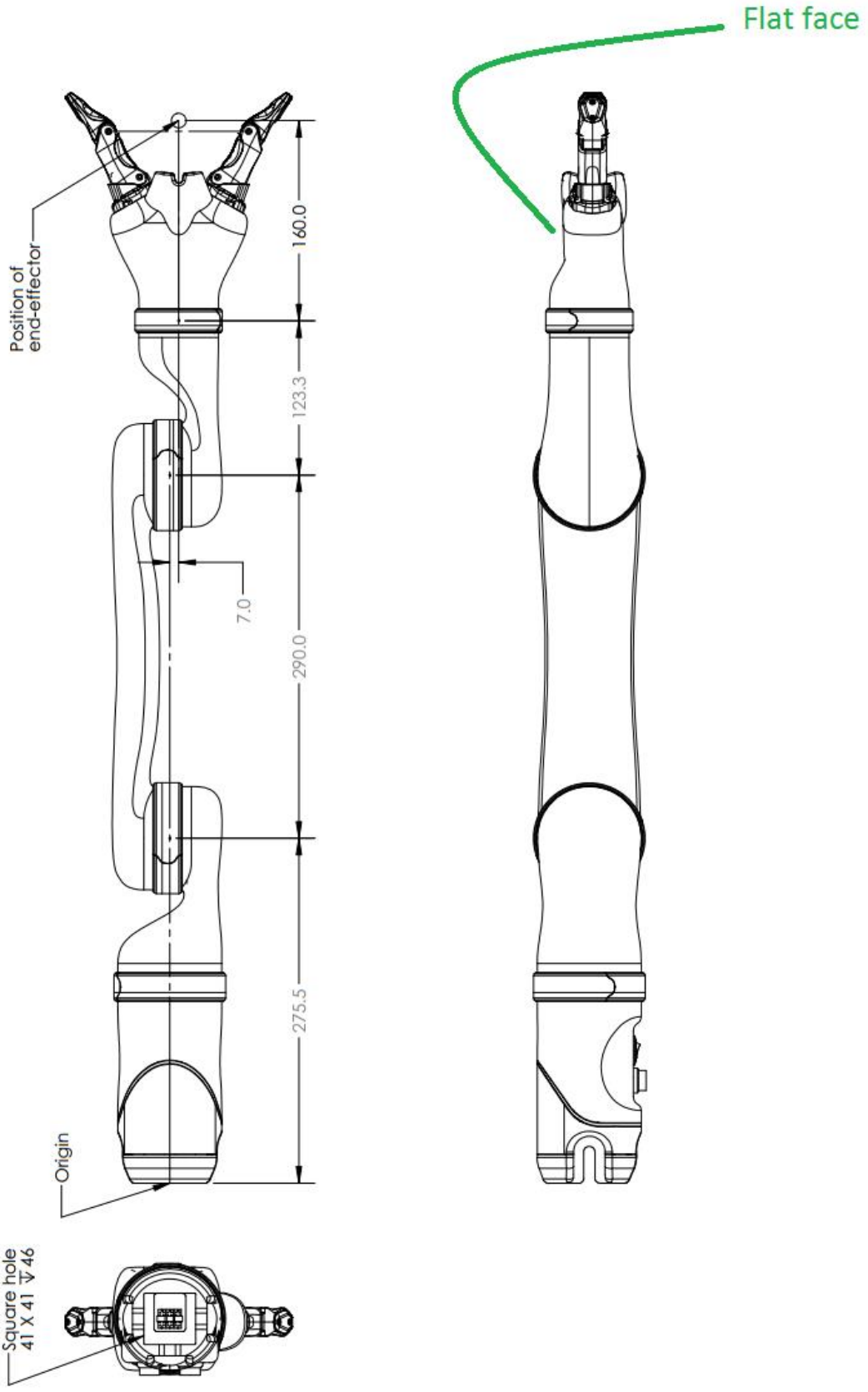


Figure 3: Detailed MICO 4 DOF robot length values (units in mm)

Basic geometric parameters - MICO 6 DOF curved wrist

This section describes the basic geometric parameters of the MICO 6 DOF curved wrist.

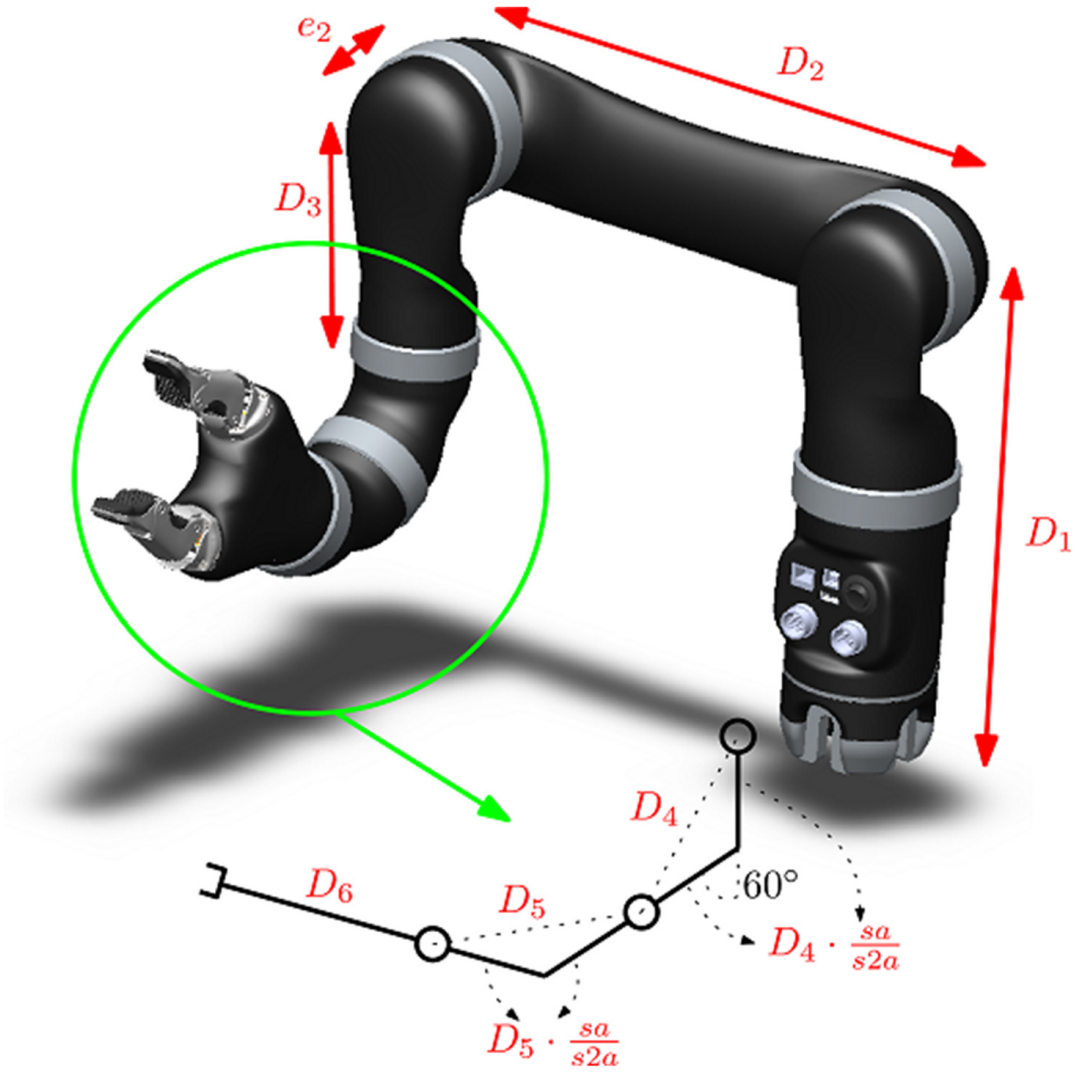


Table 16: MICO 6 DOF basic geometric parameters

Parameter	Description	Length (m)
D1	Base to shoulder	0.2755
D2	Upper arm length (shoulder to elbow)	0.2900
D3	Forearm length (elbow to wrist)	0.1233
D4	First wrist length (center of actuator 4 to center of actuator 5)	0.0741
D5	Second wrist length (center of actuator 5 to center of actuator 6)	0.0741
D6	Wrist to center of hand	0.1600
e2	Joint 3-4 lateral offset	0.0070

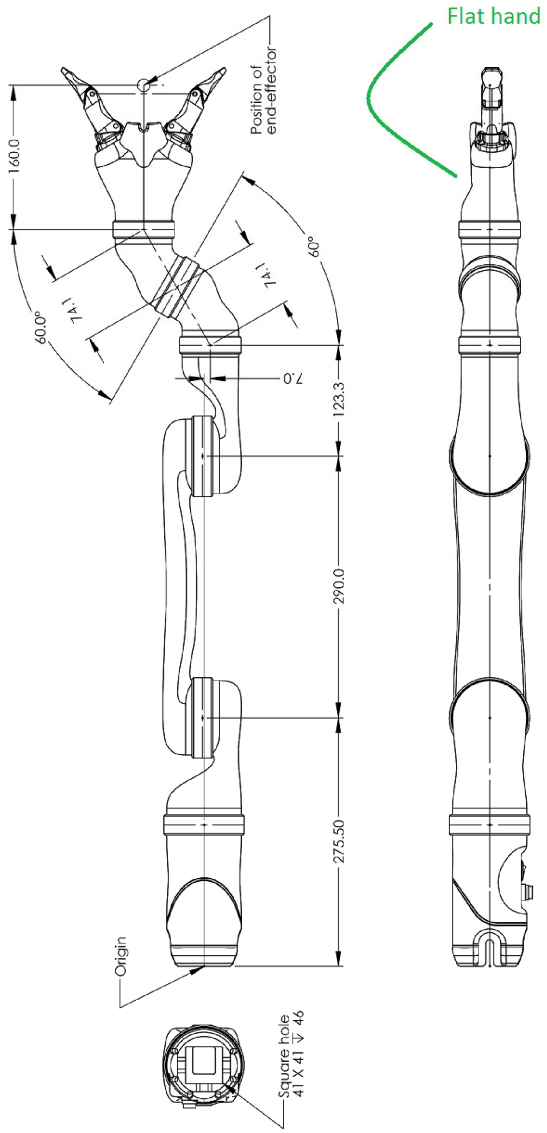
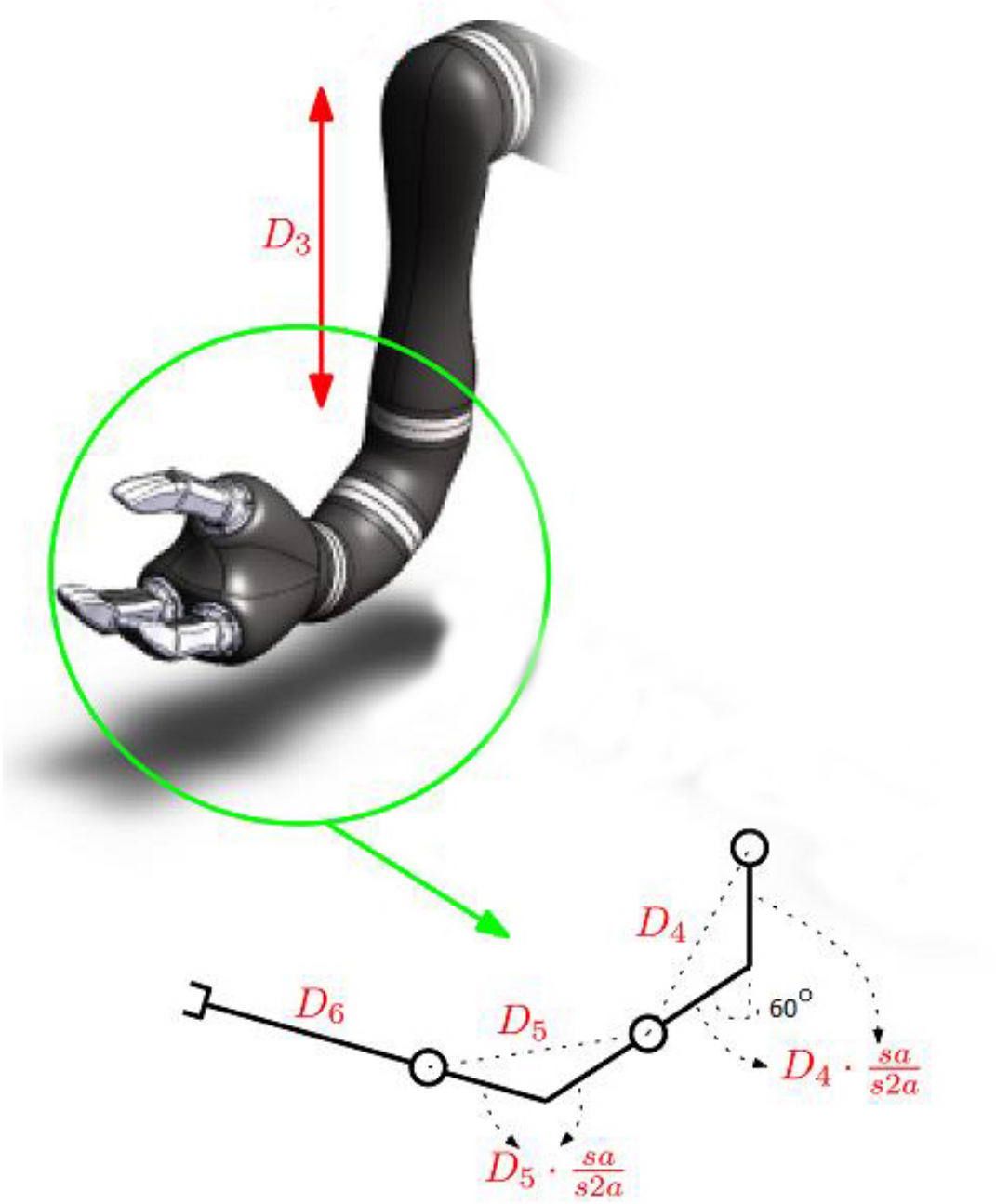


Figure 4: Detailed MICO 6 DOF curved wrist robot length values (units in mm)

Alternate geometric parameters - 6 DOF curved wrist

This section describes alternate parameters that are useful for describing the geometry for kinematics of the 6 DOF curved wrist configuration.

The kinematics of the 6 DOF curved wrist configuration are more complicated than for a spherical wrist due to the more complicated geometry. To simplify the analysis, it is useful to break down each of the two curved wrist segments into two component straight-line sub-segments of equal length, with the second sub-segment angled 60° from the first.



In this way, the arm from the elbow to the center of the hand can be analyzed as three straight-line segments:

- d4b - distance from elbow to end of first sub-segment of first wrist segment
- d5b - distance from end of first sub-segment of first wrist segment to end of first sub-segment of second wrist segment
- d6b - distance from end of second sub-segment of second wrist segment to center of hand

Table 17: Alternate parameters

Parameter	Description	Value
aa	Half of the angle of curvature of each wrist segment (60°), measured in radians	(30.0 * PI) / 180.0
sa	Sine of half the angle of curvature of wrist segment	sin(aa)
s2a	Sine of angle of curvature of wrist segment	sin(2*aa)
d4b	Length of straight-line segment from elbow to end of first sub-segment of first wrist segment.	D3 + (sa / s2a) * D4
d5b	Length of straight-line segment consisting of second sub-segment of first wrist segment and first sub-segment of second wrist segment	(sa / s2a) * D4 + (sa / s2a) * D5
d6b	Length of straight-line segment consisting of second sub-segment of second wrist segment and distance from wrist to the center of the hand	(sa / s2a) * D5 + D6

The DH parameters for the lower part of the robotic arm are most naturally expressed in terms of these alternate parameters.

Classic DH parameters - MICO 4 DOF

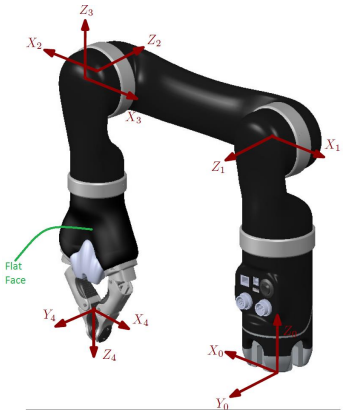
This section describes the Classic DH parameters for the 4 DOF robotic arm.

Table 18: 4 DOF DH parameters

i	α_{i-1}	a_{i-1}	d_i	θ_i
1	π / 2	0	D1	q1
2	π	D2	0	q2
3	π / 2	0	-e2	q3
4	π	0	D3 + D4	q4

Table 19: Transformation from DH algorithm to robotic arm physical angles

Q1(physical) = -Q1(DH algo)
Q2(physical) = Q2(DH algo) + 90
Q3(physical) = Q3(DH algo) - 90
Q4(physical) = Q4(DH algo) - 270



Represented angular position: (180, 270, 90, 270)

Transformation matrix from BASE to 0 axis system:

$$R = \begin{pmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & -1 \end{pmatrix}$$

Classic DH parameters - MICO 6 DOF curved wrist

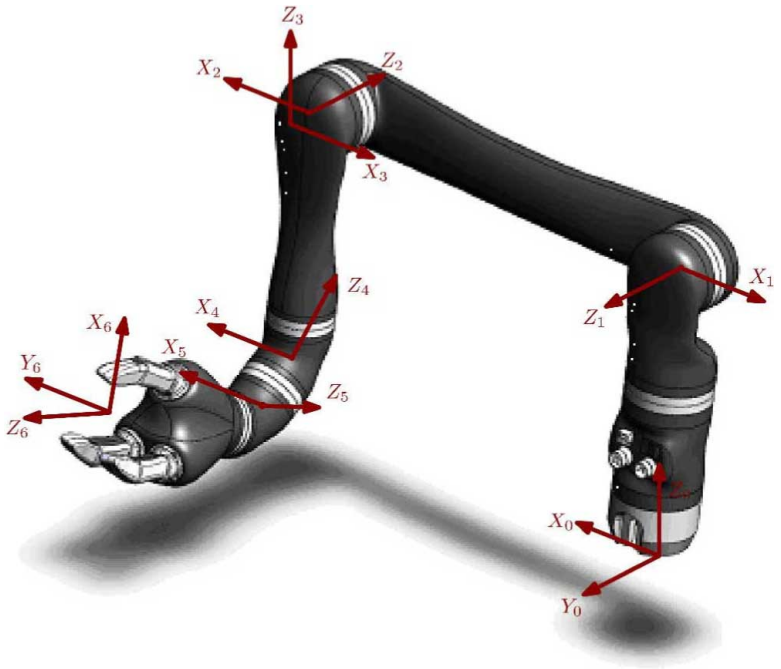
This section describes the Classic DH parameters for the MICO 6 DOF with curved wrist.

Table 20: MICO 6 DOF curved wrist DH parameters

i	α_{i-1}	a_{i-1}	d_i	θ_i
1	π / 2	0	D1	q1
2	π	D2	0	q2
3	π / 2	0	-e2	q3
4	2*aa	0	-d4b	q4
5	2*aa	0	-d5b	q5
6	π	0	-d6b	q6

Table 21: Transformation from DH algorithm to robotic arm physical angles

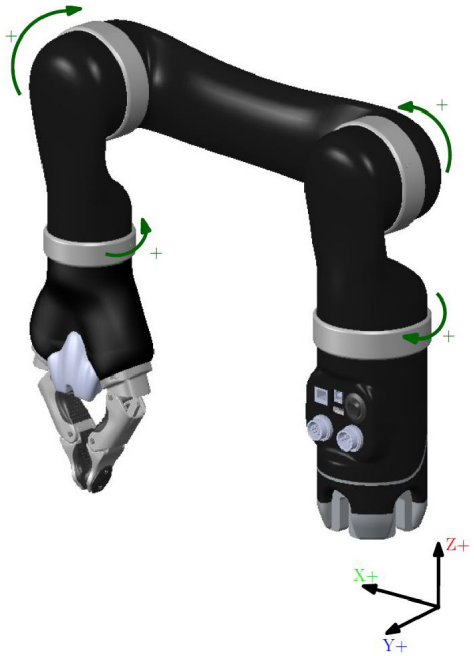
Q1(physical) = -Q1(DH algo)
Q2(physical) = Q2(DH algo) + 90
Q3(physical) = Q3(DH algo) - 90
Q4(physical) = Q4(DH algo)
Q5(physical) = Q5(DH algo) + 180
Q6(physical) = Q6(DH algo) - 90



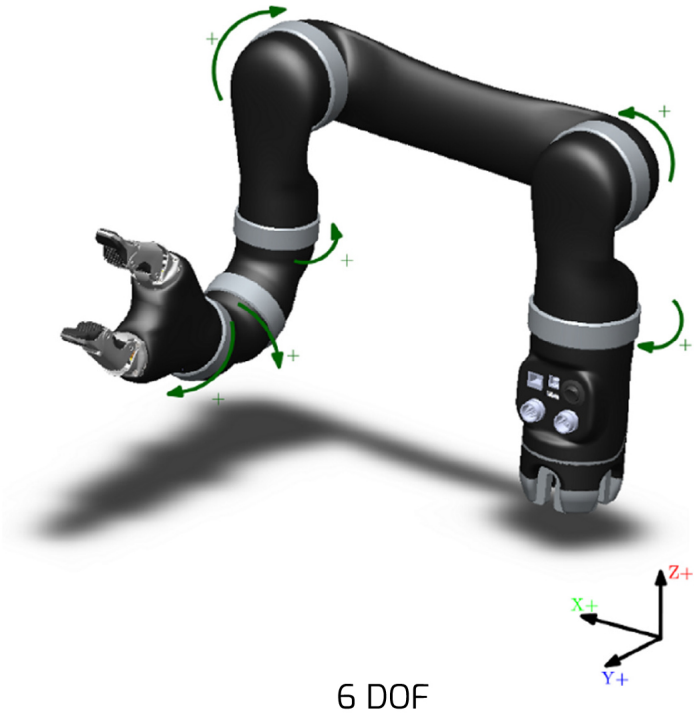
Represented angular position:
[180, 270, 90, 180, 180, 0]

Direction of joints in angular space

The following image represents the positive direction of rotation of each actuator for the different configurations of the 4 DOF MICO robotic arm:



4 DOF

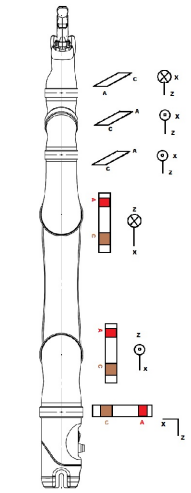


6 DOF
curved wrist

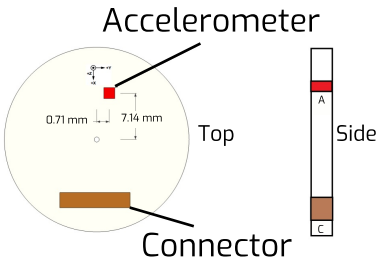
Advanced sensors information

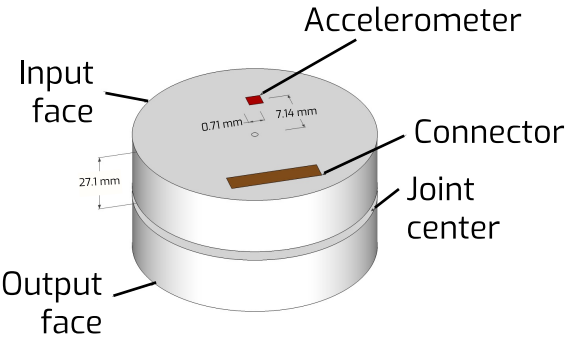
This section has information about the accelerometers in each actuator.

The image below shows information about the accelerometers in each joint actuator.



6 DOF arm shown for illustration purposes





Normal use definition

This section describes the normal use of the robotic arm.

The definition of a normal use of the robotic arm includes that you can lift, push, pull or manipulate a maximum load of:

- **Continuously** 2.1 kg from minimum to middle reach (35 cm distance between actuator #2 and the load) for 6 DOF and 5.2 Kg from minimum to middle reach (25 cm distance between actuator #2 and the load) for 4 DOF.
- **Temporary** 1.5 kg from middle to full reach (70 cm distance between actuator #2 and the load) for 6 DOF and 2.7 kg from middle to full reach (55 cm distance between actuator #2 and the load) for 4 DOF.

The arm is designed to be able to hold objects in the environment of the user, but it is a manipulator that in some positions and loads near the maximum reach and maximum loads holds for a long period, it can heat. When this occurs, before overheating and being dangerous for either the user or the arm, red lights on the joystick will blink. This is a warning. Simply put down any object in the gripper, and bring back the arm to the HOME or RETRACTED positions and wait until the warning goes away before using the arm.

If you don't use a Joystick in your application, make sure to read all the error statuses and temperature of all actuators modules via the API to ensure that they do not go higher than recommended parameters. If this occurs, the arm should be held in an idle position near the base for a certain time without any object in the gripper to cool down the arm.

⚠ When lifting weight near the maximum load and reach, if the red lights of the controller blinks, put down the object in the gripper, and bring back the arm to HOME or RETRACTED position and wait until the warning goes away before using it.

Note: During normal operation, the joints are subject to heating. The joints are normally covered with plastic rings which will protect the user from any danger that may be occurred by the heating of the metal parts.

The fingers of the arm are made flexible in order to protect the internal mechanism. When using the fingers to push on objects, the user must take special care not flex the fingers beyond their maximal opening as this could damage the internal mechanism.

⚠ Do not force the fingers beyond their maximal opening as this could damage some internal components.

Electromagnetic interference from radio wave sources

This section describes electromagnetic interference considerations for the JACO robotic arm.

Even if the product complies with all relevant standards, your arm may still be susceptible to electromagnetic interference (EMI), which is interfering electromagnetic energy (EM) emitted from sources such as radio stations, TV stations, amateur radio (HAM) transmitters, two way radios, and cellular phones. The interference (from radio wave sources) can cause the product to stop moving for a period of 10 seconds. In this case, the device will simply re-initialize and you will be able to continue to use it. In extremely rare case, it can also permanently damage the control system.

The intensity of the interfering EM energy can be measured in volts per meter (V/m). The product can resist EMI up to certain intensity. This is called “immunity level”. The higher the immunity level is, the greater is the protection. At this time, current technology is capable of achieving at least a 20 V/m immunity level, which would provide useful protection from the more common sources of radiated EMI.

There are a number of sources of relatively intense electromagnetic fields in the everyday environment. Some of these sources are obvious and easy to avoid. Others are not apparent and exposure is unavoidable. However, we believe that by following the warnings listed below, your risk to EMI will be minimized.

The sources of radiated EMI can be broadly classified into three types:

1. Gripper-held portable transceivers (e.g. transmitters-receivers with the antenna mounted directly on the transmitting unit, including citizens band (CB) radios, walkie-talkie, security, fire and police transceivers, cellular phones, and other personal communication devices). Some cellular phones and similar devices transmit signals while they are ON, even if not being actively used.
2. Medium-range mobile transceivers, such as those used in police cars, fire trucks, ambulances and taxis. These usually have the antenna mounted on the outside of the vehicle.
3. Long-range transmitters and transceivers, such as commercial broadcast transmitters (radio and TV broadcast antenna towers) and amateur (HAM) radios. Other types of gripper-held devices, such as cordless phones, laptop computers, AM/FM radios, TV sets, CD players, cassette players, and small appliances, such as electric shavers and hair dryers, so far as we know, are not likely to cause EMI problems to your device.

Because EM energy rapidly becomes more intense as one move closer to the transmitting antenna (source), the EM fields from gripper-held radio wave sources (transceivers) are of special concern. It is possible to unintentionally bring high levels of EM energy very close to the control system while using these sorts of devices. Therefore, the warnings listed below are recommended to reduce the effects of possible interference with the control system.

⚠ Do not operate gripper-held transceivers (transmitter’s receivers), such as citizens band (CB) radios, or turn ON personal communication devices, such as cellular phones, while the device is turned ON.

⚠ Be aware of nearby transmitters, such as radio or TV stations, and try to avoid coming close to them.

⚠ Be aware that adding accessories or components, close to the device may make it more susceptible to EMI.

⚠ Report all incidents of unintended shut down to your local distributor, and note whether there is a source of EMI nearby.

Maintenance and Disposal

This section describes maintenance and disposal considerations.

Cleaning instructions

Only the external surfaces of the product may be cleaned. Cleaning may be done using a damp cloth and light detergent. The following described the steps for the cleaning the product:

- Prepare a water/soap preparation using a proportion of about 2ml of dish soap for 100ml of water
- Immerse a clean cotton cloth in the preparation
- Take out the cloth and wring out thoroughly
- Gently rub the external surface to be cleaned

⚠ Do not wash more than three times per day.

⚠ Do not immerse any part of the product under water or snow.

⚠ The product is not intended to be sterile. No sterilization process should be applied to the product.

⚠ Do not rub the external surfaces with abrasive materials.

Preventive Maintenance

The product requires no maintenance.

⚠ Refer all services to qualified service personnel. A service is required when the apparatus has been damaged in any way, for example if the power-supply cord or plug is damaged, if the product does not operate normally or has been dropped.

⚠ There is no “home serviceable” part inside the product. Do not open..

Disposal

The product contains parts that are deemed to be hazardous waste at the end of their life. For further information on recycling, contact your local recycling authority or local Kinova distributor. In any way, always dispose of product through a recognized agent.

Packing Materials

The product packing material can be disposed as recyclable material.

Metal parts

Metal parts can be disposed as recyclable scrap metal.

Electrical parts, circuit boards, and carbon fiber

Please contact your local distributor to have information regarding disposal of such parts. You can also address questions directly to Kinova through our website (see Contacting Support).

Contacting support

If you need help or have any questions about this product, this guide or the information detailed in it, please contact a Kinova representative at support@kinovarobotics.com.

We value your comments!

To help us assist you more effectively with problem reports, the following information will be required when contacting Kinova or your distributor support:

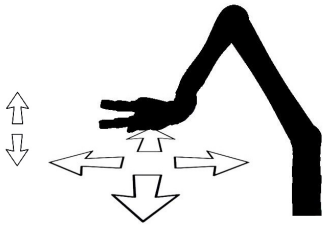
- Product serial number (This will allow the support agent to have all the information regarding your product as the software version running in the device, the part revisions and characteristics, etc.)
- Date/Time of the problem
- Environment where the problem occurred
- Actions performed immediately before the problem occurred

3-axis mode joystick controls reminder

This section is a visual reminder of the joystick controls in 3-axis mode.

Interface Display

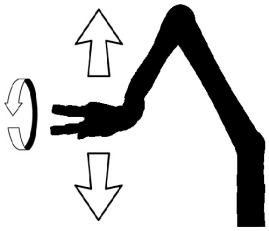
Translation Mode



Joystick control	Hand movement
Joystick forward	Forward
Joystick back	Backward
Joystick left	Left
Joystick right	Right
Stick rotation CW	Up
Stick rotation CCW	Down

Interface Display

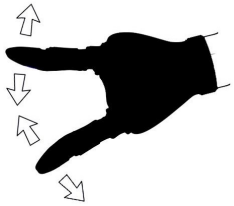
Wrist Mode



Joystick control	Wrist movement
Joystick forward	Top orientation
Joystick back	Bottom orientation
Joystick left	Thumb side orientation
Joystick right	Index side orientation
Stick rotation CW	Rotation of wrist
Stick rotation CCW	Rotation of wrist

Interface Display

Finger Mode



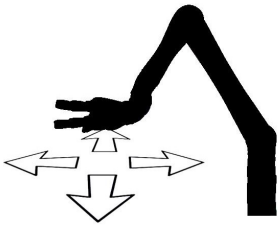
Joystick control	Finger movement
Joystick forward	Open 2 fingers
Joystick back	Close 2 fingers
Joystick left	Close 3 fingers
Joystick right	Open 3 fingers
Stick rotation CW	N / A
Stick rotation CCW	N / A

2-axis mode joystick controls reminder

This section is a visual reminder of the joystick controls in 2-axis mode.

Interface Display

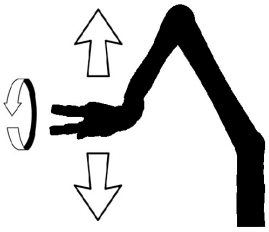
Translation X-Y



Joystick control	Hand movement
Joystick forward	Forward
Joystick back	Backward
Joystick left	Left
Joystick right	Right

Interface Display

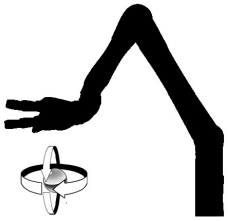
Translation Z / Wrist rotation



Joystick control	Movement
Joystick forward	Up
Joystick back	Down
Joystick left	Wrist rotation
Joystick right	Wrist rotation

Interface Display

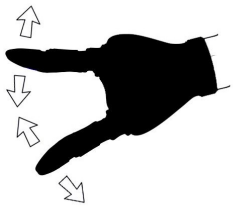
Wrist Orientation



Joystick control	Wrist orientation
Joystick forward	Top
Joystick back	Bottom
Joystick left	Thumb side
Joystick right	Index side

Interface Display

Finger Mode



Joystick control	Finger movement
Joystick forward	Open 2 fingers
Joystick back	Close 2 fingers

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