MCS500 SCARA INDUSTRIAL ROBOT (R1)

USER MANUAL

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Original instructions

CONTENTS

MECADEMIC
INDUSTRIAL ROBOTICS

ABOUT THIS MANUAL

There are two manuals that come with the MCS500 industrial robot system (revision R1): this one and the Mecademic Robots Programming Manual. This manual will guide you through the steps required for setting up your MCS500 and for using it in a safe manner. You must read this user manual thoroughly during the unpacking and first use of your MCS500.

Keep this manual for future reference.

Symbol definitions

The following table lists the symbols that may be used in Mecademic manuals to denote certain conditions. Particular attention must be paid to the warning messages in this manual.

SYMBOL	DEFINITION
(i)	NOTICE. Identifies information that requires special consideration.
(!) yellow triangle	CAUTION. Provides indications that must be respected in order to avoid equipment or work (data) on the system being damaged or lost.
(!) red triangle	WARNING. Provides indications that must be respected in order to avoid a potentially hazardous situation, which could result in injury.

Revision history

The firmware that is installed on Mecademic products has the following numbering convention:

{major}.{minor}.{patch}.{build}

Each Mecademic manual is written for a specific {major}.{minor}.{*}.{*} firmware version. On a regular basis, we revise each manual, adding further information and improving certain explanations. We only provide the latest revision for each {major}.{minor}.{*}.{*} firmware version. Below is a summary of the changes made in each revision.

REVISION	DATE	COMMENTS
A	November 6, 2023	Original version.
B	December 18, 2023	Minor improvements and some additional specifications.

The document ID for each Mecademic manual in a particular language is the same, regardless of the firmware version and the revision number.

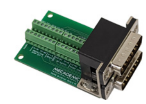
1. INTRODUCTION

The MCS500 is a four-axis industrial robot arm of type SCARA that is easy to use, robust and lightweight. However, the robot is a precision device with rapidly moving parts and should therefore be used only by technical personnel who have read and understood this user manual, to avoid damages to the robot, its end-effector, the workpiece and adjacent equipment, and, most importantly, to avoid injuries.

1.1. Inside the box

Table 1 shows the items that come with a standard shipment of a MCS500 robot system. Remove all items carefully and do not discard your shipping box and packing foam.

Table 1: Standard parts list

Qty	SKU	Description	Photo
1	9000-003	MCS500 SCARA industrial robot, revision R1	
1	9200-002	Smart power supply, revision R1	
1	9403-002	Breakout board for prototyping	
1	2003-005	2-meter, M12 D-Code to RJ45, Ethernet cable	
1	2003-008	2-meter proprietary DC power cable for MCS500	

Note, that you must provide your own AC power cord, with three-prong IEC C13 connector on one end, and your own country's power plug on the other. You must also provide M6 screws of appropriate length for fixing the robot's base and the power supply.

1.2. Basic description

The MCS500 is a four-axis SCARA robot consisting of four actuated joints, numbered as shown in Figure 1. Joint 1 is between the base and the *proximal link* and joint 2 is between the proximal link and the *distal link*. Finally, two motors work in tandem to control the translational and rotational motion of the *spline shaft* with respect to the distal link, so the translational degree of freedom is referred to as joint 3, while the rotational one as joint 4. The axes of joints 1, 2 and 4 are parallel to the direction of joint 3.

A *retaining ring* is mounted on both sides of the spline shaft. The two retaining rings are used for mounting tools but also for retaining the spline shaft. Never remove these rings or else you will permanently damage the spline shaft assembly.

In Figure 1, all joints are at their zero position. The figure also shows the positive directions of rotation or translation.

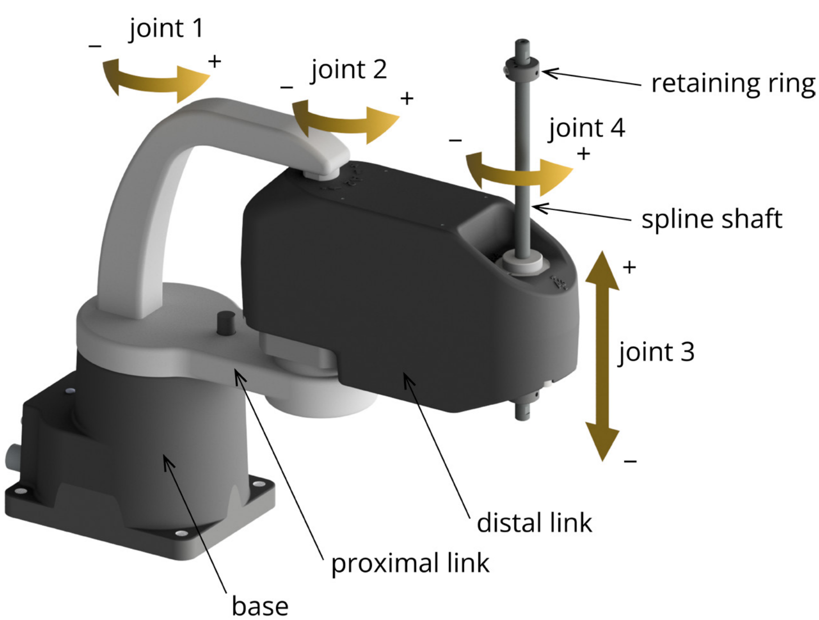


Figure 1: Joint numbering and nomenclature of the MCS500 SCARA robot

2. SAFETY AND SMART POWER SUPPLY

The MCS500 weighs less than 5 kg, but it can move very fast and cause injuries, especially when certain end-effectors are attached to its flange (e.g., a sharp tool). The robot also has pinch points where robot joints can squeeze a finger (Figure 2).

It is imperative that you follow the guidelines of ISO 12100:2010 and ISO 10218-2:2011 and conduct a risk assessment of your complete robot cell, including the MCS500, its end-effector and all adjacent equipment.

When the robot is folded (i.e., the angle between the distal and proximal links is small), the robot can be temporarily deposited on its base. In other robot positions, the robot will tip and should not be placed on its base without fixing it. If the robot tips and falls from a height, it may cause an injury, and certainly get damaged.

- Handle the robot with care.
- Do not force the brakes on the robot's spline shaft, unless there is an emergency!
- Never unscrew the retaining rings on the spline shaft.
- Inspect the robot and power supply for damages. If either appears damaged, do not use them and contact us immediately.
- Do not modify or disassemble the robot arm or its power supply.
- Do not use or store the MCS500 in a humid environment.
- Do not operate the MCS500 at temperatures below 5°C or above 45°C.
- Use only the power supply provided with your system.
- Use only the Ethernet and DC-power cables provided. Contact us if you need longer cable.

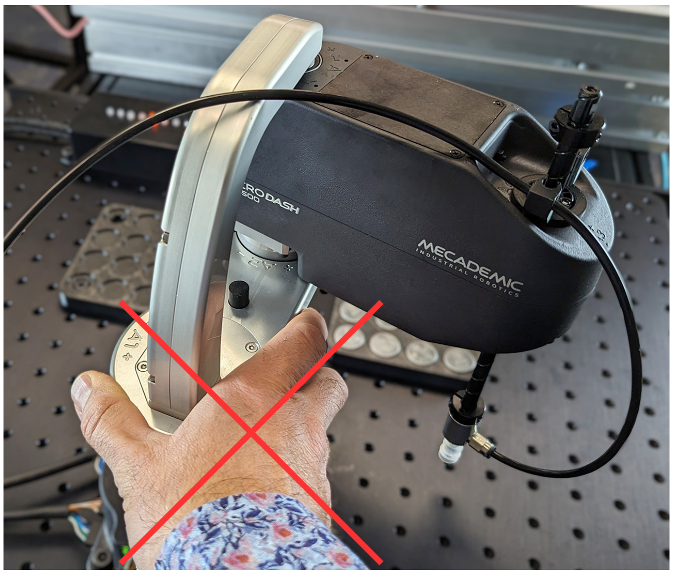


Figure 2: Pinch point between distal and proximal links

Due to the extremely compact size of the robot, there are no provisions for adjustable hardware joint limits.

2.1. Brakes

As already mentioned, the MCS500 is equipped with brakes at joints 3 and 4, i.e., at the spline shaft. These brakes can be disabled electronically (e.g., with the command `BrakesOff`). The brakes can also be disabled mechanically by removing the screw cap near the spline shaft, using a 2.5-mm Allen key, and keeping the button inside the hole pressed, as shown in Figure 3.

(a) Remove the screw cap (b) Press the recessed brakes release button

Figure 3: Releasing mechanically the brakes on the spline shaft

When the brakes on the spline shaft are released, the shaft will not fall down, even if a 0.5 kg tool is attached to it. This is due to the friction in the assembly. You therefore need to apply external force to make the spline shaft move.

Finally, in case of an emergency, you can always overpower the brakes on the spline shaft. However, <u>doing so frequently will damage the brakes</u>.

2.2. Overview of the smart power supply

The Mecademic power supply unit (PSU), shown in Figure 4, integrates several safety features. Use only the smart power supply provided by us to power your specific MCS500 robot arm. The MCS500 will not function with the power supply of another revision or with a third-party power supply.

Connect the power supply to an AC source that supplies voltage at 90–250 V at frequency of 50–60 Hz. <u>Supplying AC voltage outside this range may damage the power supply</u>.

Figure 4: The MCS500 smart power supply unit (PSU), MSIPS

Referring to Figure 5, the main features of the MCS500 power supply are:

- A: system on/off switch;
- B: emergency stop button (Stop Category 1), designed as PL=d with Safety Category 3;
- C: LEDs;
- D: reset button;
- E: operating mode key switch;
- F, G: D-SUB 15-position interface for connecting safety I/Os to the robot;
- H: connector for robot DC power cable.

Unlike the Meca500 six-axis industrial robot, the MCS500 does not come with a bypass D-SUB 15-position dongle. NEVER CONNECT THE DONGLE OF A MECA500 TO THE POWER SUPPLY OF THE MCS500, OR ELSE YOU WILL DAMAGE THE MCS500.

To start using the MCS500, you must first wire the appropriate external safety input connections explained in this section. The E-STOP button on the power supply must be appropriately wired in order to function (see Section 2.6). For prototyping purposes, a breakout board is provided with every power supply.

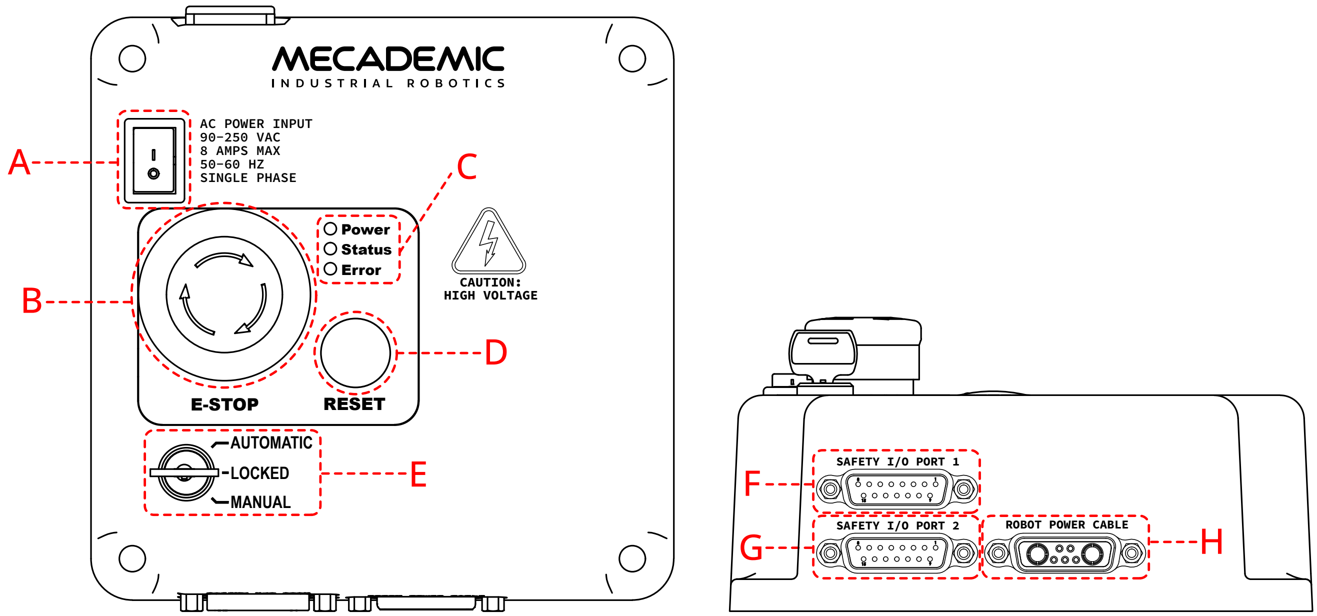


Figure 5: Power supply features and connectors

To connect the power supply to the robot, use the DC power cable provided and never modify it. This is a custom-made cable. Once the robot connected to the power supply, and the power supply connected to the proper AC source, you may switch on the power supply.

Stand away from the robot when it is activated, wear safety goggles and be attentive and alert. In case of an emergency, press the properly wired Emergency stop button immediately.

When disconnecting the AC power, either by using the on/off switch on the power supply or by unplugging the AC cord, the brakes on the last two motors will be immediately applied and the spline shaft will be immobilized instantly. Therefore, to avoid premature use of the brakes, do not disconnect the AC power when the robot is moving.

When disconnecting the AC power, pressing the E-STOP button, or activating the external E-Stop or the protective stop 1, joints 1 and 2 of the robot become free. This minimizes the risks of pinning and pinching from the robot.

2.3. Operating mode selector

The key switch on the smart power supply is used to select the operating mode of the robot. The switch has three positions: (1) automatic mode, (2) manual mode, and (3) locked (motors off) mode.

In the current firmware version, the operating mode selector is ignored and the robot can only be in automatic mode. However, the upcoming firmware update will implement the two other modes.

2.3.1 Automatic mode

In automatic mode, all safety conditions must be satisfied (i.e., the Emergency stop function, and the two protective stops must remain at logic high) and the reset must have been activated. In this mode, the 3P Switch signal is ignored and the robot can move at full speed.

2.4. Emergency and protective stops

The power supply is equipped with

- one E-STOP button (also referred to as E-Stop switch);
- one RESET button,
- one input connection for an external Reset,

safety (redundant) input connections for

- one E-Stop function (Stop Category 1),
- one external protective stop (Stop Category 1) that will be referred to as P-Stop 1,
- one external protective stop (Stop Category 2) that will be referred to as P-Stop 2,
- one external three-position enabling device,

and output connections for

- one safety (redundant) Power Status signal,
- one Reset Ready signal.

Once you power up the robot, you must make sure all E-Stops are released. Then, pressing the RESET button (or enabling the RESET input) sends power to the robot motors.

Once the robot is activated, pressing an E-Stop at any time instantly sends a signal to the robot to rapidly decelerate and come to a complete stop. The power supply then waits for a signal from the robot indicating that the robot is completely stopped, and as soon as that signal is received, but no later than in 500 ms, the power supply completely cuts power to the robot motors. The robot brakes are then automatically applied to the spline shaft (i.e., to joints 3 and 4). To use the robot again, you must remove all stops signals, and press Reset, then activate the robot.

2.5. LEDs

The power supply is also equipped with three LEDs. Their description is presented in Table 2.

Table 2: Power supply LED pattern sequences

LED PATTERN SEQUENCES			
Situation	**Power (green)**	**Status (yellow)**	**Error (red)**
Power supply is switched off	off	–	–
A fatal error was detected (e.g., invalid voltage or safety input mismatch)	fast blink (100 ms on, 100 ms off)	–	on
The power supply is turned on	on	–	–

Table 5: Keyboard shortcuts for source code editing (continued)

COMBINED LED BLINKING SEQUENCES			
Situation	**Power (green)**	**Status (yellow)**	**Error (red)**
The robot motors are not powered and a RESET is not allowed	–	off	–
The robot motors are not powered but a RESET is allowed	–	slow blink (500 ms on, 500 ms on)	–
The robot motors are powered	–	on	–
There is no error or a stop signal	–	–	off
P-Stop 2 is activated	–	–	1 flash per second
P-Stop 1 is activated	–	–	2 flashes per second
E-Stop is activated	–	–	3 flashes per second
Shutdown	all LEDs are on for about 7 seconds		

2.6. Safety I/O connections

After performing a risk assessment for your installation, you must design and connect the appropriate safety circuit to the safety I/O D-SUB connector. Figure 6 shows the pinout of the D-SUB connector. The following explains the different connections:

- E-Stop Switch, four pins. These are the four terminals of the E-Stop button on the power supply. The four pins of the E-Stop Switch MUST BE WIRED to the circuitry of the E-Stop Function, along with other external E-Stops (if necessary).
- E-Stop Function, four pins. This is the input that provides the E-Stop functionality to the robot.
- Protective Stop Category 1 (P-Stop 1), four pins. This (redundant) safety input is intended for connecting optical curtains, etc.
- Protective Stop Category 2 (P-Stop 2), four pins. This (redundant) safety input is used to stop the robot's motion without removing power from the motors.
- Reset, two pins. This input is for wiring an external reset button that will have the same functionality as the one on the power supply.
- 3P Switch, four pins. This is for connecting a three-position enabling device, necessary for operating the robot in manual mode.
- Reset Ready, two pins. This output is enabled when the motors are ready to be powered (i.e., no safety stop is active) by activating the reset function.
- Power Status, four pins. This (redundant) safety output indicates whether the robot motors are powered.

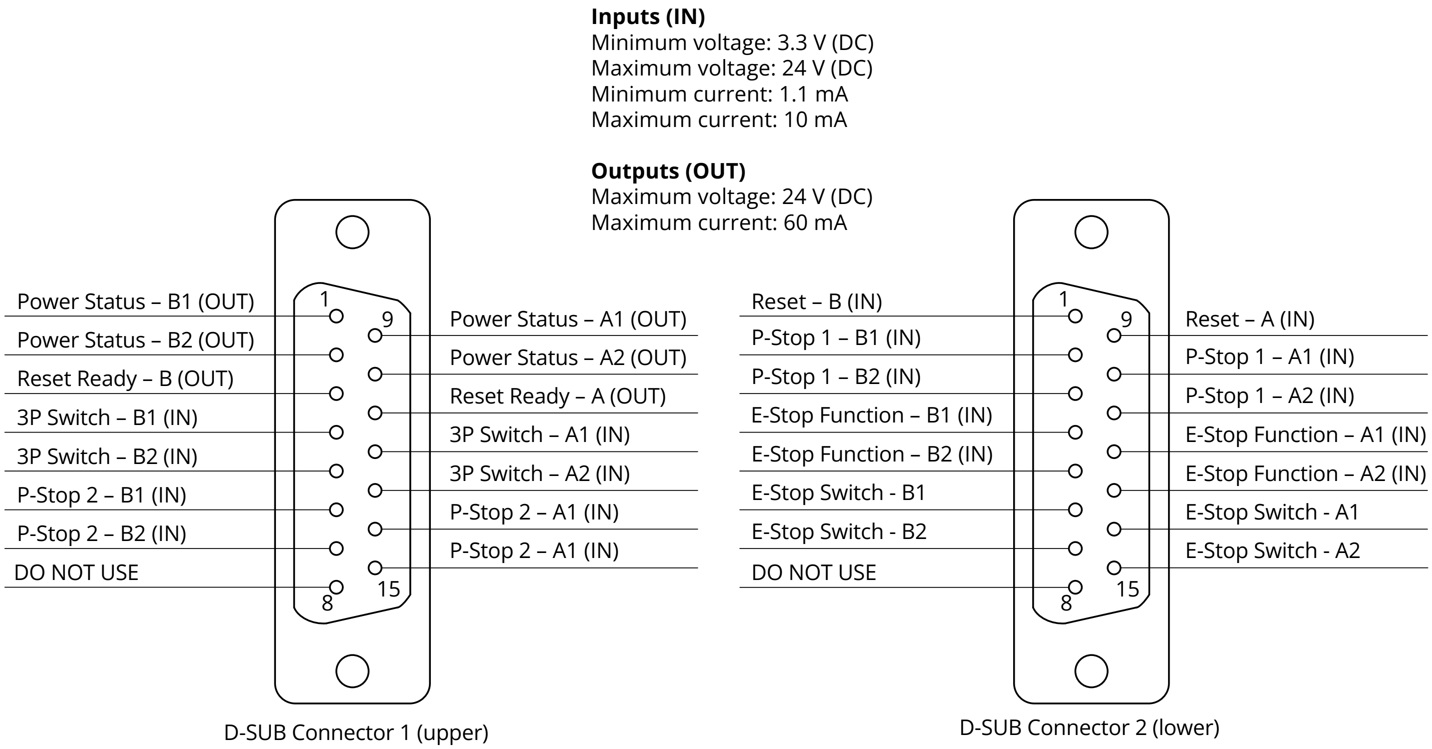


Figure 6: Pinout for the two D-SUB connectors

- The E-Stop Function, 3P Switch, P-Stop 1 and P-Stop 2 are activated when the corresponding signal is logic low.
- The Reset is activated when its signal is logic high.
- The four pins of the E-Stop Switch MUST BE WIRED to the circuitry of the E-Stop Function, along with other external E-Stops (if necessary).

Beware that the two D-SUB connectors are identical on the outside.

Do not use pins 8 from both D-SUB connectors. These are for internal use only.

Table 4 and Table 3 show further important details regarding the two connections of the two Safety I/O ports. In addition, Figure 7 shows the electric diagrams for the safety inputs and outputs, as well as for the E-Stop button on the PSU.

The PSU outputs are designed to be connected to PLC inputs and not to control loads, especially inductive ones (e.g., a relay or a solenoid). There is no internal protection against the high voltage spike at the release of an inductive load.

Table 3: Notes for the Safety I/O port 1 (upper)

Safety I/O port 1					
Pin	**Name**	**Type**	**Polarity**	**Usage**	**Notes**
3	Reset Ready – B	Output	COM	The robot is ready to reset	• This signal is logical high when the robot is ready to reset (safety conditions E-Stop and P-Stop 1 are satisfied and therefore PSU Status LED is blinking.).
11	Reset Ready – A		OUT		
1	Power Status – B1	Output	COM	Robot motor power status	• This signal is logical high when robot motor power is enabled. • Use this signal for zero-energy monitoring if needed. • This is a redundant safety signal. It must be connected using two independent signals.
9	Power Status 1 – A1		OUT		
2	Power Status 1 – B2		COM		
10	Power Status – A2		OUT		
4	3P Switch – B1	Input	COM	Enabling device (for upcoming manual mode)	• This signal is logical high when the enabling device is pressed midway. • When this signal is logical high and the PSU key is in manual mode, the robot can be powered, activated and jogged (at < 250 mm/s) even if the P-Stop 1 (fence) is open. • This is a redundant safety signal. It must be connected using two independent signals. • All faults (differences) between signals will generate a non-resettable PSU error.
12	3P Switch – A1		IN		
5	3P Switch – B2		COM		
13	3P Switch – A2		IN		
6	P-Stop 2 – B1	Input	COM	P-Stop 2 (hold) signal	• Robot can't move while P-Stop 2 signal is logical low. • Robot motor power can be restored/reset while P-Stop 2 signal is logical low. • P-Stop 2 cannot be reset by reset button. P-Stop should be reset by `ResetPStop2` command. • This is a redundant safety signal. It must be connected using two independent signals. • All faults (differences) between signals will generate a non-resettable PSU error.
14	P-Stop 2 – A1		IN		
7	P-Stop 2 – B2		COM		
15	P-Stop 2 – A2		IN		
8	DO NOT USE	n/a	n/a	n/a	n/a

Table 4: Notes for the Safety I/O port 2 (lower)

Safety I/O port 2					
Pin	**Name**	**Type**	**Polarity**	**Usage**	**Notes**
1	Reset – B	Input	COM	External Reset signal	• Pulse logical high for at least 100 ms to reset robot. • Safety conditions E-Stop and P-Stop 1 must be satisfied (PSU Status LED blinking) to reset the robot.
9	Reset – A		IN		
2	P-Stop 1 – B1	Input	COM	P-Stop 1 signal (e.g., fence)	• Robot motor power is disabled while P-Stop 1 signal is logical low. • This is a redundant safety signal. It must be connected using two independent signals. • All faults (differences) between signals will generate a non-resettable PSU error.
10	P-Stop 1 – A1		IN		
3	P-Stop 1 – B2		COM		
11	P-Stop 1 – A2		IN		
4	E-Stop Function – B1	Input	COM	E-Stop signal	• Robot motor power is disabled while E-Stop signal is logical low. • This is a redundant safety signal. It must be connected using two independent signals. • All faults (differences) between signals will generate a non-resettable PSU error.
12	E-Stop Function – A1		IN		
5	E-Stop Function – B2		COM		
13	E-Stop Function – A2		IN		
6	E-Stop Switch – B1	Switch	COM	E-Stop button on power supply	• The E-Stop switch must be connected to E-Stop circuit. • If E-Stop switch is not connected, it will not stop the robot even if it pressed. • Not connecting this button will cause major safety risks. • This is a redundant safety signal. It must be connected using two independent signals.
14	E-Stop Switch – A1		IN		
7	E-Stop Switch – B2		COM		
15	E-Stop Switch – A2		IN		
8	DO NOT USE	n/a	n/a	n/a	n/a

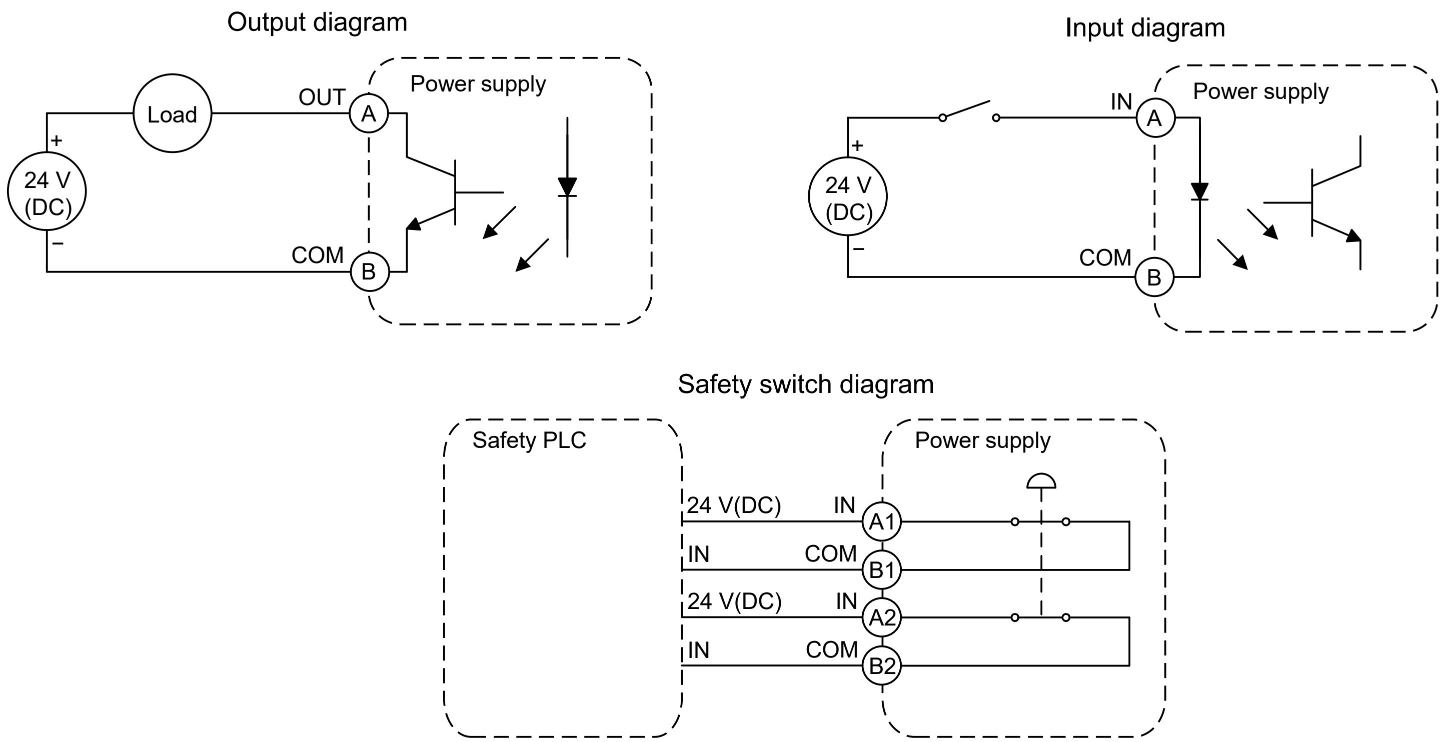


Figure 7: Electric diagrams for the outputs, the inputs and the E-Stop button on the power supply

Finally, Figure 8 shows the breakout board supplied with every MSC500 system for prototyping purposes. The names for the terminals on that board are the same as for the 28 pins in Figure 6 (all but pins 8 from each connector, which are not identified on the breakout board). Do not use the unidentified terminals on the breakout board.

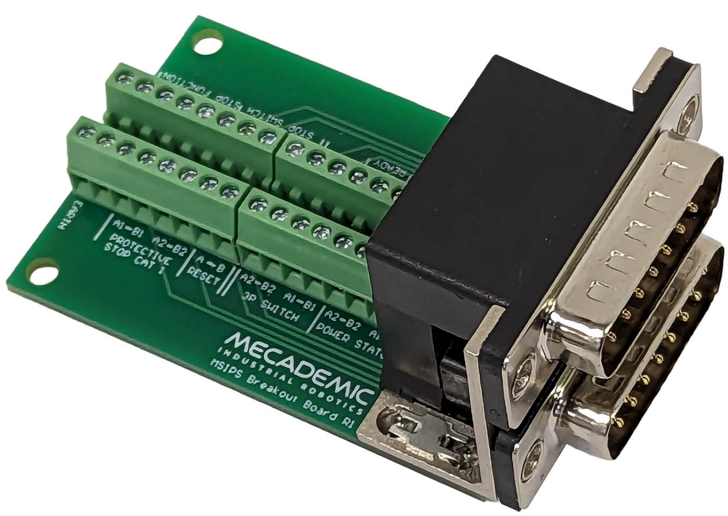


Figure 8: Breakout board

Wire correctly the signals on the breakout board, make sure the power supply is switched off, and only then plug the board into the two D-SUB connectors.

3. TECHNICAL SPECIFICATIONS

Table 5 and Table 6 list the main technical specifications of the MCS500 robot system.

Table 5: Technical specifications for the MCS500 (R1) robot arm

TECHNICAL SPECIFICATIONS FOR ROBOT ARM	
Characteristic	**Value**
Position repeatability	0.005 mm
Rated payload	0.5 kg
Maximum payload	1.0 kg (under special conditions)
Weight of robot arm	4.3 kg
Mounting orientations	tabletop or upside down
Range for joint 1	[−140°, 140°]
Range for joint 2	[−145°, 145°]
Range for joint 3	[−102 mm, 0 mm]
Range for joint 4	[−3,600°, 3,600°]
Maximum speed for joint 1	300°/s
Maximum speed for joint 2	500°/s
Maximum speed for joint 3	900 mm/s
Maximum speed for joint 4	5,000°/s
Input voltage	36 V (DC)
Operating ambient temperature range	[5°, 45°]
Operating ambient relative humidity range	[10%, 80%] (non-condensing)
IP rating	IP 40

Table 6: Technical specifications for the MSIPS-R1 intelligent power supply

TECHNICAL SPECIFICATIONS FOR POWER SUPPLY	
Characteristic	**Value**
Weight	1.3 kg
Mounting orientations	any
Power factor	0.99 @ 115 V (AC)
Average/maximum power output	200 W / 432 W @ 5% (DC)
Input voltage	90–250 V (AC), single phase
Input frequency	50–60 Hz
Operating ambient temperature range	[5°, 35°]
Operating ambient relative humidity range	[10%, 80%] (non-condensing)
IP rating	IP 40

Figure 9 shows all important dimensions of the MCS500. Recall that all joints are at zero in the configuration shown in this figure and in Figure 1. In addition, Figure 10 shows a top view of the workspace of the MCS500 for an end-effector the origin of which lies on the axis of the spline shaft. Note that most attainable end-effector poses can be attained with two different robot configurations, one which is ofter referred to as "lefty" and the other as "righty". This issue is explained in further detail in the Mecademic Robots Programming Manual.

The CAD files of the MCS500 (in STEP format) can be downloaded from our web site. Alternatively, you can use one of several robot simulation and offline programming software packages that include a model of our MCS500, including Visual Components and RoboDK. Note that we also offer a Mecademic-only version of RoboDK, for exclusive use with our robots.

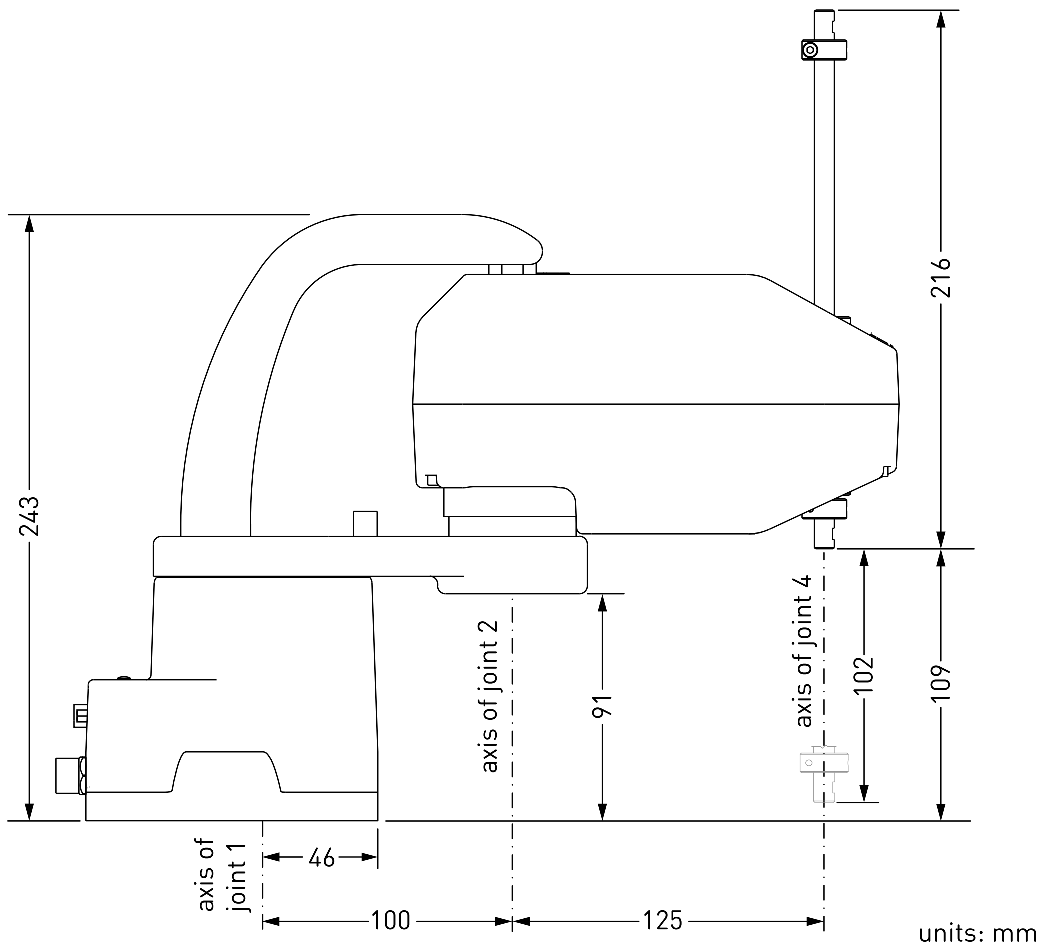


Figure 9: The principal dimensions and offsets of the MCS500 robot

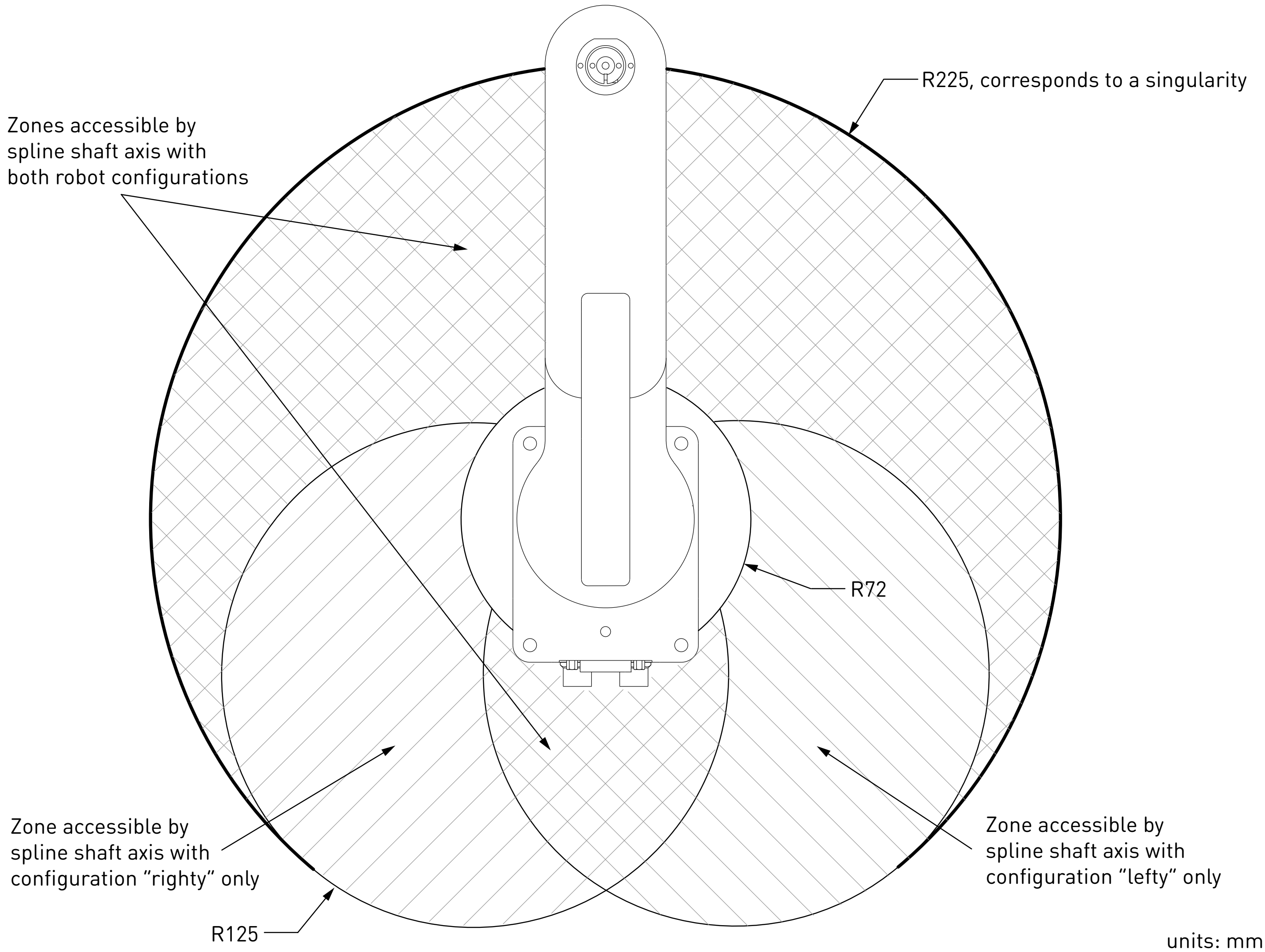


Figure 10: The working range of the MCS500 robot

Finally, as already mentioned, the power supply provided has an IEC C14 connector that accepts an AC power cord with three-prong IEC C13 connector on one end, and your own country's power plug on the other. You can connect this power cord to any AC source that supplies voltage between 90 V and 250 V at frequency between 50 Hz to 60 Hz.

4. INSTALLING THE MCS500

It is imperative that you fix solidly the base of your robot arm with four M6 screws (tightened at 3 Nm) before activating the robot. We typically use metric breadboards such as those from Thorlabs, but you can also use our adaptor plate MUAP02, build your entire robot cell at Vention, or use the modular system made by Tessella Automation. We recommend that you use three kinematic positioners to constraint your base, so that you can always remove and then install it in the exact same location.

The dimensions of the base are shown in Figure 11 and an example of an installation is shown in Figure 12. Note that you can also install the robot base upside-down. The robot will automatically detect angle between the base and the gravity vector (no need to manually specify this angle). Also, note that you can mount the robot's base on a mobile body (e.g., on the carriage of a linear guide), but care must be taken to ensure that the combined acceleration of the robot and the linear guide won't exceed the capacity of the robot in case an emergency deceleration is required.

Finally, note that the base of the MSC500 has the same bolt pattern as the base of the Meca500, but is slightly larger. Therefore, you cannot use our adapter plate for the Meca500 (MUAP01) unless you remove the locating pins. You should rather use our MUAP02 adapter plate, designed for the MCS500.

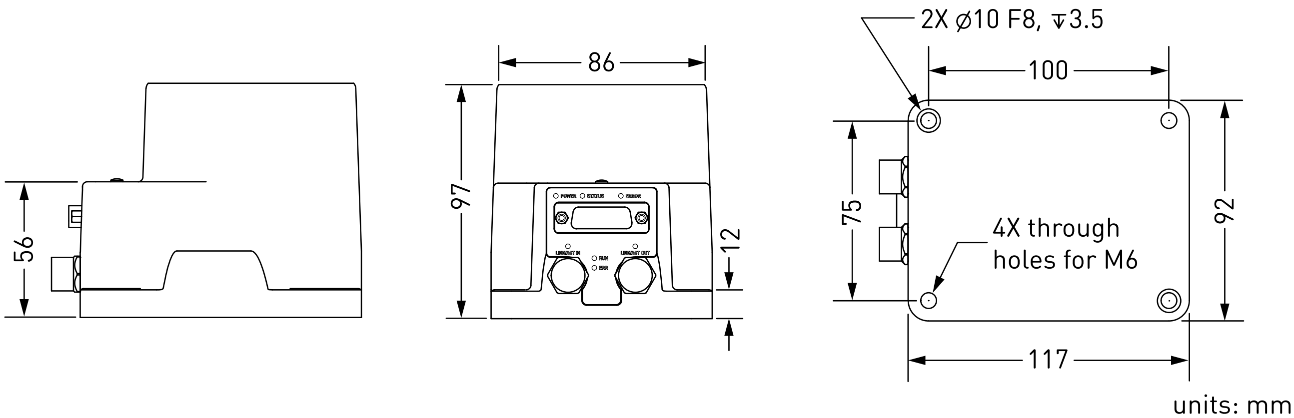


Figure 11: Dimensions of the base of the MCS500

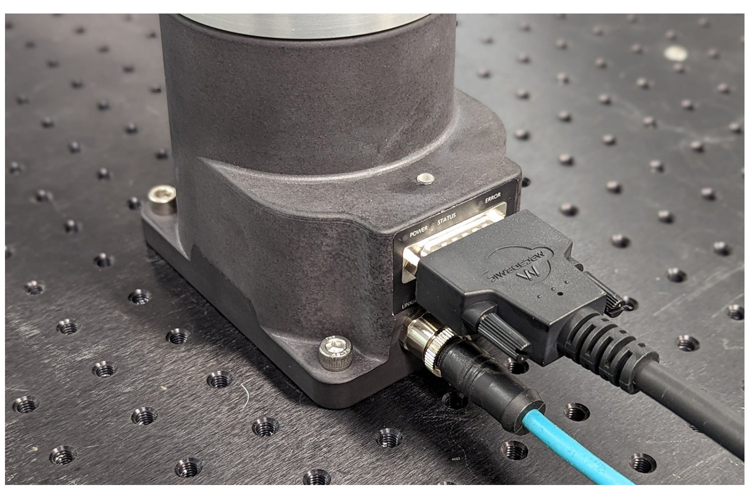


Figure 12: The robot base installed, with the connectors attached

Do not install any end-effector yet. We will cover this topic in Section 7.

Next, you must solidly attach the power supply using four M6 screws (Figure 13), at a location sufficiently close to the robot's base to allow connection with the 2-meter DC cable provided. However, unless you are using an external emergency stop wired via the D-SUB connector, you must fix the power supply at a location that makes the integrated E-STOP button readily accessible by an operator and outside the working range of the robot.

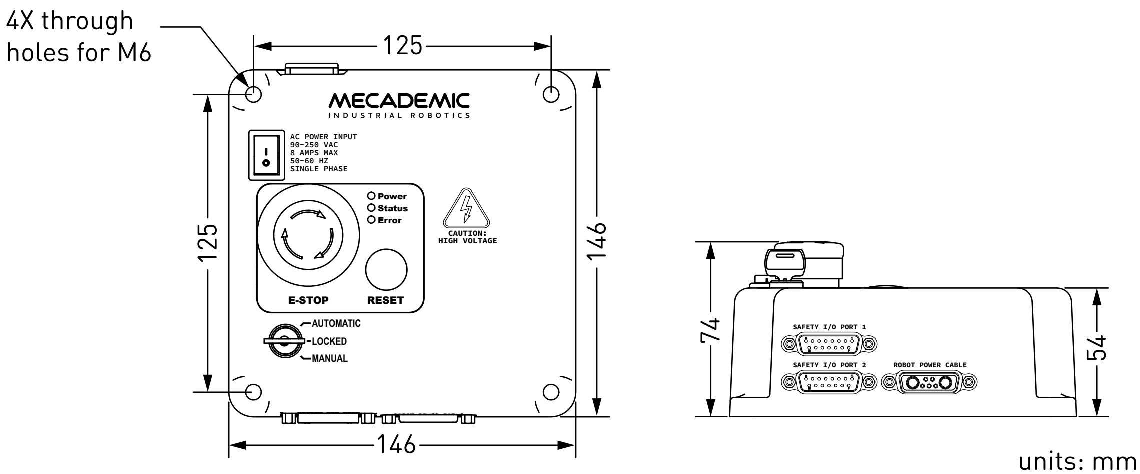
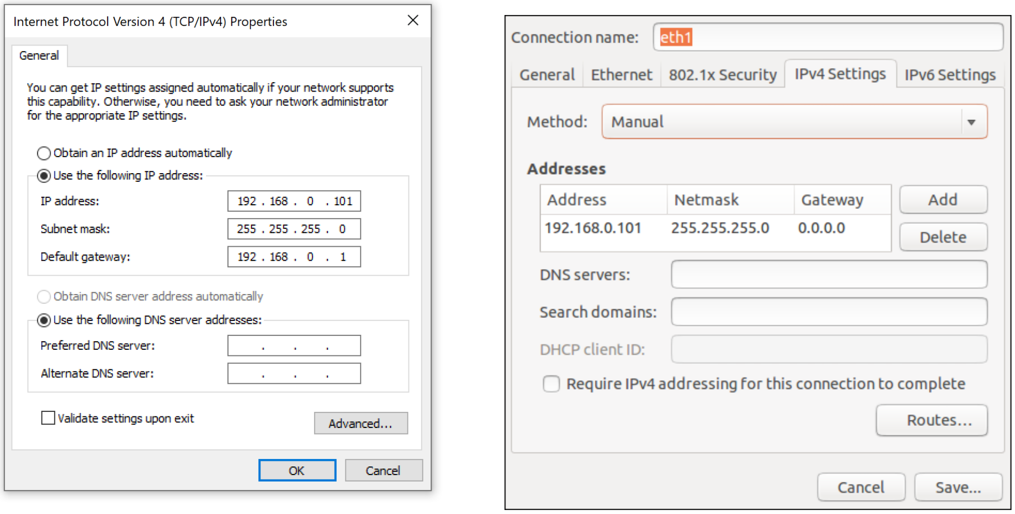


Figure 13: Dimensions of the MCS500 intelligent power supply

The following steps must then be executed before you can start using your MCS500:

1. Attach the circular connector of the Ethernet cable to the ETHERNET1 port on the robot's base and connect the RJ-45 jack to your computer or router (Figure 12). The two Ethernet ports on the robot's base act as a bridge, so you can daisy-chain several MCS500 robots, or connect an Ethernet I/O module on the ETHERNET2 port.
2. Use the DC power cable provided to connect the unpowered power supply to the robot's DC power connector (Figure 12). Make sure the connectors are completely screwed, or else you may damage the robot. Then, connect the power supply to your country-specific AC power cord (not provided). Only then, you can connect the AC power cord to an AC outlet, and switch the power supply on using its on/off button.
3. The green LED on the power supply (next to "Power") will be illuminated. The robot's LEDs will start flashing for about twenty seconds while the robot's controller is booting. Once the controller is ready, the three small LEDs on the robot's base will stop flashing, unless there is a stop condition.
4. Now, you must provide power to the robot motors by pressing the RESET button on the power supply. (Before you do so, make sure the E-STOP button is disengaged and that all safety conditions are satisfied.) You will hear a clicking sound and the big yellow LED on the robot's base will light up.
5. Configure your computer Ethernet connection with a static IP address, on the same subnet as the robot's default IP address, i.e., 192.168.0.x. The way to do this differs from one operating system to another. Figure 14 shows how to do this in Windows and in Linux.
6. Open (preferably) the latest version of Google Chrome and type the robot's default IP address 192.168.0.100 in the address bar.
7. Mecademic's web interface, called the MecaPortal, should load instantaneously.



(a) Windows (b) Linux

Figure 14: Two examples of how to configure the IP address of your computer

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Always connect the DC power cable before connecting the power supply to an AC outlet. Always disconnect the power supply from the AC outlet before disconnecting the DC power cable.

It is also possible to change the robot's network configuration. This option is available through the robot's web interface, which will be described in detail in Section 5. Here is the procedure for doing so, once you have loaded the MecaPortal but not activated your robot.

1. Click on the connection state button on the top right of the MecaPortal and select "Control" (see Figure 15).
1. Click on the configuration menu button, ≡, in the top left corner of the MecaPortal and select "Network configuration".
2. Depending on your configuration, activate the toggle DHCP to automatically receive an address from your router or leave untoggled to force a specific IP. You don't need to reboot the robot; the new configuration will be applied as soon as you click on the Apply button (Figure 16).

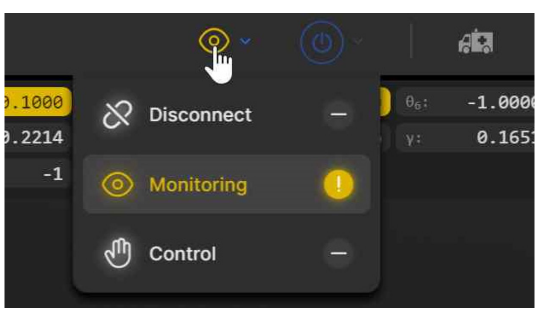


Figure 15: Connection state button

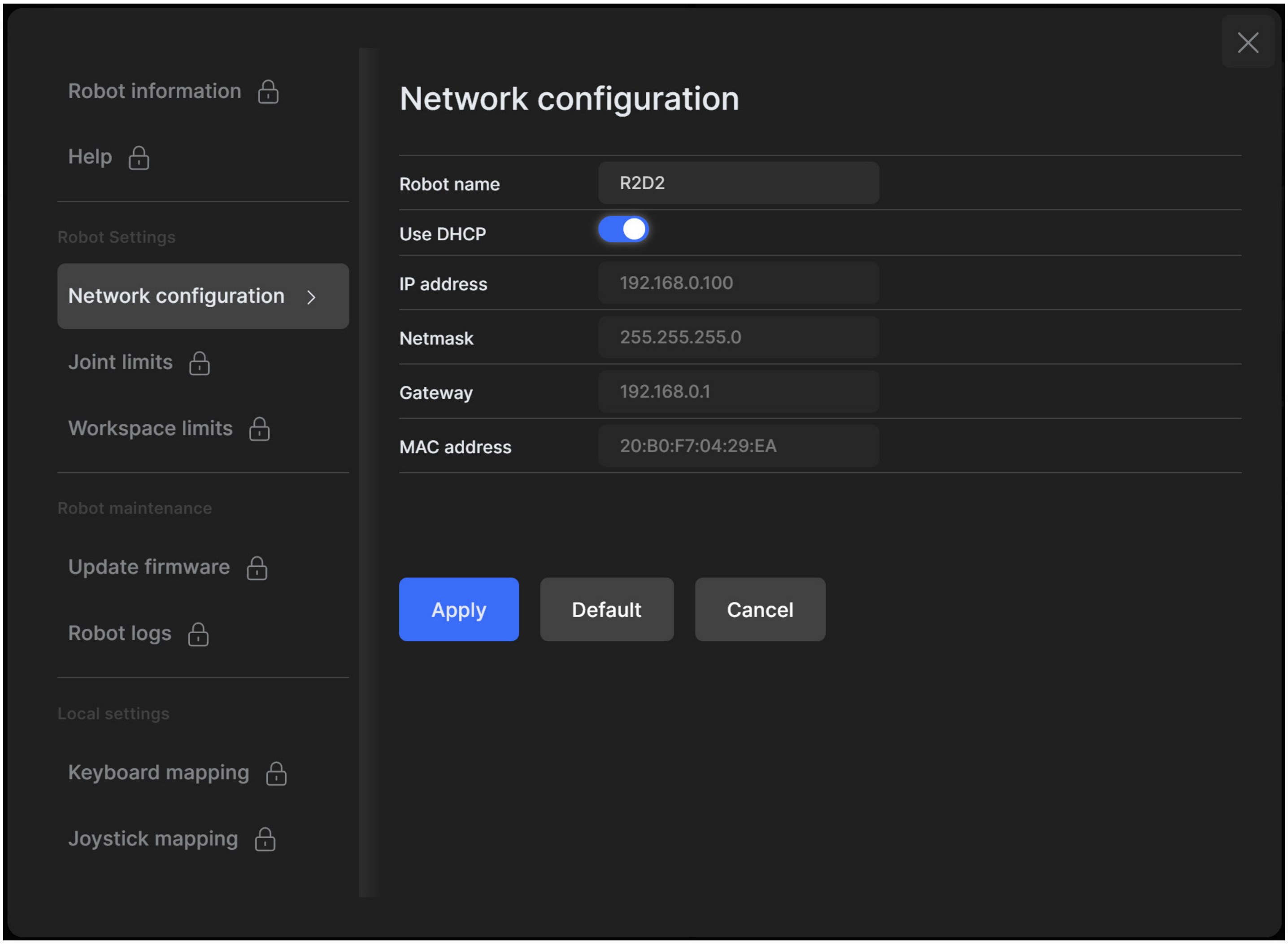


Figure 16: Changing the robot's network configuration

5. THE MECAPORTAL

Mecademic's web interface, called MecaPortal, is more or less the equivalent of the teach pendant's interface of a traditional industrial robot. The interface is essentially an HTML 5 web page with JavaScript and WebGL scripts. All of these files reside in the robot's controller, so you do not need to install anything on your computer, but an internet browser such as Google Chrome.

The interface converts your mouse clicks, joystick actions, and keyboard inputs into proprietary commands that are sent to the robot's controller. These are primarily the same commands described in the Programming Manual that you will eventually start sending from your own application, written in C++, Java, Python or any other modern programming language. In addition, the web interface displays the feedback messages received from the robot and the 3D model of the actual robot.

The MecaPortal is intended mainly for testing and writing simple programs. You must create your own software application or program if you intend to use the robot for complex tasks, such as interacting with inputs and outputs (in which case you also need a third-party I/O module).

The web interface is also used for updating the firmware of your robot.

5.1. Updating the robot's firmware

Before you continue to read any further, make sure that you have the latest firmware installed on the robot and that you read the manuals corresponding to that firmware. In the Mecaportal, click on the configuration menu button, ≡, then on Robot information, to see the version of your robot's firmware. Then go to the Downloads section of our web site and if there is a more recent firmware, download it. Unzip the file. Then, make sure that your connection is still in "Control" of the robot, i.e., the icon ✋ is diplaced in the top right corner of the Mecaportal. Make sure that the robot is deactivated, i.e., the icon ⏻ is shown next to ✋. Next, go the the configuration menu, ≡, then to Update firmware, and finally click on the Browse button and select the MCS500*.update that you just extracted. Wait a couple of minutes for the update to be completed. Once completed, the robot will reboot and the new web interface will reload.

Now that you have installed the latest robot firmware, make sure to download the latest user and programming manuals from the Downloads section of our web site and keep these manuals until you update again your firmware.

Next time you update your robot's firmware, you must also read the PDF file that is in the zip package (i.e., the Release Notes). That document lists of all the recent firmware changes.

5.2. Overview

Figure 17 shows the main elements of the MecaPortal web interface. These are:

- The menu bar
- The code editor panel
- The jogging panel
- The 3D view panel
- The event log panel

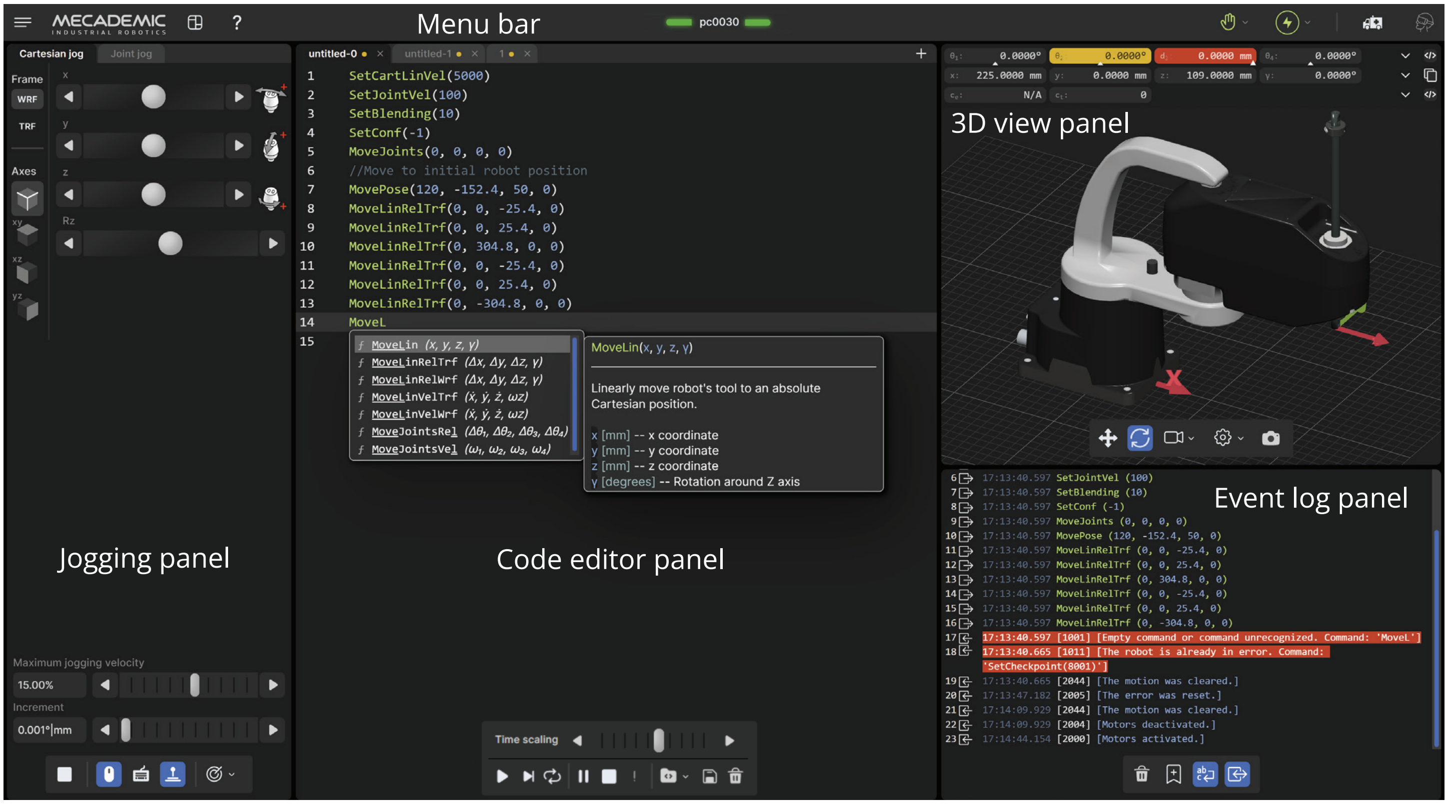


Figure 17: Overview of the MecaPortal

You can show/hide each of the four panels from the button, in the menu bar.

5.3. The menu bar

From left to right, the menu bar features

- The configuration menu button,
- The panels show/hide menu button,
- The show/hide tooltips button, ?
- The robot name surrounded by state bars (see Table 7)
- The connection state selector, (disconnect) or (monitoring) or (control)
- The robot state selector, (deactivate) or (activate)
- The recovery mode button,
- The simulation mode button,

Until you get to know the MecaPortal, we recommend that you activate the tooltips using the button ?, in the menu bar. Most tooltips are disabled by default.

Table 7: The robot state bars in the MecaPortal

ROBOT STATE BARS	
Visual state	**Explanation**
Gray, solid	The robot is deactivated.
Yellow, solid	The robot is in recovery mode but not moving.
Yellow, blinking	The robot is in recovery mode and executing motion commands.
Green, solid	The robot is activated.
Green, blinking	The robot is activated and executing motion commands.
Blue, solid	The robot motion is paused.
Red, blinking	The robot is in error mode.

5.3.1 The connection and robot state selectors

Normally, once the web user interface is loaded, you have not only established an HTTP connection with the robot, but also activated the socket messaging which is the only communication channel between the web interface and the robot. By default, the web interface connects to the robot in monitoring mode only (as seen in Figure 15). To control the robot click on the icon and select . If the robot is in error when you connect to the robot, the connection state button will show a red blinking icon. You can still press that button and select to only monitor or control the robot. The monitoring option can be used to see in real-time the motion of the robot when another client (e.g., another MecaPortal, a Python program, or a Profinet application running on a PLC) is controlling the actual robot.

Next, you need to activate the robot by selecting the button. A list with two options will unroll. Click the icon to activate the robot. (In case you are familiar with our Meca500 six-axis robot, note that the MCS500 does not need homing, contrary to the Meca500.)

5.4. The code editor panel

The code editor is used mainly for writing and executing simple programs, i.e., for testing. These programs are sequences of the proprietary commands described in the Programming Manual. The robot's command interface does not support conditionals, loops, or other flow control statements, nor variables. The robot only accepts request commands (to get information from the robot) and motion commands (to tell the robot to perform an action). The robot also supports comments in C/C++ style (e.g., // and /* */).

For complex tasks, you must write a program outside the web interface (e.g., in your preferred integrated development environment) that parses the robot's feedback, controls the robot, and handles all flow control logic. For this, you can use any language that supports communication over TCP/IP (e.g., C/C++, C#, Python, Java or even Structured Text, in the case of a PLC). Note that we offer a Python API on our GitHub account.

5.4.1 Using programs

You can create a new program using the + button in the upper right corner of the panel. The program name can be changed and the program saved to the robot's memory by either double-clicking on the program tab or by clicking the icon at the bottom of the code editor panel, which is equivalent to pressing the shortcut Ctrl-Shift-s. You can also save the program directly using the shortcut Ctrl-s.

Programs can be saved in different folders. To specify a folder, and simultaneously create it if it does not exist, simply type the name of the folder followed by a slash, immediately before the name of the program. You can specify multiple layers of folders. Naturally, the program names in a given folder must be unique, as well as the sub-folder names in a given folder.

Program and folder names are case sensitive and must contain a maximum of 63 characters among the 62 alphanumericals (A..Z, a..z, 0..9), the underscore and the hyphen.

A yellow dot to the right of the program's name indicates that the program has been changed and needs to be saved. If a syntax error is found in the code, during the saving, the yellow dot will turn red, and a red ⚠ will appear in front of each line of code containing a syntax error. Note that the syntax validation is performed by the robot (and not by the MecaPortal) when the program is saved. Local changes won't be completely validated until the program is saved again.

The programs that appear in the code editor panel are simply those open in the MecaPortal and not necessarily in the robot's memory. To open a program that is already in the robot's memory, click on the icon. You can also delete programs from the same menu. Alternatively, you can delete a program that is open and in focus, by clicking the icon. To simply close an open program, click the × on the tab with the program name.

A program can be called in another program with the `StartProgram` command, as in the following example: `StartProgram("my_folder/my_subfolder/program123")`.

To save and load programs from the robot, you must be connected to it in control mode, i.e., the connection state icon displayed in the menu bar must be .

5.4.2 Writing programs

The code editor provides syntax highlighting. In addition, once you start typing a command, a list of suggestions appears, allowing auto-completion. Furthermore, a brief description of the command appears, as shown in Figure 17. Additionally, pressing the secondary mouse button when your mouse cursor is over the code editor text field brings a context menu with all available commands (Figure 18). The most important group is in "TO CURRENT POSITION" which inserts the selected command at the text cursor with the arguments corresponding to the current robot position, the current tool reference frame (TRF), and the current world reference frame (WRF). To cancel the context menu without inserting a command, press Esc or click away.

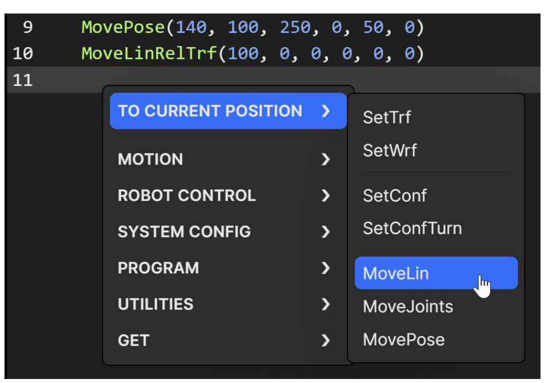


Figure 18: Context menu in the code editor

The code editor includes various editing features for productive source code editing. The shortcuts for accessing these features are presented in Table 8. You can select a block of text, a box of text (column select), or even have multiple cursors. Each line that has a text cursor or a selection of text becomes highlighted in gray and is called an *active line*. For example, in Figure 18, line 11 is an active line.

Table 8: Keyboard shortcuts for source code editing

KEYBOARD SHORTCUTS FOR SOURCE CODE EDITING	
Shortcut	**Action**
Ctrl+Space	Open the auto-complete popup menu
Ctrl+Shift+Space	Open the command help popup
Ctrl+a	Select all
Ctrl+d	Add selection to next find match
Ctrl+f	Open the find and replace dialog
Ctrl+g	Open the "go to line" dialog
Ctrl+/	Comment/uncomment active line(s)
Ctrl+Home	Move cursor to the beginning of the first line
Ctrl+End	Move cursor to the end of the last line
Ctrl+Right	Move cursor to next group
Ctrl+Left	Move cursor to previous group
Double click	Select group
Triple click	Select line
Alt+Up	Move active line(s) up
Alt+Down	Move active line(s) down
Shift+Alt+Up	Duplicate active line(s) and insert result above
Shift+Alt+Down	Duplicate active line(s) and insert result below
Alt+Click & drag	Select a box of text (column select)
Ctrl+Click	Place multiple cursors for simultaneous editing

5.4.3 Executing programs

You can execute the complete current program (even if it is not saved yet) by pressing the ▶ button at the bottom of the code editor panel. Alternatively, you can execute only the active line(s), by pressing the ⏯ button, or by pressing Ctrl+Enter. For both actions, the robot must be activated and not in error mode.

Once the robot starts executing motion commands, the ■ button will become highlighted in yellow, and the green status bars in the menu panel will start blinking. You can press that button (or Alt+;) at any time to stop the robot and clear its motion queue (i.e., to send the `ClearMotion` command to the robot). Alternatively, you can press the ⏸ button (or Alt+.) to pause the execution of motion commands (i.e., to send the `PauseMotion` command to the robot). To resume the execution of motion commands, press the ⏸ button again (which sends the `ResumeMotion` command).

At any time, if a motion error occurs (either while the robot is executing a command or is idle), the ! button will become red. Pressing that button, or clicking the "Reset error" link in the red popup that will appear, acknowledges and resets the error (i.e., the MecaPortal sends the `ResetError` command to the robot). Once the error was reset, you need to "unpause" the robot, by clicking the ⏸ button (now blue).

Finally, recall that you can execute other programs, using the command `StartProgram`. With that command, you can only execute programs that have already been saved on the robot.

5.5. The event log panel

By default, the event log panel lists most commands sent to the robot, called *request messages*, AND most robot responses. Exceptions include the commands sent from the jogging panel, the configuration menu, and a few others. All messages are preceded with a time stamp and an integer number, starting from 1. Request messages are identified with the icon, while robot responses are preceded with the icon. The messages, which all start with a unique four-digit code enclosed in brackets, are explained in the Programming Manual.

The control buttons at the bottom of the event log panel are self-explanatory:

- Clear the event log
- Insert a text bookmark
- Toggle the word wrapping
- Toggle the listing of new request commands (robot responses are always listed)

Detailed robot logs can also be downloaded as a single text file from the configuration menu, ☰.

5.6. The 3D view panel

The 3D view window shows a perspective projection of the robot in its current position, as well as the current *WRF* (*World Reference Frame*) and *TRF* (*Tool Reference Frame*). To zoom in and out, place your mouse cursor over the 3D view window and use your mouse wheel. To change the view angle, press the primary mouse button (if the button is highlighted) or the secondary mouse button (if the button is highlighted) inside the 3D view window, hold it down and drag the mouse. To pan, press the primary mouse button (if the button is highlighted) or the middle mouse button (if the button is highlighted) inside the 3D view window, hold it down and drag the mouse. You can also select one of several preset views from the menu.

Finally, you can show/hide the TRF, WRF, or the floor, and switch between perspective and orthographic projection from the menu. You can also download a high-resolution screen capture of the current 3D view by pressing the button.

5.6.1 The robot position display

As soon as the MecaPortal appears, the current robot position appears at the top of the 3D view panel. By default, we show:

- the four joint positions, θ_1, θ_2, and θ_4, in degrees, and d_3, in mm,
- the position (x, y, z) and orientation (γ) of the TRF with respect to the WRF, in mm and degrees, and
- the robot configuration parameter.

One of the main limitations, when operating a robot, is its joint limits, which are different for each joint. We have therefore added various visual cues (patent pending), that represent the approximate joint position, relative to the corresponding joint limits. These cues are the up-pointing triangles under each joint position text field. The horizontal position of each triangle relative to the left and right limits of the corresponding text field, is proportional to the position of the corresponding joint relative to the joint limits. Furthermore, when the joint position is within 5 degrees of the joint limit, the corresponding text field is highlighted in yellow, while if the joint limit is attained, the text field turns red. Similarly, when the angle of joint 2 is close to or equal to 0° (elbow singularity), the corresponding text field is highlighted in yellow.

Another set of highly useful features can be accessed in the selection menus on the right of each of the three rows of data. You can select to either copy the data that is shown in the corresponding row by pressing the icon on the right (the icon is changed to) or insert a specific command with arguments corresponding to the current robot position (the icon is changed to </>). In addition, in the case of the first row of data, you can choose to show either the joints calculated or actual positions, the joints calculated or actual velocities, or even the joints torques. Similarly, in the case of the second row of data, you can choose to show either the calculated or actual pose of the TRF with respect to the WRF, or the calculated or actual Cartesian velocity of the TRF with respect to the WRF.

Table 9 shows the default keyboard shortcut for copying data from the robot position display or inserting instructions with that data at the current cursor in the code editor.

Table 9: Keyboard shortcuts related to current robot position and reference frame definitions

DEFAULT KEYBOARD SHORTCUTS RELATED TO CURRENT ROBOT POSITION	
Shortcut	**Action**
Alt+j	Insert `MoveJoints` command with current joint set as arguments
Alt+l	Insert `MoveLin` command with current TRF pose as arguments
Alt+p	Insert `MovePose` command with current TRF pose as arguments
Alt+c	Insert `SetConf` command with current posture configuration parameters as arguments
Alt+w	Insert `SetWrf` command with current WRF pose as arguments
Alt+t	Insert `SetTrf` command with current TRF pose as arguments
Alt+Shift+j	Copy current joint set
Alt+Shift+p	Copy current TRF pose with respect to the WRF
Alt+Shift+c	Copy the current posture configuration parameters
Alt+Shift+w	Copy the current definition of the WRF
Alt+Shift+t	Copy the current definition of the TRF

5.7. The jogging panel

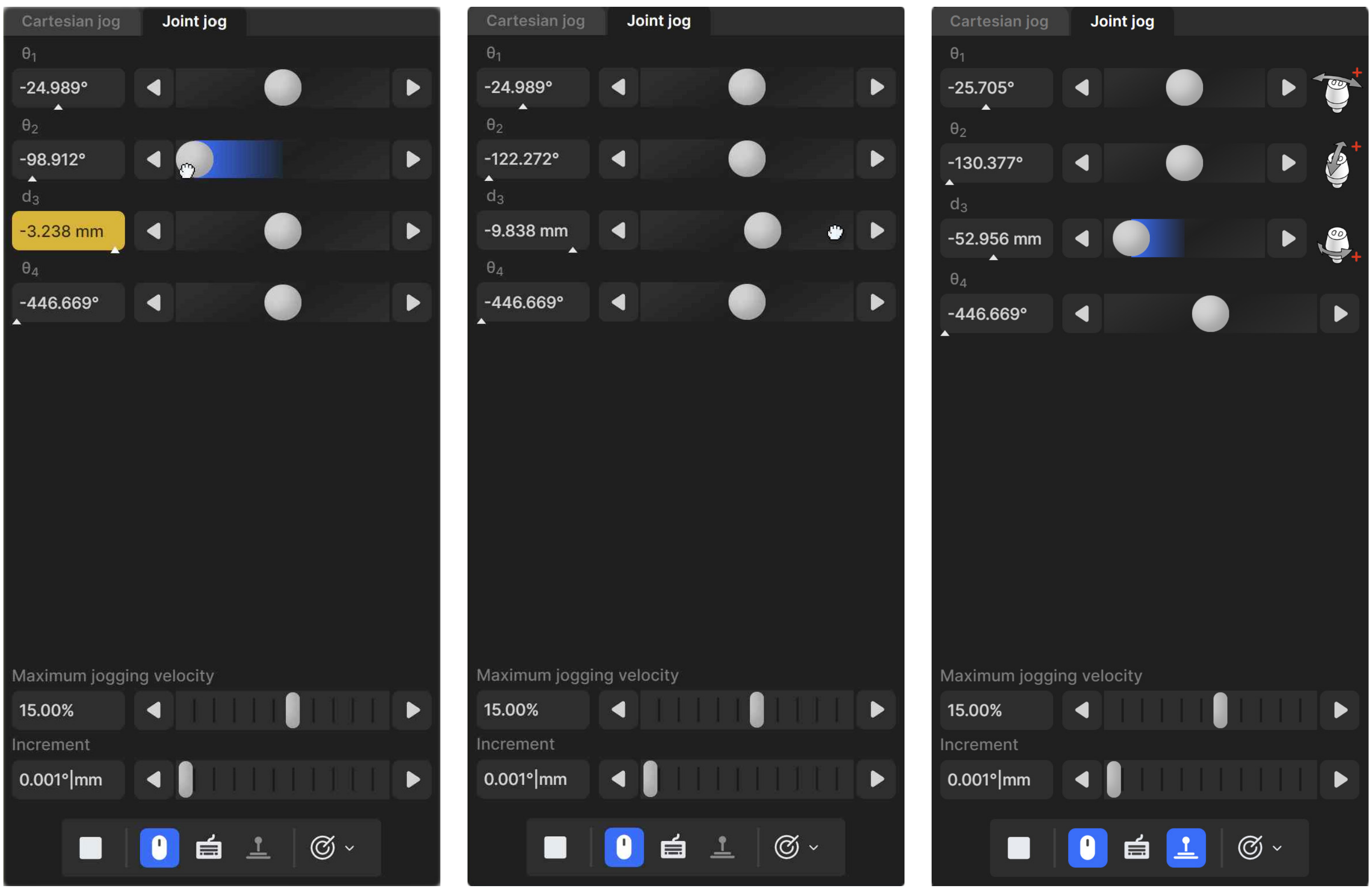
The jogging panel is used to jog (move) the robot in several different ways (in the Cartesian or joint space) and with several different input devices (mouse, keyboard shortcuts or joystick). Once a desired robot joint arrangement is reached, you can use the context menu in the program editor field to insert a motion command with current joint set or TRF pose.

The jogging panel is enabled whenever the robot is ready to receive AND execute new motion commands. Every motion that can be commanded in the jogging panel can also be performed by sending commands from the code editor panel, though in a much less user-friendly manner. For safety reasons, when jogging, the robot can move only up to 50% of its maximum speed.

The jogging panel has two tabs that will be described in the following sections.

5.7.1 The joint jog tab

We use an innovative UI element (patent pending) for jogging each joint. That *jogging bar* is a mixture of a slider and a virtual single-axis joystick and has dual functionality, depending on which mouse button is used to interact with it (Figure 19). You can also jog each joint using keyboard shortcuts, as well as a three-axis or a six-axis joystick with at least two buttons. (Technically, you can use other joysticks, such as a PlayStation controller, but the icons displayed will be those for the SpaceMouse.)



(a) Joint jogging using primary mouse button
(b) Joint jogging using secondary mouse button
(c) Joint jogging using Mecademic's three-axis joystick

Figure 19: Joint jog tab

By default, only the mouse is activated, and the button at the bottom of the jogging panel is highlighted in blue. To jog each axis as if using a joystick, click the primary mouse button onto the thumb of the corresponding jogging bar and drag it right or left (Figure 19a). The further you drag the thumb away from its central position, right or left, the faster the joint turns, in positive or negative direction, respectively. In other words, you are directly controlling the joint speed, rather than the joint position. Alternatively, you can directly click with the primary mouse button on either of the two arrow buttons of the jogging bar and hold, which makes the joint rotate at the specified maximum jogging velocity.

You can also drag the thumbs of the jogging bars using the secondary mouse button (Figure 19b). Doing so, it is the mouse horizontal velocity (rather than relative position) that is mapped to the robot joint velocity. Additionally, clicking the left or right arrow buttons with the secondary mouse button commands a single incremental joint displacement, with the increment specified in the specified in the text field at the bottom of the jogging panel.

You can also directly specify the joint value by entering the joint angle in the text field next to each jogging bar. Note that each text field changes to yellow when the joint position is close to one of its limits or to a singularity (joints 3 and 5 only), or to red, when the joint position is at a limit or at a singularity, as is the case with the robot position display in the 3D view panel. In addition, the little triangle underneath each bar indicates the relative joint position with respect to the joint limits.

You can use keyboard shortcuts to jog the robot by activating the toggle button . Table 10 shows the default keyboard shortcuts for jogging the robot. The shortcuts are active only if the toggle button is selected and the mouse cursor is over the jogging panel, in which case the panel is surrounded by a blue frame. You can change most of these shortcuts in the configuration menu, .

Table 10: Keyboard shortcuts for jogging (focus must be on jogging panel)

DEFAULT KEYBOARD SHORTCUTS FOR JOGGING	
Shortcut	**Action**
Shift+q* or q	Rotate joint 1 or move end-effector along x-axis, in negative direction
Shift+w* or w	Rotate joint 1 or move end-effector along x-axis, in positive direction
Shift+a* or a	Rotate joint 2 or move end-effector along y-axis, in negative direction
Shift+s* or s	Rotate joint 2 or move end-effector along y-axis, in positive direction
Shift+z* or z	Rotate joint 3 or move end-effector along z-axis, in negative direction
Shift+x* or x	Rotate joint 3 or move end-effector along z-axis, in positive direction
Shift+e* or e	Rotate joint 4 or rotate end-effector about z-axis, in negative direction
Shift+r* or r	Rotate joint 4 or rotate end-effector about z-axis, in positive direction
Shift+arrow* or arrow	Jog along each of the four directions chosen in the jogging pad
1	Open Cartesian jog panel and select WRF mode
2	Open Cartesian jog panel and select WRF mode
3	Open joint jog panel
.	Toggle between TRW and WRF mode, if Cartesian jog panel open
-	Reduce jog velocity
=	Increase jog velocity

* Hold Shift for continuous jog, otherwise robot will jog in increments.

Finally, you can jog the robot using either our MJ3 3-axis USB precision joystick (Figure 20a) or the SpaceMouse® 6-axis joystick from 3Dconnexion (Figure 20b). To use the MJ3 or the SpaceMouse, you need to activate the button . For the MecaPortal to detect the joystick, you will need to press one of the device's buttons or, occasionally, unplug and replug the device. Once the joystick is detected you will see the respective joystick icons next to each slider (Figure 19c).

Contrary to the keyboard shortcuts for jogging the robot, the joystick is active even if the mouse cursor is not over the jogging menu, as long as the focus is on the MecaPortal.

Do not install the driver and the software that come with the SpaceMouse as these will interfere with the desired functioning of the device in the MecaPortal. Also, if you opt for the wireless model, keep the device close to the universal USB receiver and remember to recharge the device regularly.

You can deactivate certain joystick directions by clicking on the respective joystick icon, to the right of each slider bar. You can even customize the mapping between the joystick "axes" and the jogging directions in the configuration menu, ≡.

(a) Mecademic's MJ3 3-axis precision joystick

(b) SpaceMouse® 6-axis joystick

Figure 20: USB joysticks that can be used with the MecaPortal

To select between joint jog, Cartesian jog with respect to the TRF or Cartesian jog with respect to the WRF, you can either use your mouse or press (up to two times if necessary) the right button of the SpaceMouse or of the MJ3 until the desired selection is obtained.

For much more precise jogging, we strongly recommend the use of our MJ3. In the case of the MJ3, the left button of the joystick toggles the assignments for the three axes.

Finally, for convenience, the same stop button ■ available at the bottom of the code editor is also provided at the bottom of both jogging menus. Lastly, a list of predefined robot positions (essentially, joint sets) are stored and available in the ◎ menu button. Clicking on one of these robot positions moves the robot to that joint set, in joint mode.

5.7.2 The Cartesian jog tab

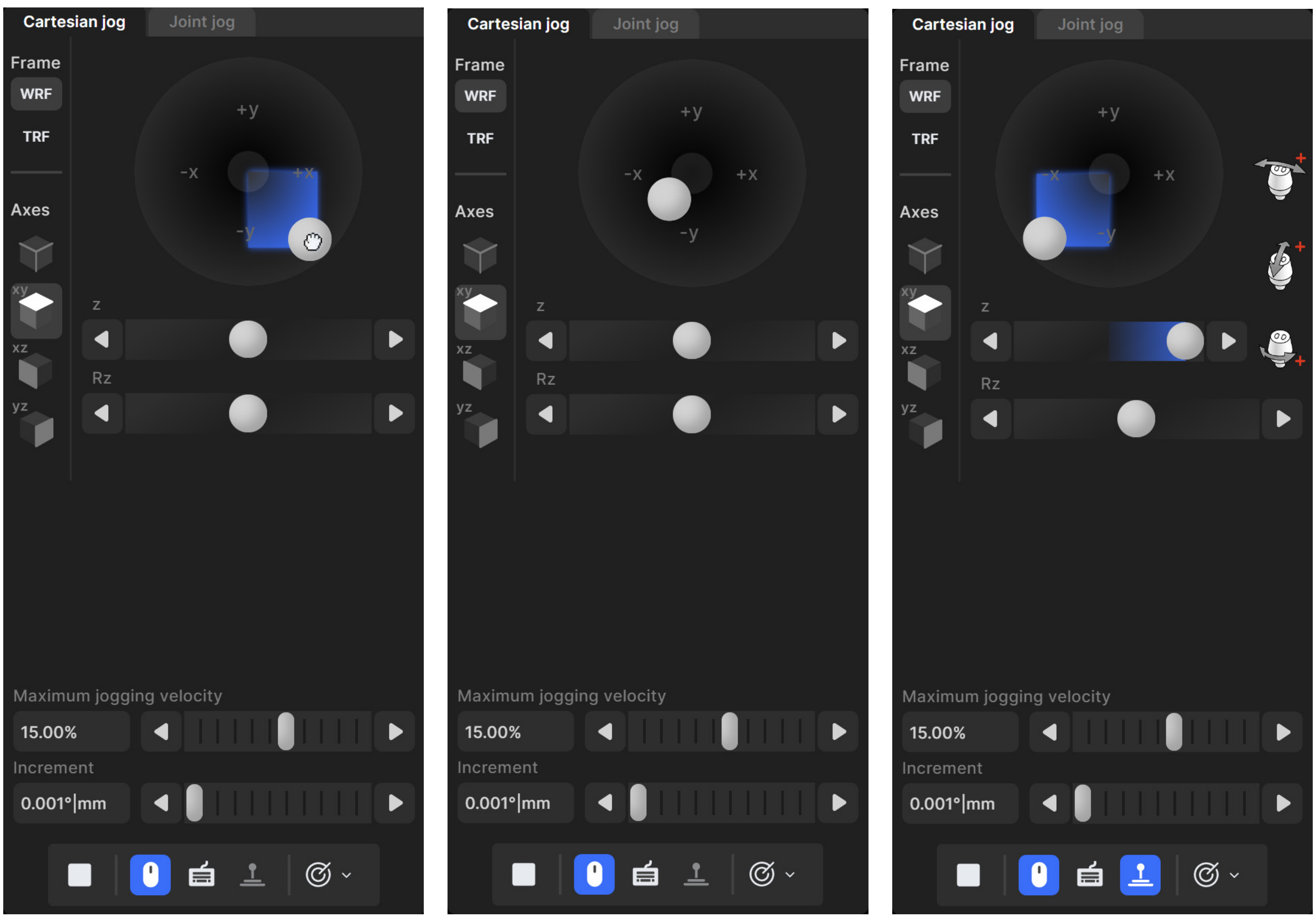
In the Cartesian jog tab (Figure 21), you can move the robot along (labels X, Y, Z) or about (label Rz) the z-axis of the TRF (if the TRF button is selected, as in the figure) or along each of the three axes or about the z-axis of a reference frame having the same orientation as the WRF but with origin at the TCP (if WRF is selected).

As with the joint jog tab, the jogging bars can be controlled with both the primary (Figure 21a) and secondary (Figure 21b) mouse buttons, using the same logic. However, you can merge two jogging bars for linear movement (i.e., X and Y, Y and Z, or Z and X) into a *2D jogging pad* using the buttons under the label "Axes". Note that subsequent clicks on one of these buttons changes the jogging directions in the 2D jogging pad (there are a total of eight combinations).

The other major difference is that there are no text fields showing the position and orientation of the TRF with respect to the WRF, next to each jogging bar, let alone visual cues for indicating whether Cartesian jogging in one direction might soon reach a workspace limit.

The keyboard shortcuts for Cartesian jogging are shown in Table 10.

Finally, you can jog in Cartesian mode using a joystick. Figure 21c shows the Cartesian jog tab in the case of the MJ3 joystick.



(a) Cartesian jogging using the primary mouse button

(b) Cartesian jogging using the secondary mouse button

(c) Cartesian jogging using the MJ3 joystick

Figure 21: Cartesian jog tab

5.8. The configuration menu

The configuration menu can be accessed from the top left corner of the MecaPortal window, ≡. It features the following sections:

- Robot information, such as the serial number and the complete version number of the firmware;
- Help, primarily links to documentation, the support website, and to the legacy web interface;
- Network configuration, such as entries of the IP address of the robot or the netmask,
- Joint limits, for reducing the joint ranges;
- Workspace limits, for preventing self-collisions and defining Cartesian limits, a feature which is, however, still under development, and is therefore not described in this manual;
- Update firmware, for upgrading (or downgrading) the firmware of the robot;
- Get logs, for downloading the complete (all files) or partial robot logs (only robot.log file), or the latest robot logs;
- Keyboard mapping, for listing all and changing certain keyboard shortcuts;
- Joystick mapping, for assigning robot jogging directions to joystick axes.

6. OPERATING THE ROBOT

6.1. Power-up procedure

If you have read all preceding sections carefully and followed the steps, your robot is already powered up, updated and ready to move. Nevertheless, here is a quick summary of the steps that you need to follow in order to power up your robot, as described before, as well as alternative methods.

6.1.1 Powering the robot

- Turn the power supply on.
- Select the operating mode with the switch key.
- Make sure that all stop signals are removed and the three small LEDs on the robot's base has stopped flashing (after about twenty seconds), and the Status LED on the power supply is blinking, and then press the RESET button.

6.1.2 Connecting to the robot

- Connect to the robot's web interface (MecaPortal).
- Click the button in the menu bar and select "Control".
- As soon as the robot is connected, you will get the following welcome message in the Event log panel: [3000][Connected to MCS500 R1 v.10.0.x].

6.1.3 Activating the robot

- Click the button in the menu bar and select "Activate".

6.1.4 Moving the robot

After activating the robot, click the button in the jogging panel and select "Zero all joints". The robot will move all of its joints to their zero positions. In this robot joint set (shown in Figure 1), the robot is in a so-called singularity. Most industrial robots cannot move in Cartesian mode from such a singularity. In order to simplify the use our robots, we have implemented an algorithm that allows them robot to move through such a singularity.

The Cartesian coordinates displayed above the robot in the web interface are those of the Tool Reference Frame (TRF) with respect to the World Reference Frame (WRF). Both frames are displayed in the web interface. By default, the TRF is located at the mechanical interface of the robot (as in Figure 25) and the WRF at the bottom of the robot's base (as in Figure 22). The origin of the TRF is called the TCP (Tool Center Point).

In the MCS500, the z-axis of all reference frames point "upwards" (relative to a table-top installation), so we use only one angle, γ (gamma), to define the orientation of one reference frame with respect to another.

Thus, for example, you can simply go to the Cartesian tab of the jogging menu, and with the TRF option selected, press the right arrow button of the x jogging bar. Alternatively, you can perform the same kind of linear motion by following any of these steps:

- Clear the programming text field, type `MoveJoints(-45,45,-80,0)`, and press ▶.

Figure 22 shows the resulting robot position.

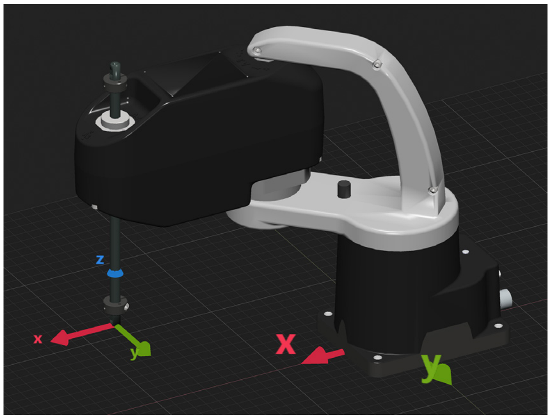


Figure 22: Robot position for `MoveJoints(-45,45,-80,0)`

6.2. Power-off procedure

6.2.1 Zeroing the robot joints (optional)

It might be a good idea to always bring the robot joints to their zero positions before turning the robot off. This can be done in two ways:

- send a `MoveJoints` command with all four arguments equal to 0

OR

- click the button in the jogging panel and select "Zero all joints".

6.2.2 Deactivating the robot

To deactivate the robot

- click the button and then select "Deactivate"

OR

- send the `DeactivateRobot` command via the programming editor.

If you accidentally close your web interface before deactivating the robot, the robot will stop (in case it was moving) but will remain activated.

6.2.3 Disconnecting the robot

To disconnect the web interface from the robot, select the ⛓ option from the connection state group.

If you disconnect the web interface from the robot before deactivating the robot, the robot will stop moving.

6.2.4 Removing power

Finally, unplug the power supply from the AC outlet or switch the power supply off.

Never detach the DC power connector from the robot's base, before unplugging the power supply's AC power cord from the AC outlet or switching the power supply off.

6.3. Robot's base

A series of LEDs are located at the rear of the robot's base (Figure 23). The meanings of these LEDs will be summarized in what follows.

Figure 23: Robot's base

6.3.1 LEDs

After a power up, the Power, Status and Error LEDs will flash fast simultaneously during a couple of seconds. After that, the LEDs will be lit as described below.

Motors ON LED

The large yellow LED on the top of the robot's base is on when the motors are powered and off when power is removed from the motors (e.g., after an E-stop or when the switch key is in Locked operating mode position).

Power LED

The Power LED is green and indicates that the robot is powered:

- off, when the robot is not powered;
- on, when the robot is powered (though not necessarily its motors).

Status LED

The Start/Pause LED is yellow and indicates the state of the robot:

- off, when the robot can not be activated (e.g., safe boot);
- on, when the robot is activated;
- slow blink, when the robot can be activated.

Error LED

The Error LED is red and indicates the error state of the robot:

- off, when there is no error or a protective/emergency stop;
- on, when the robot is in error state;
- one flash (every second), when a P-Stop 2 is activated;
- two flashes (every second), when a P-Stop1 is activated;
- three flashes (every second), when an E-Stop is activated.

Combined LED sequences

In some special situations, all three LEDs flash simultaneously or in sequence, as described in Table 11. Additional sequences occur during network and factory reset, as described in Section 10.

Table 11: LED pattern sequences for special situations

LED PATTERN SEQUENCES			
Situation	**Power (green)**	**Status (yellow)**	**Error (red)**
Booting	slow blink (all three LEDs blink simultaneously once per 1 s)		
Booting in Safe mode (occurs during firmware update)	quick blink (all three LEDs blink simultaneously once per 200 ms)		
Updating the firmware	quick traveling blink (each LED blinks quickly one after the other, once per 1 s)		

Link/Act IN and Link/Act Out LEDs

Both LEDs are green and flash when there is network activity in the corresponding Ethernet port. The LEDs function in the same manner as on a normal Ethernet RJ-45 port.

Run LED

This green LED is used only when the robot is controlled via EtherCAT (see the Programming Manual).

ERR LED

This red LED is used only when the robot is controlled via EtherCAT (see the Programming Manual).

7. INSTALLING AN END-EFFECTOR

You can install end-of-arm tooling (EOAT) on the MCS500 and control it via the I/O interface on the robot's power supply or directly from your PLC.

The MCS500 can be mounted table-top or upside-down. For that purpose, the two ends of the spline shaft are identical and symmetric. Each of these two ends is called the mechanical interface and should be used for fixing EOAT. The dimensions of the mechanical interface are shown in Figure 24.

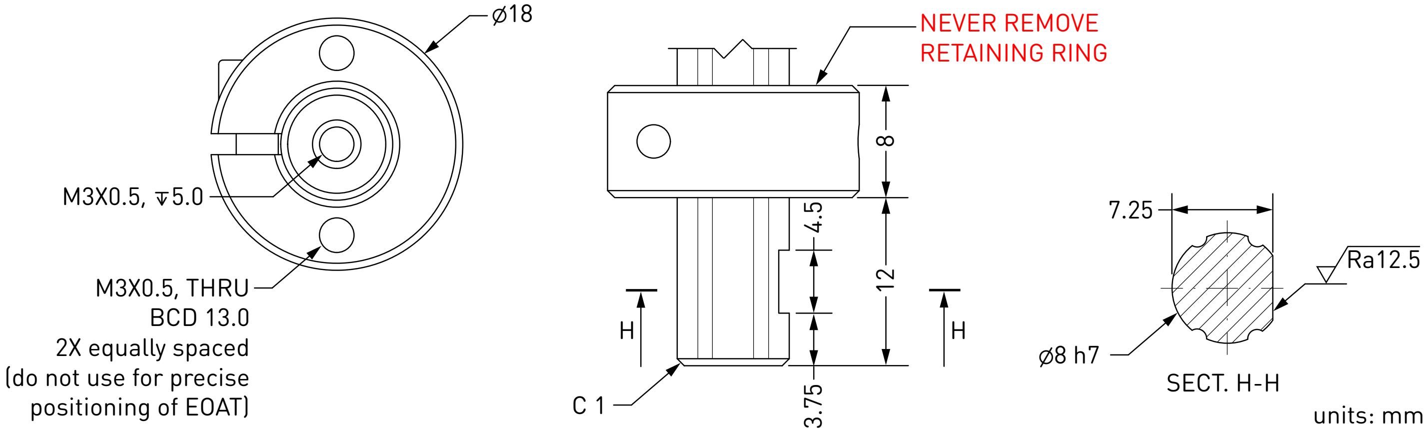


Figure 24: The mechanical interface of the MCS500

Note that the FRF (flange reference frame) is fixed to the end of the spline shaft that is closer to the robot's base, so that its *z* axis coincides with the axis of the spline shaft and points away from the robot's base, its origin is at the very end of the spline shaft, and its *x* axis is perpendicular to the plane of the Weldon flat, as shown in Figure 25.

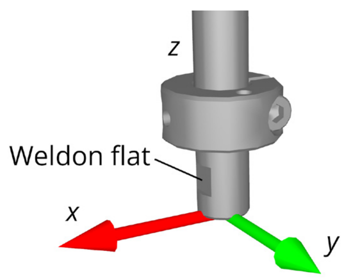


Figure 25: Placement of the FRF

- Keep the robot unpowered while installing/removing EOAT to its mechanical interface
- Do not exceed the robot payload.
- Securely fasten the EOAT to the mechanical interface using M3 screws and a set screw applied against the Weldon flat.

- Never remove the retaining rings from the spline shaft or you will damage permanently the ball-screw spline assembly.
- Do not over-tighten the M3 screws. Use a torque of 1.5 Nm.
- Attach the EOAT cabling using adhesive cable tie mounts in such a manner that it obstructs as little as possible the motions of the robot.

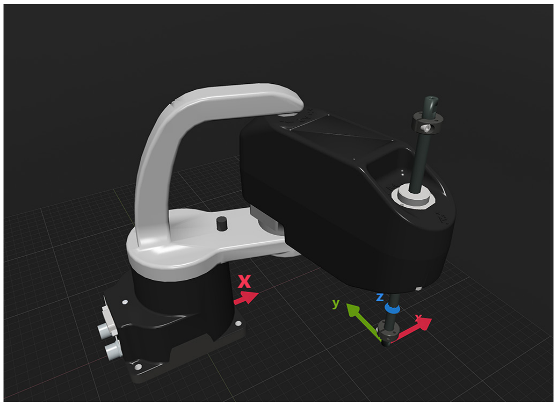
8. EXAMPLES

8.1. Make a simple pick and place

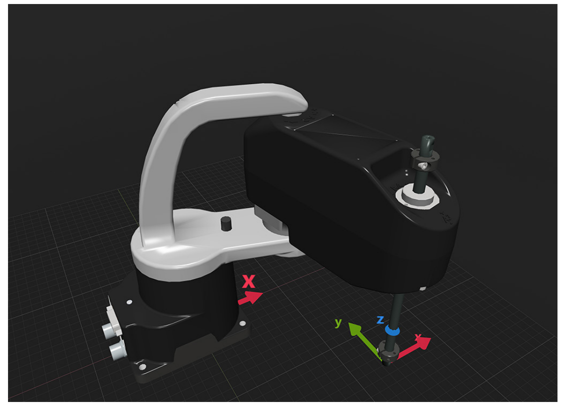
Here is an example of a very simple program that makes a pick and place motion:

```
// Set reference frames
SetTrf(0, 0, 0, 0)
SetWrf(0, 0, 0, 0)

// Set motion parameters
SetCartLinVel(5000)
SetJointVel(100)
SetBlending(10)

// Fix robot configuration
SetConf(-1)

// Move to pick position
MovePose(120, -152.4, 50, 0)
MoveLin(120, -152.4, 24.6, 0)
MoveLin(120, -152.4, 50, 0)
MoveLin(120, 152.4, 50, 0)

// Move to drop position
MoveLin(120, 152.4, 24.6, 0)
MoveLin(120, 152.4, 50, 0)
MovePose(120, -152.4, 50, 0)

// For faster cycle times, use the command MoveJump
```

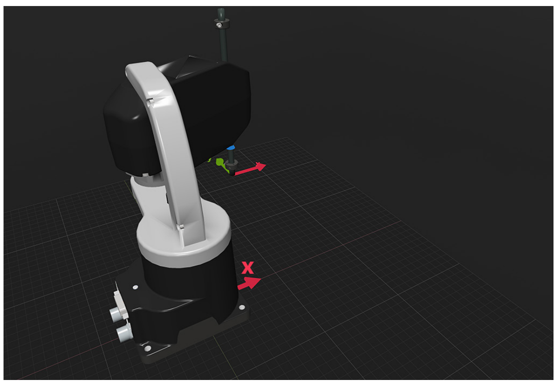
Figure 26 shows the result of four of the motion commands.



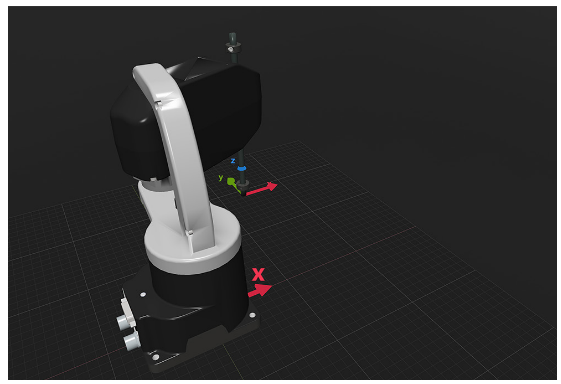
(a) `MovePose(120, -152.4, 50, 0)`



(b) `MoveLin(120, -152.4, 24.6, 0)`



(c) `MovePose(120, 152.4, 50, 0)`



(d) `MovePose(120, 152.4, 24.6, 0)`

Figure 26: The four separate robot positions that define the motion sequence

9. MAINTENANCE

Depending on the usage of your MCS500, the robot may require some minimum maintenance. However, it does never require disassembly. There is no battery to replace and joints 1 and 2 do not require greasing.

9.1. Greasing the ball screw spline

The first application of grease on the spline shaft is needed after approximately 50 000 m of travel. Subsequent applications of grease must be made every 100 000 m of travel. Use only AFB-LF grease, from THK. AFB-LF Grease is a general-purpose grease developed with a lithium-based consistency enhancer using refined mineral oil as the base oil. It excels in extreme pressure resistance and mechanical stability.

We do not provide this grease, but it can be easily ordered from THK or various distributors.

Keep the ball screw spline assembly sufficiently greased. Operating the robot with insufficient grease will permanently damage the assembly (i.e., joints 3 and 4).

Follow the safety instructions provided by the manufacturer of the grease, THK. A summary of these instructions is given below.

- Avoid breathing mist or vapor. Work in a properly ventilated area. Contaminated work clothing must not be allowed out of the workplace. Wear protective gloves. Avoid release to the environment.
- If grease gets onto your skin, wash with plenty of water. If skin irritation or rash occurs, get medical attention. Wash contaminated clothing before reuse.
- If grease gets into your eyes, rinse immediately with water. Get medical attention if irritation develops and persists.
- If grease gets into your mouth, rinse mouth immediately. Get medical attention if symptoms occur.
- The grease is inflammable. If contents gets on fire, extinguish with foam, carbon dioxide or dry powder. Do not use water or halogenated extinguishing media.
- Store in tightly closed container. Store away from strong oxidizing agents, and from heat.

To grease the spline shaft, cover the surrounding area and the end-effector in case the grease drips and follow the steps below:

1. Turn the power off.
2. Move the robot (joints 1 and 2) to a position where joint 3 can achieve it full stroke.
3. Move the spline shaft to its upper limit manually while pressing the brake release button (Figure 3).
4. Wipe off the old grease from the upper part of the spline with a clean cloth and then apply new

grease, by directly filling the groves on the shaft. Wipe off excess grease from the shaft.

5. Move the spline shaft to its lower limit manually while pressing the brake release button.
6. Repeat step 4 for the lower part of the spline.
7. Move the shaft up and down several times while pressing the brake release button. Wipe off excess grease from the shaft.
8. Store away grease and remove all cloths and covers.
9. Power on the robot and verify the motion of joints 3 and 4.

9.2. Making large-amplitude joints movements

If you operate the revolute joints of your robot repeatedly within a small angle of 10° or less, an oil film shortage will develop locally and the bearings will get damaged. To prevent premature failure, move the joints at least 60°, ten times a day.

Similarly, if you repeatedly move joint 3 of your robot within less than 20 mm, move it at least 50 mm up and down, ten times a day.

9.3. Verifying the overall condition of the robot

Verify on a regular basis the overall condition of your robot by following these steps:

1. During boot-up, and then once the robot is activated, verify the correct functioning of the LEDs on the power supply (Section 2.5) and on the robot's base (Section 6.3.1).
2. Move joints, one by one, slowly and then at maximum speed, as much as you can without risking interference and listen carefully for suspicious noise.
3. Remove power from the robot and gently press up or down the spline shaft, by applying no more than the equivalent of about 1 kg of load. The spline is not supposed to move under a small load like this.
4. Make sure all cables are correctly screwed in the robot's base and on the power supply.
5. Make sure there are no loose D-SUB connections.

If you detect any anomalies, cease using the robot and contact our support team by creating a ticket at https://support.mecademic.com.

10. TROUBLESHOOTING

No LEDs are on upon power up

- Make sure all connectors are properly attached.
- Make sure the AC outlet works (the green LED on the power supply should be on).

No connection to the robot's web interface

- Make sure EtherCAT mode has not been enabled. To switch the robot back to Ethernet TCP/IP mode, the simplest way is to do a network configuration reset.
- Make sure the Ethernet cable is properly connected. The green Ethernet LED should pulse like on an RJ-45 connector. If the green LED is not illuminated, detach and reconnect the Ethernet cable.
- Make sure the router/switch works by checking the LEDs of the connection socket.
- Make sure you are connected to the same network as the robot.
- If you are using static IP addresses, make sure that the robot's IP default address (192.168.0.100) does not conflict with any other device on the network. For example:

  Robot: IP = 192.168.0.100, netmask = 255.255.255.0, gateway = 192.168.0.1

  Computer: IP = 192.168.0.101, netmask = 255.255.255.0, gateway = 192.168.0.1

- If you are using DHCP, make sure to verify the robot's IP address via your router's web interface.

Robot fails to boot

- Disconnect the power supply from the AC outlet and wait for the green LED of the power supply to turn off. Then reconnect the power supply and boot the robot.

Robot's IP address forgotten

- You can reset the robot's Ethernet configuration (i.e., set the robot's IP address to 192.168.0.100 and the communications mode to TCP/IP) by performing a network configuration reset.

Network configuration reset

Continuously pressing for about 10 s the button between the two Ethernet connectors on the robot's base, once the robot is powered resets the robot's IP address and the communication mode to Ethernet TCP/IP. When you press that button, the Power (green) LED will start blinking slowly. As soon as the network configuration reset is done (after about 10 s), the Power (green), Status (yellow) and Error (red) LEDs will start flashing quickly in a sequence (two quick flashes each) and you can release the button.

Factory reset

Continuously pressing the button on the robot's base during boot-up for about 45 s will reset all configuration parameters (including the network ones) to their defaults, as well erase all robot programs. During the procedure, there will be different sequences of LEDs flashing and blinking:

1. The first 5 s of pressing the button, the three LEDs (Power, Status and Error) will blink slowly, then they will start blinking faster for another 10 s. This is the boot-up sequence.
2. Next, it is the network configuration reset that will take place and, as explained earlier, the Power LED only will start blinking slowly for about 10 s, and then the three LEDs will start blinking in a sequence for about 5 s.
3. Then, the Power LED only will start blinking, but faster than before, for about 15 s. Finally the three LEDs will start blinking fast in a sequence. You can now release the button.

Storing the robot in its shipping box

To put the MCS500 back into the foam insert of its original shipping box, click the ◎ button in the jogging panel of the MecaPortal and select "Shipping position" or simply send the command `MoveJoints(-140,145,-102,0)`. Recall that you must not force the brakes on the spline shaft.

Never disassemble the robot. If you think the robot is damaged, stop using it immediately and contact us.

If you are unable to solve your technical problem, do not hesitate to contact our technical support team by creating a ticket at https://support.mecademic.com.

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