User Manual

Original instructions

Meca500 (R3)

Robot Firmware: 8.3

Document Revision: A

February 17, 2021

Contents

1 Introduction

There are two manuals that come with the Meca500 (R3): this one and the Programming Manual. This manual will guide you through the steps required for setting up your Meca500 and for using it in a safe manner. You must read this user manual thoroughly during the unpacking and first use of your Meca500.

The Meca500 is a six-axis industrial robot arm that is relatively easy to use, robust and lightweight. The robot is, however, a precision device with rapidly moving parts. This robot should therefore be used only by technical personnel who have read and understood every part of this user manual, in order to avoid damages to the robot, its end-effector, the workpiece and adjacent equipment, and, most importantly, in order to avoid injuries.

2 Warning messages, notes and emphases

Particular attention must be paid to the warning messages in this manual. There are only two types of warning messages, as shown bellow:

WARNING
This presents instructions that must be followed in order to prevent injuries and possibly damage to your robot cell (robot arm, power supply, end-effector, workpiece and/or adjacent equipment).

CAUTION
This presents instructions that must be followed in order to prevent damage to your robot cell (robot arm, power supply, end-effector, workpiece and/or adjacent equipment).

In addition, important notes and definitions are formatted as follows:

NOTICE
This highlights important suggestions or definitions, the purpose of which is to improve the understanding of this manual and of how the robot works.

Finally, occasionally, small portions of the text in this manual that are particularly important are underlined (as already done in the previous section).

3 What's inside the box

Your shipping box contains a Meca500 robot arm (Fig. 1a), a 24 V DC intelligent power supply with an integrated safety module (Fig. 1c) and a D-SUB 15-position dongle (Fig. 1b), a 2-meter M12 D-Code to RJ45 Ethernet cable (Fig. 1d), and a 2-meter M12 circular male to M12 circular female DC power cable (Fig. 1e).

Your box may also contain the MEGP 25E electric gripper and other accessories. Remove all items carefully and do not discard your shipping box. If your order contained a gripper, do not open its package immediately. You must read the MEGP 25E user manual prior to installing the gripper.

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 proper length for fixing the robot's base and the power supply.

(a) The Meca500 robot arm

(b) Power supply

(c) D-SUB dongle

(d) Ethernet cable

(e) DC power cable

Figure 1: The main contents of your shipping box (optional items not shown)

CAUTION

- Handle the robot with care.
- The Meca500 is equipped with brakes on the first three joints (the ones close to the base). When the robot is not activated, these brakes are automatically applied. Do not force the brakes of the robot, unless there is an emergency!
- Inspect the robot and the power supply for damages. If you think either of them is damaged, do not use them and contact us immediately.
- Do not modify or disassemble the robot arm or the power supply.
- Do not use or store the Meca500 in a humid environment.
- Do not operate the Meca500 at temperatures bellow +5°C or above +45°C.
- Do not use any other power supply but the one provided.
- Do not replace the Ethernet and DC power cables provided with longer ones, without contacting us first.

4 Safety

The Meca500 weighs less than 5 kg. It can, however, move fast and cause injuries, especially when certain end-effectors are attached to its flange (e.g., a sharp tool or a laser). The robot also has pinch regions where two adjacent links of the robot can squeeze a finger (Fig. 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 Meca500, its end-effector and all adjacent equipment.

WARNING

- When the Meca500 is activated, stand away from it, wear safety goggles and be attentive and alert.
- If deemed necessary, place the robot in a safety enclosure.
- In case of an emergency, press immediately the E-STOP button located on the power supply.

Figure 2: When the Meca500 is activated, keep away from the zones labeled with the pinch-point warning sign, to avoid injuries.

4.1 Power supply and stopping functions

To power your Meca500 robot arm, you can only use the intelligent power supply provided by us. If you use one of our older power supplies or your own 24 V DC source, the robot would not function. Our new power supply has an integrated safety module, including a button for emergency stop (Stop Category 1), a reset button, status LEDs, and a D-SUB 15-position interface for connecting an external emergency stop (Stop Category 1), a protective stop 1 (Stop Category 1), and a protective stop 2 (Stop Category 2). The emergency stops and the protective stop 1 are designed as PL=d with Safety Category 3.

To start using your robot immediately, connect the dongle provided to the D-SUB 15-position interface. This would deactivate the additional protective stops and emergency stop. Read section 9.2 if you want to remove the dongle and install such additional stops. Furthermore, to connect the power supply to the robot, you must use the DC power cable provided and never modify it.

CAUTION
Never install an emergency stop or any kind of on/off switch on the DC side of the power supply.

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 joints 1, 2 and 3 will be immediately applied and the joints 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 or activating the emergency stop or the external protective stop 1 and emergency stop, the wrist joints of the robot become free. This minimizes the risks of pinning and pinching from the wrist and the end-effector. However, beware that the end-effector might slowly move downwards under the effects of gravity. Depending on the type of end-effector used, this residual motion might lead to an injury.

By definition, the protective stop 2 does not cut power to the robot, so after the robot stops all motors are active and maintain the position of all joints. The brakes are not applied and there is no residual motion due to gravity.

4.2 Disabling the brakes of the robot

In case of a collision, you can disable the brakes of joints 1, 2 and 3. This can only be done if the robot is powered AND not activated. How to activate and deactivate the robot is explained later in this manual, but for now, it suffices to say that the robot is deactivated after pressing the E-STOP button. Thus, in case of a collision—though ideally prior to that—you must press the E-STOP button.

Then, to release the brakes of joints 1, 2 and 3, press one of the two 0G buttons on the base of the robot continuously while holding the robot with your other hand. After 3 seconds, you will hear the deactivation of the brakes. Continue holding the 0G button pressed and move the robot as far as possible from obstacles. Finally, release the 0G button, and move away from the robot. Note that there is a pair of commands to disable and re-enable the brakes. These are described in the Programming Manual.

> **WARNING**
> In case of an emergency, it is relatively easy to force the robot brakes and move the robot's joint manually. However, forcing the brakes too often will damage the robot.

4.3 Functioning of the brakes

It is extremely important to remember that the robot has brakes on joints 1, 2 and 3 only. Therefore, when the robot is deactivated or powered off, the robot's end-effector will go down under the effects of gravity.

In addition, it is important to remember that the brakes used on joints 1, 2 and 3 are emergency brakes, not locking brakes. Therefore, if you leave the robot in a configuration where the robot's forearm is nearly horizontal, the robot will very slowly fall down under the effects of gravity (e.g., after several hours), especially if you have the maximum payload. Therefore, always deactivate the robot in a configuration that minimizes the static torques on joints 1, 2 and 3.

5 Technical specifications

Table 1 lists the main technical specifications of the Meca500 robot arm. Note that the maximum tool-center point (TCP) speed is software limited to 1,000 mm/s when the robot executes Cartesian-space motion commands, regardless of the definition of the TCP with respect to the robot's flange. However, if the robot is fully stretched and all joints move at maximum speed, due to a joint-space command, the TCP speed can surpass 2,000 mm/s.

WARNING

Note that in some special configurations, the robot's end-effector can move at 2,000 m/s or even faster. You must consider this fact in your risk assessment.

Figure 3 shows the main dimensions of the Meca500. Note that all joints are at zero degrees in the configuration drawn in black line. Also note that the gray zone is the area attainable by the center of the robot's wrist (the intersection point of the last three axes), for a fixed angle of joint 1. This area, or even the volume obtained by sweeping this area about the axis of joint 1 is NOT the workspace of the robot. The workspace of the robot is a six-dimensional entity depending on the definition of your tool reference frame. The workspace is the set of attainable poses (positions and orientations) of the tool reference frame with respect to the robot's base. Even for a specific choice of a tool reference frame, it is impossible to represent this six-dimensional workspace (read this tutorial of ours).

The CAD files of the Meca500 (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 Meca500, including Visual Components and RoboDK.

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 264 V at frequency between 50 Hz to 60 Hz.

Table 1: Technical specifications for the Meca500

Position repeatability	0.005 mm
Rated payload	0.5 kg
Maximum payload	1.0 kg (under special conditions)
Weight of robot arm	4.5 kg
Range for joint 1	$[-175°, 175°]$
Range for joint 2	$[-70°, 90°]$
Range for joint 3	$[-135°, 70°]$
Range for joint 4	$[-170°, 170°]$
Range for joint 5	$[-115°, 115°]$
Range for joint 6	$[-36,000°, 36,000°]$
Maximum speed for joint 1	150°/s
Maximum speed for joint 2	150°/s
Maximum speed for joint 3	180°/s
Maximum speed for joint 4	300°/s
Maximum speed for joint 5	300°/s
Maximum speed for joint 6	500°/s
Maximum TCP speed	1,000 mm/s
Max.imum power consumption	200 W
Input voltage	24 VDC
Operating ambient temperature range	[5 °C, 45 °C]
Operating ambient relative humidity range	$[10\%, 80\%]$ (non-condensing)
IP rating	IP 40

6 Installing the Meca500

You are surely eager to start using your Meca500. It is, however, imperative that you fix solidly the base of your robot arm before activating the robot. We typically use metric breadboards such as those from Thorlabs, but you can also use our adaptor plate for aluminum T-slotted framing, or even build your entire robot cell at Vention.

WARNING

Fix securely the robot's base via the mounting holes (Fig. 4a) with four M6 screws, on any flat surface of a rigid body.

Do not install any end-effector yet. We will cover this topic in Section 10.

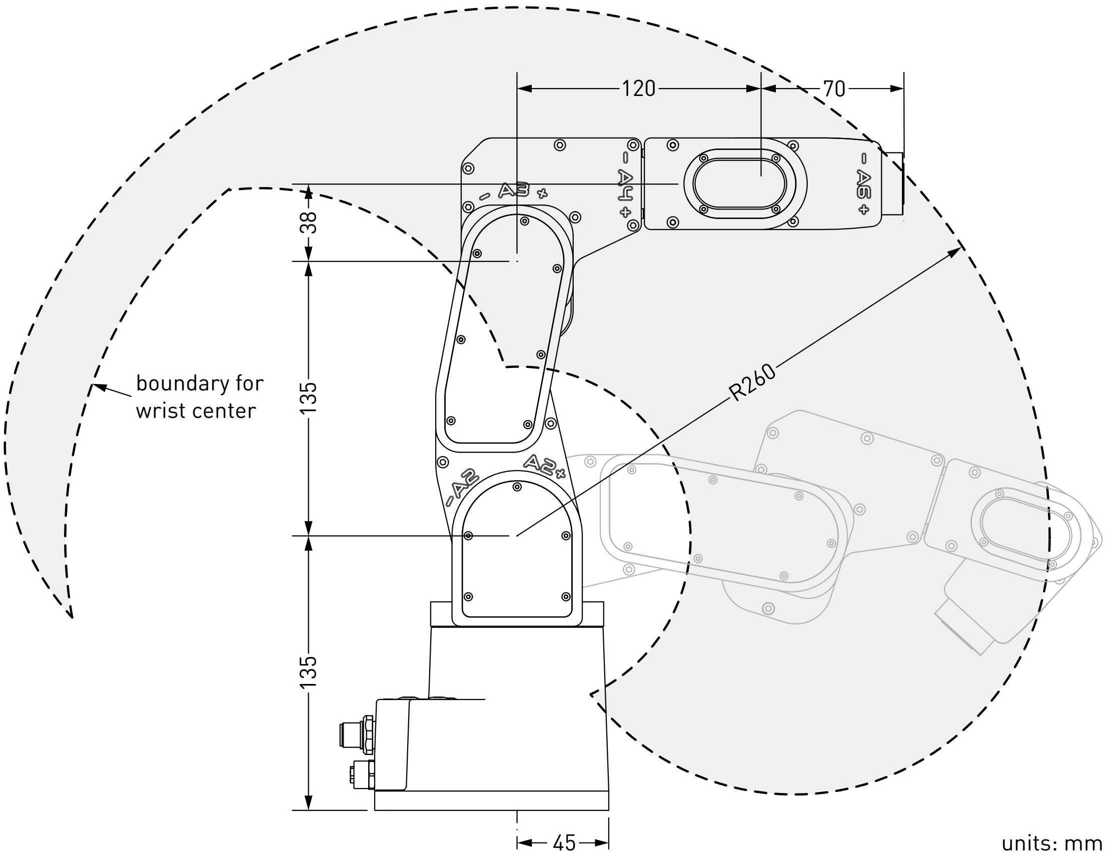


Figure 3: The dimensions of the Meca500

Note that the robot will automatically detect the angle between the axis of joint 1 and the gravity vector. Also, note that you can mount the robot's base on a mobile body (e.g., on the carriage of a linear guide), but only if you do not intend to move the robot's joints, while the robot's base is moving with respect to the ground.

Next, you must solidly attach the power supply using four M6 screws (Fig. 5), 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.

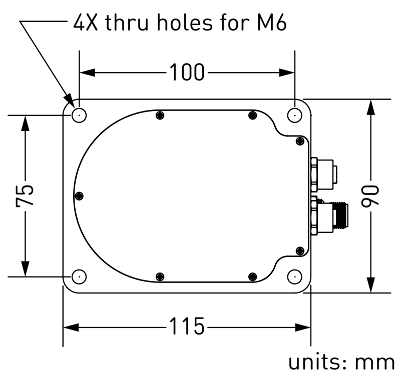
The following steps must then be executed before you can start using your Meca500:

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 (Fig. 4b-c). The two Ethernet ports on the robot's base act as a bridge, so you can daisy-chain several Meca500 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 (Fig. 4b-c). Make sure the connectors are completely screwed on both sides, or else you may damage the robot controller. Then, connect the power supply to your country-specific AC power cord (not provided by us). Only then, can you connect the AC power cord to an AC outlet, and, if not already done, switch the power supply on using its on/off button.

CAUTION

- Do not use any other power supply but the one provided, or else the warranty will be voided and the CE certification no longer valid.
- Always connect the DC power cable before connecting the power supply to an AC outlet.
- Always disconnect the power supply from the AC outlet (or switch it off) before disconnecting the DC power cable.
- Avoid un-plugging the DC power supply too often and always make sure both connectors are completely screwed.



(a) Dimensions

(b) Connectors

(c) Connectors properly attached

Figure 4: The base of the Meca500

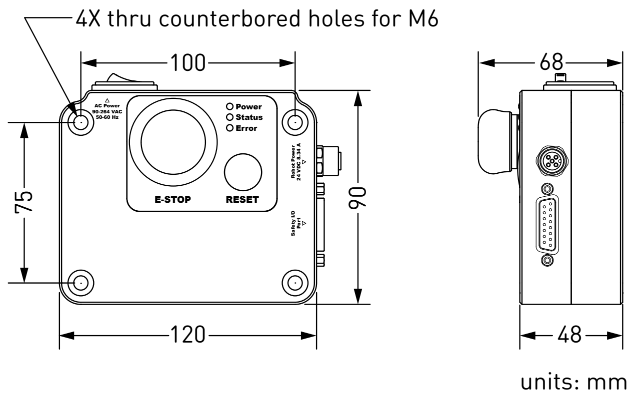
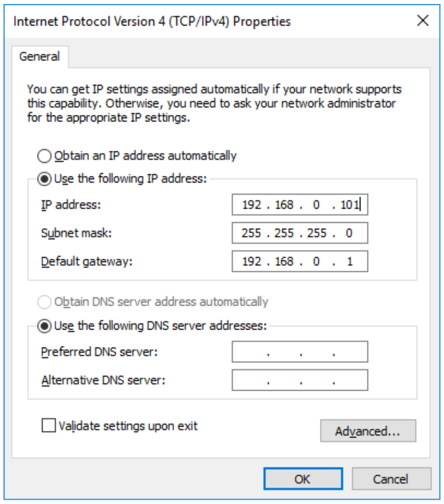


Figure 5: Dimensions of the power supply

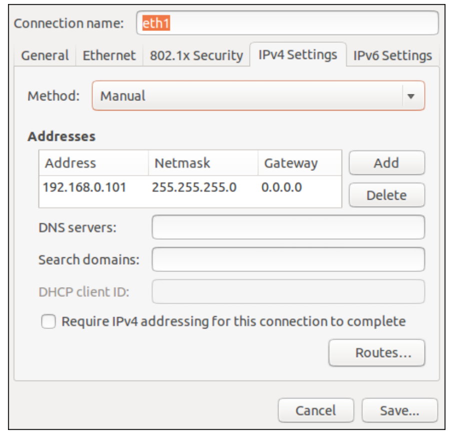
4. The green LED on the power supply (next to "Power") will be illuminated. Now, you must provide power to the robot by pressing the RESET button on the power supply.
5. You will hear a clicking sound coming from the power supply, and the robot's LEDs will start flashing for a few seconds while the robot's controller is booting. Once the controller ready, the red LED on the robot's base will start flashing intermittently.
6. Depending on which of the two Ethernet ports was used in step 1, the Link/Act IN (for ETHERNET1) or Link/Act OUT (for ETHERNET2) green LED should be illuminated. If it is not, detach the Ethernet cable and repeat step 1.
7. Configure your computer with a static IP address. The way to do this differs from one operating system to another. Figure 6 shows how to do this in Windows and in Linux.
8. Open (preferably) the latest version of Google Chrome and type Meca500's default IP address **192.168.0.100** in the address bar.
9. Meca500's web interface should load instantaneously. If it doesn't, repeat the previous step with a different browser.

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 8. Here is the procedure for doing so:

1. Click on the Options dropdown menu and then on Settings (Fig. 7).
2. Depending on your configuration, choose DHCP to automatically receive an address from your router or Static 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 Save button (Fig. 8).



(a) Windows



(b) Linux

Figure 6: Two examples of how to configure the IP address of your computer

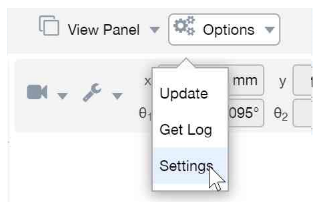
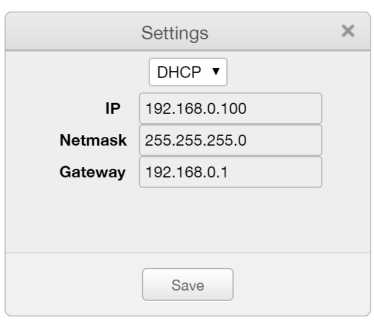
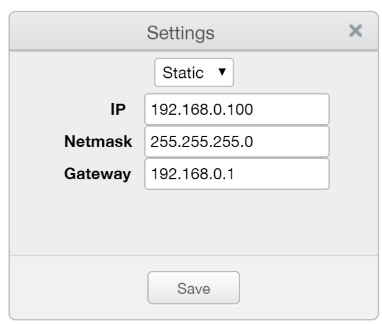


Figure 7: Options dropdown menu



(a) DHCP



(b) Static

Figure 8: Two ways to change the robot's network configuration

7 The web interface

Meca500's web interface 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 Google Chrome.

The interface basically translates your mouse clicks, joystick movements and keyboard entries into proprietary commands that are sent to the robot's controller. These are 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 web interface 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.

7.1 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. Go to the Downloads section of our web site and download the latest firmware (a zip file). Unzip it. Then, once you have followed the procedures of Section 6, and before activating the WebSocket/TCP connection on port 10,000 (i.e., before selecting the checkbox) and activating the robot, click on Update in the Options menu in the web interface (Fig. 7). A new interface will load in the same browser tab. Click on Choose File and select the file with the extension *.update that you just extracted. Then click on the Upload button. 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.

7.2 Overview

Figure 9 shows the main elements of the web interface. These are:

- The menu bar
- The programming panel
- The quick command panel
- The jogging panel
- The current joint set and TRF pose panel
- The 3D view window

You can hide the programming panel, the jogging panel and the quick command panel from the View Panel drop-down menu in the menu toolbar.

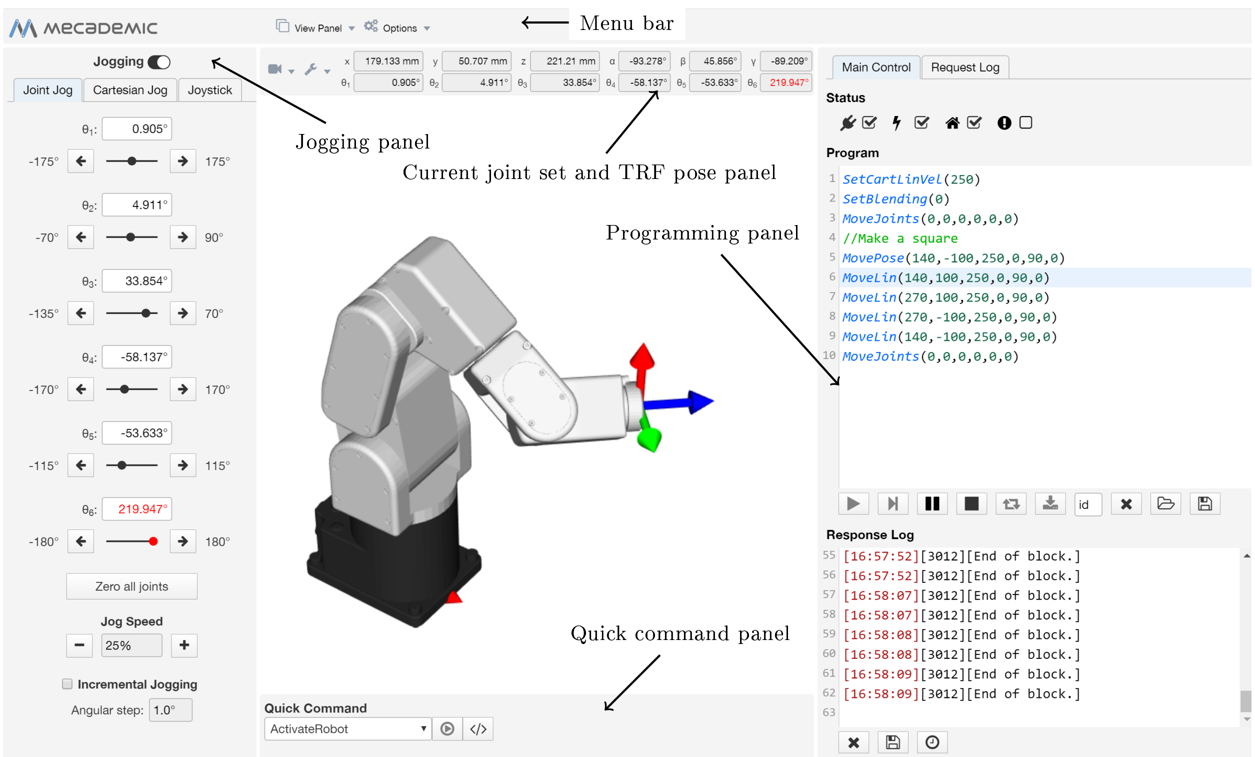


Figure 9: Overview of Meca500's web interface

7.3 The programming panel

The programming panel has two tabs: the Main Control and the Request Log tabs.

7.3.1 The status control checkboxes

Once the web user interface is loaded, the first step is to connect it to the robot. So far, you have only established an HTTP connection with the robot, but not activated the socket messaging which is the only communication channel for controlling the robot via the web interface. To connect to the robot, select the checkbox.

A pop-up window will be displayed with two radio buttons. For now, leave the Control radio button selected. The Monitoring option can be used to see in real-time the motion of the robot when another client (other than the web interface, e.g., Matlab running on the same PC) is controlling the actual robot.

Next, you need to activate the robot by selecting the checkbox. Once, the robot is activated, you need to home it by selecting the checkbox. During homing, all joints rotate slightly for approximately 4 seconds.

CAUTION
Before homing, make sure that there is no risk for mechanical interference.

Finally, whenever you have a motion error, the checkbox will become selected and red. To reset the error, you will need to clear the checkbox (or press the ▶ below the Program field, as we will explain later).

7.3.2 The program editor field

The program editor is used mainly for writing and executing very 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 editor 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).

The control buttons bellow the editor field have the following functionality:

- ▶ Execute the complete program.
- ⏭ Execute the command where the cursor is, and move the cursor to the next line.
- ⏸ Hold motion (pauses the robot and keeps the current program; motion is restarted with the same button, when it becomes red).
- ■ Clear motion (stops the motion and clears the command queue).

- Loop the program.
- Save the program in the robot for offline execution (Section 8.4), with the id number defined in the number field on the right of this button, only when the robot is deactivated.
- Delete all entries in the program editor field.
- Open an existing program.
- Save the contents of the program editor field to a file.

In the event of a motion error, the ▶ button changes to ❗ and all other buttons on the same row are disabled. Pressing ❗ resets the error.

In addition, you can use the keyboard shortcut Ctrl+Enter, instead of the ⏭ button.

Finally, an important feature of the programming editor is the context menu called by pressing the right mouse button when the mouse cursor is over the programming editor (Fig. 10). Essentially, this gives us access to inserting all available commands at the current position of the cursor in the programming editor. This functionality is quite similar to the quick command menu, with a few differences. The only major difference is the possibility to insert the commands MoveJoints, MoveLin, and MovePose with the current joint set or end-effector pose.

To cancel the context menu without inserting a command, press Esc or click away.

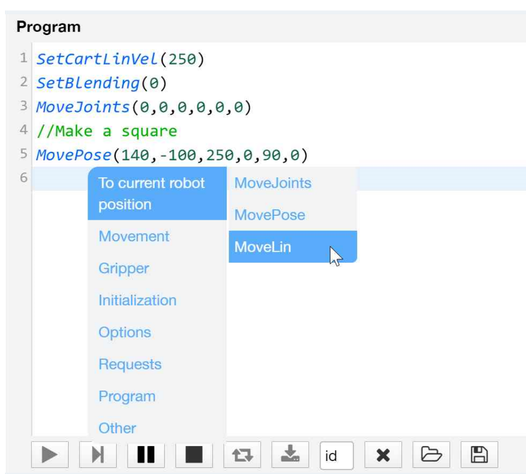


Figure 10: Context menu in the programming editor

7.3.3 The Response Log field

The log field displays all the messages that are sent by the robot. The control buttons associated with this field are self explanatory:

- ✖ Clear the log.
- 🖫 Save the log.
- 🕘 Show/hide timestamp for each message.

7.3.4 The Request Log

The request log is the log of all commands sent to the robot, by using the programming panel, the quick command panel, or the jogging panel. The only commands that are not logged are the velocity-mode motion commands sent while jogging the robot.

7.4 The robot joint set and end-effector pose panel

Once the robot is activated and homed, you will be able to see its current joint values as well as the current pose of the *TRF* (*Tool Reference Frame*) with respect to the *WRF* (*World Reference Frame*). The TRF and WRF are those defined by the user, but not necessarily in the programming editor or the quick command field. For example, you can connect to your robot and change these two reference frames from a PLC, and then connect your browser to the robot. The TRF and WRF are shown in the 3D view window (the x-axes are in red, the y axes are in green, and the z axes are in blue). You can show or hide these two reference frames from the 🔧 drop-down menu.

Finally, you can choose between several preset views for the 3D view window from the 📹 drop-down menu.

7.5 The 3D view window

The 3D view window shows an orthographic projection of the robot in its current position and the current WRF and TRF. 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 left mouse button inside the 3D view window, hold it down and drag the mouse. To change the view angle along a different choice of two axes, press the left and right mouse buttons inside the 3D view window, hold them down and drag the mouse. Finally, to pan, press the mouse wheel inside the 3D view window, hold it down and drag the mouse.

7.6 The Quick Command panel

The drop-down list in the quick command panel has all proprietary commands supported by the Meca500. If a command selected has arguments, additional numerical fields will appear.

Once these fields are filled in correctly, you can either execute the command by pressing the button or insert it in the programming editor at the last cursor position by pressing the </> button.

7.7 The jogging panel

The jogging panel is used to *jog* (move) the robot in several different ways. 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 toggle switch is used to activate or deactivate the jogging functions. It is important to understand that activating the jogging deactivates the execution of commands from the quick command panel and the programming editor, and vice versa, for safety reasons. Furthermore, when jogging is activated, the robot speed is reduced to 50%, again for safety reasons. You can also activate/deactivate jogging with the shortcut Alt+T.

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

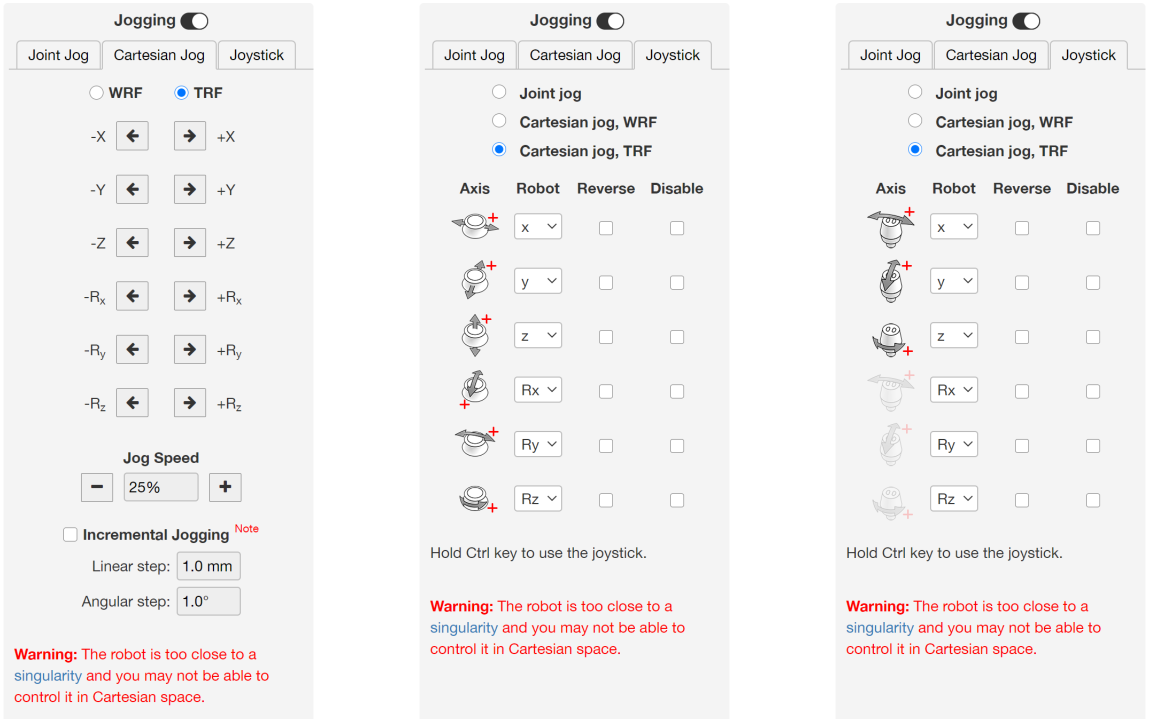
7.7.1 The Joint Jog tab

In the Joint Jog tab (Fig. 9), you can rotate each joint separately using the arrow buttons (🡐 or 🡒), or you can enter a joint value directly. When a joint value is too close to its limit, the corresponding slider as well as the the joint value in both the joint jog tab and the robot posture panel becomes red. While joint 6 is limited to ±100 rotations, its normal operational range is limited to only ±180°. Specifically, a Cartesian motion command can be executed only if joint 6 is in the ±180° range and can remain in that range throughout the whole motion. Therefore, as soon as joint angle 6 becomes outside the ±180° range, the slider of joint 6 and the joint angle value will become red.

For convenience, a Zero all joints button is provided that sets all joint angles to zero. Note, however, that this joint set corresponds to a singularity. If the robot is in a singular configuration, you will not be able to jog it in the Cartesian Jog panel.

You can also select the jog speed from a list of preset percentage values using the "+" and "−" buttons, or positioning your mouse over the jog speed textfield and using your mouse wheel. The jog speed can also be selected in the Cartesian Jog tab (there is an identical jog speed selector). The jog speed selected has effect even when the Joystick tab is active.

Finally, selecting the Incremental Jogging checkbox allows you to inch with predefined angular steps (from 0.001° to 5.000°). However, in incremental jogging, if a joint reaches a limit, a motion error is generated and jogging is disabled. You will need to reset the error and re-enable jogging if you want to continue jogging the robot.



(a) Cartesian jog tab

(b) Joystick tab (in case of 3DConnexion's SpaceMouse)

(c) Joystick tab (in case of Mecademic's MJ3 joystick)

Figure 11: The Cartesian jog and joystick tabs

7.7.2 The Cartesian Jog tab

In the Cartesian Jog tab (Fig. 11a), you can move the robot along (by pressing the X, Y, or Z arrow buttons) or about (by pressing the Rx, Ry, or Rz arrow buttons) the axes of the TRF (if the TRF radio button is selected) or along or about the axes of a reference frame having the same orientation as the WRF but with origin at the TCP (if the WRF radio button is selected).

As in the Joint Jog tab, you can select the jog speed and choose to jog both continuously and incrementally. For the incremental jogging, you can choose both a linear step (from 0.001 mm to 5.000 mm) and an angular step (from 0.001° to 5.000°). However, in Cartesian incremental jogging, we cannot guarantee that the actual step will be exactly as specified. If the robot is close to a singularity or to a joint limit, the actual step will be smaller or even zero and there will be a motion error, unlike when jogging in continuous mode. You will need to reset the error and re-enable jogging if you want to continue jogging the robot.

NOTICE

Note that in Cartesian jog, when reorienting the end-effector using the Rx, Ry and Rz arrow buttons, you do not modify independently each Euler angle, but rather rotate the TRF about axes passing through its origin (the TCP) and coincident with its x, y or z axes, if the TRF option is chosen, or parallel to the x, y or z axes of the WRF, if the WRF option is chosen.

Finally, when the robot is close to a singularity (no matter if incremental jogging is enabled or not), a warning will be displayed at the bottom of the panel.

7.7.3 The Joystick tab

Instead of using your mouse to jog the Meca500, you can also use the SpaceMouse® 6-axis mouse from 3Dconnexion (Fig. 12a) or our own MJ3 3-axis USB joystick (Fig. 12b). To use the SpaceMouse or the MJ3, you need to have the jogging enabled and the Joystick tab selected. For the web interface to detect the SpaceMouse or the MJ3, you will need to press one of the device's buttons or, occasionally, unplug and replug the device. Once the SpaceMouse or the MJ3 is detected, you will see the table of menus shown in Fig. 11b or Fig. 11c.

(a) SpaceMouse® (wireless model)

(b) MJ3

Figure 12: The SpaceMouse® wireless 6-axis mouse from 3Dconnexion and the MJ3 3-axis USB joystick from Mecademic

NOTICE

Do not install the driver and the software that come with the SpaceMouse as these will interfere with the desired functioning of the device. Also, if you opt for the wireless model, keep the device very close to the Universal USB Receiver and remember to recharge the device's battery regularly. Finally, note that if the web interface detects both a SpaceMouse and an MJ3, it will select the MJ3.

NOTICE

The MJ3 joystick must be used with its cable on the left, or else the directions shown in the icons of the Joystick tab (Fig. 11c) will be wrong.

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. Note that the choice of jogging mode is shared among the three jogging tabs. For example, if you choose Cartesian jog with respect to the TRF in the Joystick tab and then switch to the Cartesian Jog tab, the TRF radio button will be automatically selected, and vice versa.

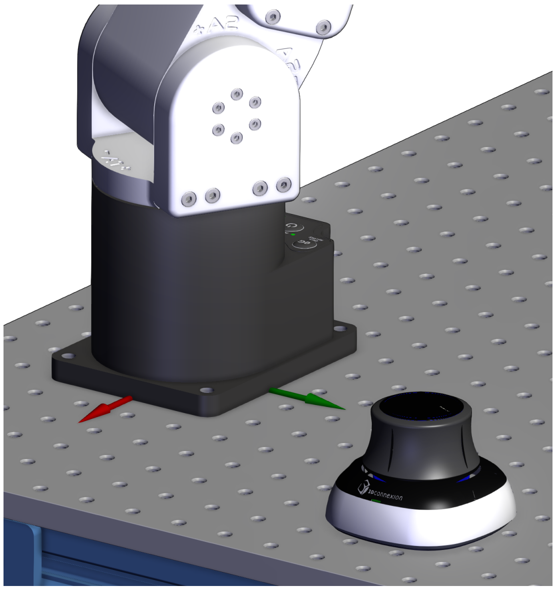
It takes some practice to become comfortable with using all six axes of the SpaceMouse at once. Until then, you should better use only three axes at a time (either translations or rotations). To select between all six axes (by default), translations only or rotations only, press (up to two times if necessary) the left button of the SpaceMouse until the desired selection is obtained. Alternatively, you can disable any of the device axes directly from the joystick menu (by selecting the checkboxes under Disable).

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

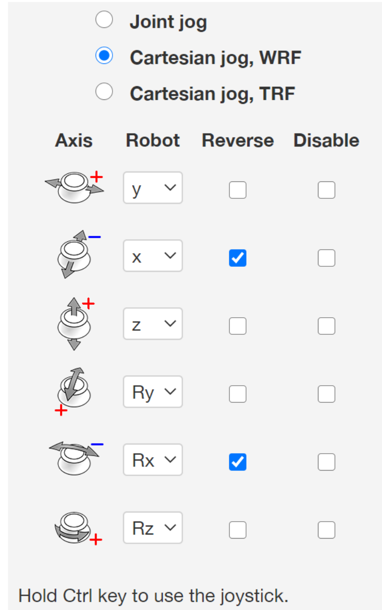
Finally, for a particular installation of your Meca500 and a particular choice of TRF and WRF, you might feel more comfortable reassigning the mapping between the axes of the SpaceMouse or of the MJ3 and the robot degrees of freedom (instead of physically reorienting your joystick). An example in the case of the SpaceMouse is shown in Fig. 13.

7.8 Opening and closing the MEGP 25E gripper

Finally, later, when you have installed our MEGP 25 gripper, you can open and close it with the shortcut Alt+G, as long as the robot is homed and the web interface connected to the robot.



(a) Particular installation and WRF choice



(b) Joystick tab with new mapping

Figure 13: Changing the mapping for the joystick axes

8 Operating the robot

8.1 Power-up procedure

If you have read Sections 6 and 7 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.

8.1.1 Powering the robot

- Turn the power supply on.
- Make sure that the E-STOP button on the power supply is released (by twisting it counterclockwise) and press the RESET button, next to it.
- Wait a couple of seconds.

8.1.2 Connecting to the robot

- Connect to the robot's web interface.
- Click the 🔌 checkbox in the Main Control tab.

- Select the Control option and click Connect.
- As soon as the robot is connected, you will get the following welcome message in the log panel: [3000][Connected to Meca500 x_x_x.x.x], where the x's are numbers.

8.1.3 Activating the robot

- Select the ϟ checkbox, in the Main Control tab **OR** type in the programming text field `ActivateRobot` and click the ▶ button.

You will hear a distinctive clicking sound.

8.1.4 Homing the robot

- Select the 🏠 checkbox in the Main Control tab or erase `ActivateRobot`, type `Home` and click the ▶ button in the programming panel.

CAUTION
The robot will move slightly during homing. Before homing it, make sure that there is no risk for mechanical interference.

8.2 Moving the robot

A six-axis robot arm is a complex mechanism and no matter how intuitive its programming interface is, the robot will still have limits. These limitations are not always obvious. For example, in any six-axis robot arm, there are often paths that the robot cannot follow, even though they seem to be inside the robot's workspace. Never forget that the workspace of a general six-axis robot is a very intricate six-dimensional entity, not just a sphere.

NOTICE
If you know nothing about orientation representations and robot singularities, we strongly advise you to read some introductory notes on robotics and our tutorials on Euler angles and on robot singularities.

After homing, click the Zerro All Joints button in the Joints Jog tab on the left. The robot will move all of its joints to their 0° positions. In this robot joint set (shown in Fig. 9), the robot is in a so-called *wrist singularity* and you will not be able to move it in Cartesian space (e.g., by jogging). The simplest way to exit this singularity is to jog joint 5, but here is another, more interesting way. Move the robot's end-effector to the pose $x = 250$ mm, $y = 0$ mm, $z = 150$ mm, $\alpha = 0°$, $\beta = 90°$, $\gamma = 0°$.

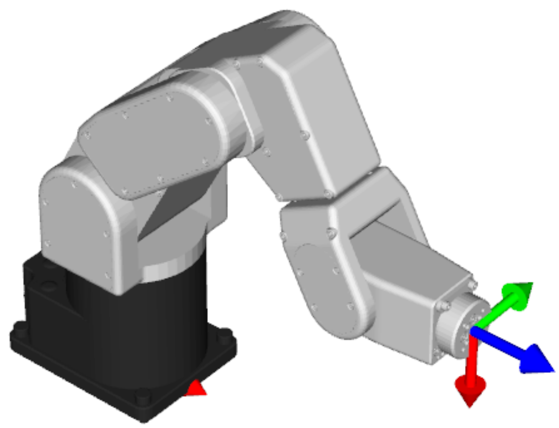


Figure 14: Robot posture when its TRF is at $x = 250$ mm, $y = 0$ mm, $z = 150$ mm, $\alpha = 0°$, $\beta = 90°$, $\gamma = 0°$ with respect to its WRF

NOTICE

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 flange of the robot and the WRF at the bottom of the robot's base. The origin of the TRF is called the *TCP* (*Tool Center Point).*

NOTICE

We use Euler angles (α, β, γ) to define the orientation of a second reference frame with respect to a first one. More specifically, if we consider both frames initially coincident, we rotate the second frame about its x axis at α degrees, then about its y axis at β degrees, and finally about its z axis at γ degrees.

You can move the robot to the new end-effector pose following these steps:

- Clear the programming text field, type `MovePose(250,0,150,0,90,0)`, and press ▶.

  OR

- In the quick command panel, select `MovePose`, fill in the arguments with the values 250, 0, 150 , 0, 90, and 0, and click on ⦿.

Figure 14 shows the resulting robot posture.

You can now jog the robot in both joint and Cartesian space. Note that when a joint reaches its limit while jogging, the robot stops but no message is displayed in the response log. Furthermore, if you jog the robot in Cartesian space, you can also run into singularities and no longer be able to jog in certain directions. No error message will appear in the response log, but a warning will be displayed in the Cartesian Jog tab.

8.3 Power-off procedure

8.3.1 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 arguments equal to 0

  OR

- click on the Zero All Joints button in the Joints Jog panel.

8.3.2 Deactivating the robot

To deactivate the robot

- clear the checkbox

  OR

- send the `DeactivateRobot` command via the programming editor or via the quick command panel.

CAUTION
Recall that there are no brakes on joints 4, 5 and 6. As soon as you deactivate the robot, the end-effector will slowly tilt down under the effects of gravity.

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

8.3.3 Disconnecting the robot

To disconnect the robot, clear the checkbox.

WARNING
If you disconnect the robot before deactivating it, the robot will continue to move (if it was moving), even if you close the web interface.

8.3.4 Removing power

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

CAUTION
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.

8.4 Offline mode

You can store an offline program in the robot and execute it without an external computer. This program is kept, even after power off, until replaced by another one. You can save up to 500 programs, but only the first one can be executed from the robot control panel.

8.4.1 Saving the program via the web interface

- To save a program via the buttons on the web interface, the robot must be deactivated, i.e., the ⚡ checkbox must be cleared.
- Write the program in the programming editor.
- To run the program on infinite loop, insert the command `SetOfflineProgramLoop(1)`. (The 🔁 checkbox has no effect on the execution of the offline program.)
- Enter 1 as the program id number in the entry field next to the 📥 button.
- Click on the 📥 button.

8.4.2 Running an offline program

To execute the offline program 1, make sure there is no user connected to the robot and press the Start/Pause button on the robot base. The Start/Pause LED will flash rapidly for three seconds, after which the robot will start executing the program.

WARNING
Immediately after pressing the Start/Pause button on the robot's base, move away your hand and stay outside the robot's reach.

Figure 15: Robot control panel

8.5 Robot control panel

The set of buttons and LEDs on the robot's base is called the robot's control panel (Fig. 15). The meanings of the LEDs and the functionalities of the buttons will be summarized bellow.

8.5.1 LEDs

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

Power LED

The Power LED is red and indicates the activation state of the robot:

- the LED will flash slowly when the robot is deactivated;
- the LED will flash fast when the robot is being activated;
- the LED will be lit continuously when the robot is activated.

Home LED

The Home LED is yellow and indicates the homing state of the robot:

- the LED will be off when the robot is not homed;
- the LED will flash slowly when the robot is being homed;
- the LED will be lit continuously when the robot is homed.

Start/Pause LED

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

- the LED will flash fast when the Start/Pause button was pressed and the program saved in the robot is about to start;

- the LED will be off when the robot is not moving;
- the LED will be lit continuously when the robot is moving.

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
Used only when the robot is controlled via EtherCAT (see the Programming Manual).

Finally, when the robot is in error mode, the Power, Home and Start/Pause LEDs flash fast simultaneously. Also, if you keep the Power button pressed continuously during power-up, which provokes a network reset of the robot, the Power, Home and Play LEDs, will first flash simultaneously eleven times, and then blink several times sequentially.

8.5.2 Buttons

The buttons on the control panel are active only when no user is connected to the robot, except for the 0G button, which is always active. In what follows, you must refer to the detailed descriptions of the commands associated with each button.

> **WARNING**
> When pressing the buttons on the robot's control panel, keep your fingers away from the pinch points of the robot, and move away from the robot as soon as a button is released.

Power button
The Power button acts as the `ActivateRobot` and `DeactivateRobot` commands:

- when the robot is deactivated, pressing Power will send the `ActivateRobot` command;
- when the robot is activated, pressing Power will send the `DeactivateRobot` command;
- when the robot is in error mode, pressing and holding Power for five seconds will send the `DeactivateRobot` command.

Pressing and holding Power during power-up will reset the robot network configuration.

Home button
The Home button acts as the `Home` and `ResetError` commands:

- when the robot is deactivated, pressing Home has no effect;
- when the robot is activated, pressing Home sends the `Home` command;

- when the robot is homed, pressing Home has no effect;
- when the robot is in error mode, pressing and holding Home for five seconds will send the `ResetError` command.

Start/Pause button

The Start/Pause button on the robot control panel acts as the `StartProgram`, `PauseMotion`, `ResumeMotion`, and `ClearMotion` commands:

- when the robot is activated, homed and not executing a program, pressing Start/ Pause will send the `StartProgram(1)` command three seconds after being pressed;
- when the robot is activated and homed, pressing Start/Pause will send the `ClearMotion` command, whether the robot is moving or not;
- when the robot is activated, homed and moving, pressing Start/Pause will send the `PauseMotion` command;
- when the robot is activated, homed and stopped (by the `PauseMotion` command), pressing Start/Pause will send the `ResumeMotion` command.

0G button

Pressing and holding the 0G button for three seconds, once the robot is deactivated, will release the brakes. While keeping 0G pressed with one hand, you can manually move the robot with your other hand. The brakes will reengage as soon as the 0G button is released.

CAUTION

Once the robot is deactivated, hold the robot with one hand, before pressing the 0G button. Otherwise, the robot may fall down under the effect of gravity.

9 Operating the intelligent power supply

Mecademic's intelligent power supply is shown in Fig. 16. As already explained, release all emergency stops and the external protective stop 2, and then press the RESET button to provide power to the robot. Once the robot is activated and homed, pressing the E-STOP button 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. Without power, the robot's brakes are instantly applied to joints 1, 2 and 3.

To restart the robot, you must release the emergency stops or the external protective stop 2, and press the RESET button. Next, you need to connect to the robot via Ethernet

TCP/IP, EtherNet/IP, or EtherCAT, activate the robot, and finally home it. Of course, you will also need to manage the stream of commands being sent to the robot. For example, if a PLC sends commands to the robot, while the robot is powered off, the program that runs on your PLC will need to be able to detect and manage this situation. To do so, you can get a signal from the intelligent power supply that power to the robot has been cut by connecting your PLC to the D-SUB connected, as will be explained in the following pages.

9.1 LEDs

The power supply is equipped with three LEDs. As long as the power supply is switched on (using the on/off button shown in Fig. 16b) and connected to an AC source that supplies voltage at 90–264 V at frequency of 50–60 Hz, the green LED next to “Power” stays illuminated. Supplying AC voltage outside this range may damage the power supply.

Once the power supply is switched on, the yellow Status LED indicates the status of the power supply. If the yellow LED is off, you need to press the RESET button, which sends power to the robot. If the proper Meca500 is correctly connected to the power supply, the yellow LED will turn on and stay lit.

If, in any situation, the yellow LED blinks regularly, this means that an emergency stop (either the one on the power supply or the external one) or the external protective stop 2 is activated. You need to release the emergency stop or remove the cause for the protective stop 2 and then press the RESET button.

(a) front view (b) back view

Figure 16: The intelligent power supply

If the yellow LED illuminates in sets of two flashes, this means that the integrated or external RESET button has been pressed too long. Make sure they are not pressed and then press any of them, in a quick fashion.

Finally, the red Error LED indicates if there is a problem with the power supply or with some of the connections to the D-SUB interface. If the red LED flashes (0.1 s on, 0.9 s off), either there is no robot connected to the power supply or the robot connected is an old version that is not supported by this power supply. If the red LED illuminates in sets of two quick flashes, the robot has detected a problem and sent a request to the power supply to be shut down. If this happens, contact us. If the red LED blinks in regular intervals (0.5 s on, 0.5 s off), this means that there is either a problem in your external emergency stop or Stop Category 1 connections or in our power supply. If you don't see any problem in your connections, contact us. Finally, if the red LED is constantly lit, there is a problem with the power supply. Switch off the power supply and contact us.

Table 2 summarizes the different states of the three LEDs as well as their meanings.

Table 2: The various states of the LEDs on the power supply

LED	**Name**	**LED state**	**Explanation**
Green	Power	Off	The power supply is turned on
		On	The power supply is turned off
Yellow	Status	Off	Robot is not powered. Press RESET.
		Blinking	Robot is not powered and a Stop Category 1 stop is pressed or the dongle is not plugged in. Remove the stop, make sure the dongle is plugged in, and press RESET.
		Two flashes	Robot is not powered because a RESET button has been pressed for too long. Press RESET again.
		On	Robot is powered.
Red	Error	Off	There is no error.
		Flashes	No proper robot connected.
		Two flashes	Robot has detected a problem and requested that power be shut down. Contact Mecademic.
		Blinking	Problem with Stop Category 1 stops detected. Check external stop connections and contact Mecademic if no solution found.

9.2 External connections

If you do not need to connect an external E-Stop, an external reset, or protective stops or be able to know whether the robot is powered, you need to plug the D-SUB 15-position dongle in the power supply. Otherwise, even if you only need to connect a single external E-Stop, you need to properly wire the rest of the connections in the D-SUB connector.

Figure 17 shows the pinout of the D-SUB 15-position connector on the power supply and gives a generic example for all connections. As already mentioned, you can connect:

- one external Stop Category 1 emergency stop (connections E-Stop – A1, E-Stop – B1, E-Stop – A2, E-Stop – B2);
- one Stop Category 1 protective stop (connections P-Stop 1 – A1, P-Stop 1 – K1, P-Stop 1 – A2, P-Stop 1 – K2);
- one reset button (connections Reset – A, Reset – K);
- one power status indicator (connections Power Status – A, Power Status – B);
- one Stop Category 2 protective stop (connections P-Stop 2 – A, P-Stop 2 – B).

Note that the external circuits shown in Fig. 17 are only suggestions. You may, for example, connect several external E-Stops in series, or instead of sending a signal to a PLC when the power to the robot is cut, you may connect a LED between the resistor and the Power Status – A line. Figure 18 shows several other examples. Specifically, Fig. 18a shows how to control the protective stop 1 from a PLC by supplying a 24 V DC signal. Figure 18b shows how to reset the power supply from a PLC. Figure 18c shows that you can supply a 12 mA continuous forward current to pins 4 and 5 if you do not want to use the protective stop 1. Lastly, Fig. 18d shows that you need to short-circuit pins 1 and 9, and pins 2 and 10, if you do not intend to use an external E-Stop.

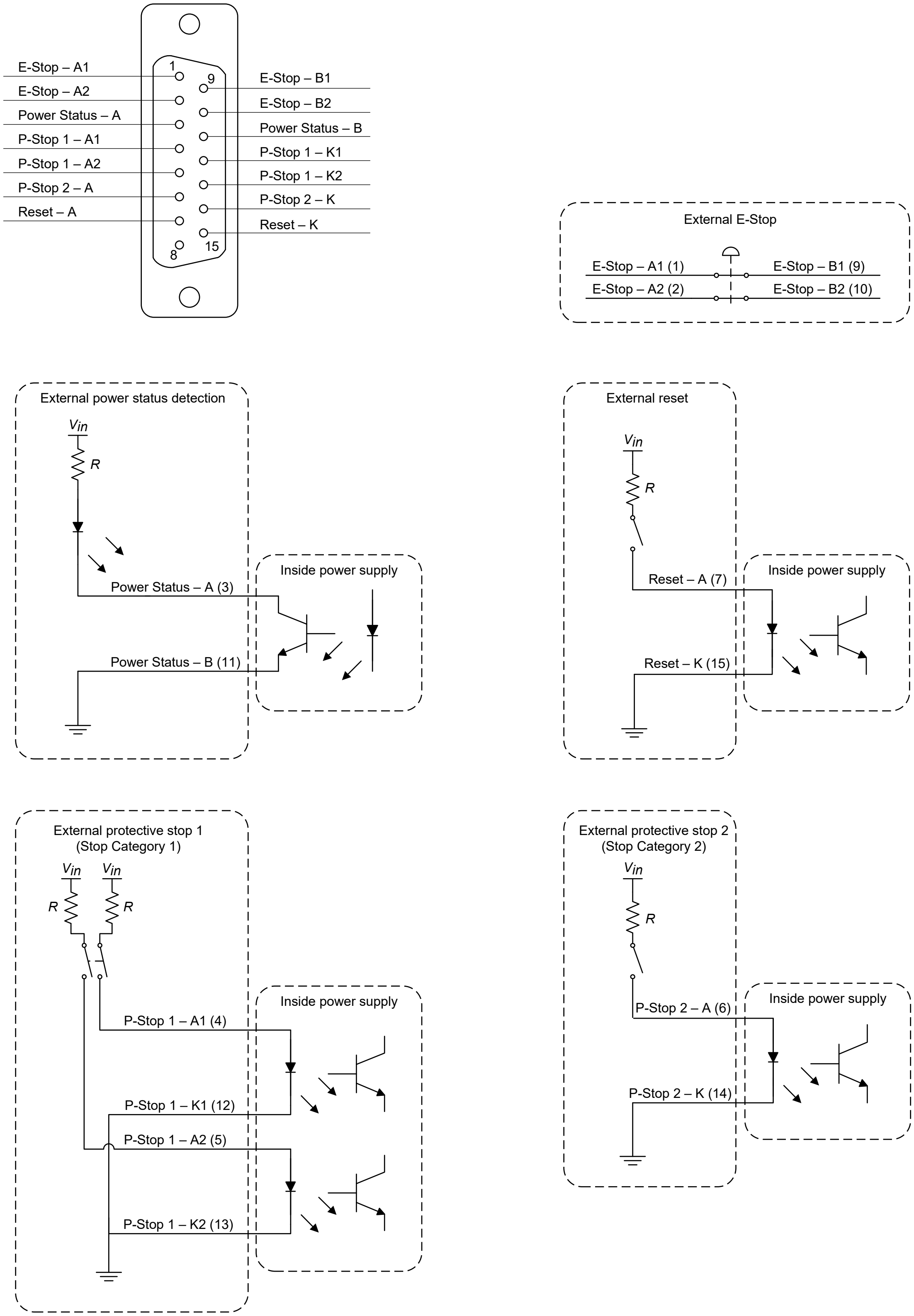
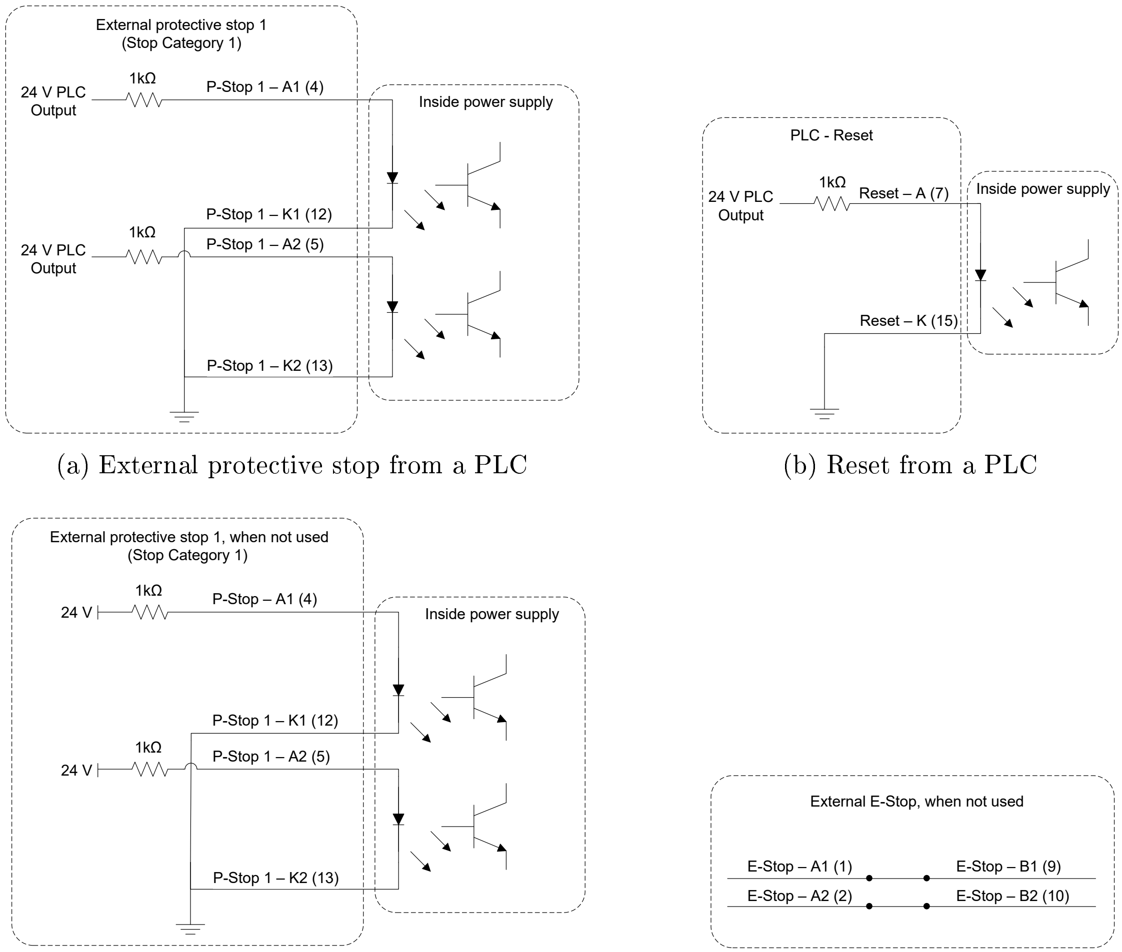


Figure 17: Electric diagram of suggested generic connections to the D-SUB connector



(a) External protective stop from a PLC

(b) Reset from a PLC

(c) External protective stop 1 not used

(d) External E-Stop not used

Figure 18: Additional examples of connections to D-SUB connector

10 Installing an end-effector

The Meca500 comes with a proprietary tool I/O (input/output) port located at the robot extremity (Fig. 19a). However, this tool port is reserved uniquely for our electric gripper MEGP 25E and our pneumatic module MPM500. We do not share the pinout of this port or its custom-made communication protocol. To install our gripper, refer to its User Manual.

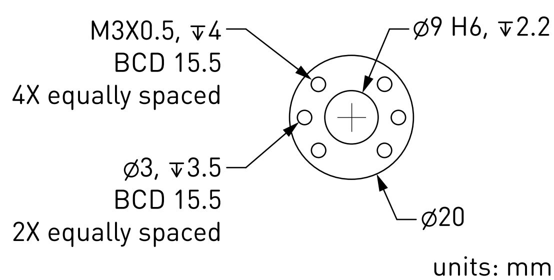
If you want to use any other end-effector with the Meca500, you will need to control it independently from the Meca500. You can attach the cabling of your end-effector along the robot arm using adhesive-backed tie mounts. Finally, you must fix the end-effector to the robot's flange (Fig. 19b) using four M3 screws and, optionally, one ⌀3 locating pin, all of properly selected length. The following rules should be respected:

WARNING

- Keep the robot un-powered while installing/removing a tool to its flange.
- Do not overpass the robot payload (0.5 kg).
- Securely fasten the tool to the robot flange.

Note that since joint 6 is multi-turn, there is no way of knowing the angle of joint 6 (even approximately), unless the robot is activated and homed. Therefore, prior to mounting an end-effector, it is important that you activate and home your robot, rotate joint 6 to its zero position, and finally unpower the robot. However, if the screw on the flange of the robot is not as in Fig. 19b when $\theta_6 = 0°$, then you need to follow the procedure described in the subsection Homing of the Programming Manual.

(a) Closeup



(b) Dimensions

Figure 19: The mechanical interface (flange) of the Meca500. The flange is the ⌀20 disk, inside the black isolation ring, and is the only one to rotate when joint 6 rotates.

CAUTION

- Make sure that joint 6 is approximately at 0° before attaching an end-effector.
- Do not over-tighten the M3 screws.
- Attach the tool cabling in such a manner that it obstructs as little as possible the motions of the robot.
- Unless you plug the connector of our own gripper, keep the cover (screw cap, not shown in Fig. 19a) of the tool I/O port in place at all times.

11 Examples

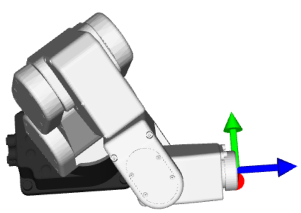
11.1 Draw a square

Here is an example of a very simple program.

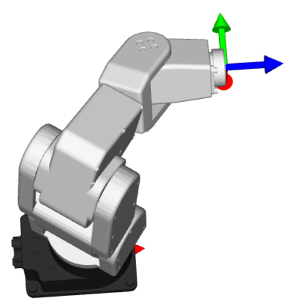
Listing 1: Square path with the MoveLin command

```
ActivateRobot
Home
MovePose(140, -100, 250, 0, 90, 0)
MoveLin(140, 100, 250, 0, 90, 0)
MoveLin(270, 100, 250, 0, 90, 0)
MoveLin(270, -100, 250, 0, 90, 0)
MoveLin(140, -100, 250, 0, 90, 0)
MoveJoints(0, 0, 0, 0, 0, 0)
```

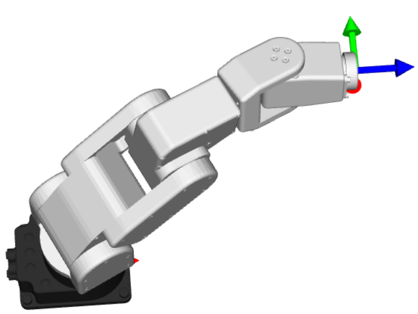
Figure 20 shows the result of each of the first four motion commands.



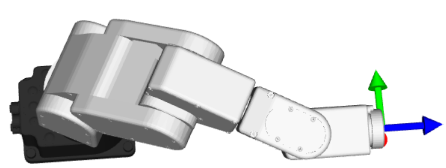
(a) `MovePose(140,-100,250,0,90,0)`



(b) `MoveLin(140,100,250,0,90,0)`



(c) `MoveLin(270,100,250,0,90,0)`



(d) `MoveLin(270,-100,250,0,90,0)`

Figure 20: The four separate robot positions that define the motion sequence

12 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 the EtherCAT mode has not been enabled. To switch the robot back to Ethernet TCP/IP mode, the simplest way is to do a factory reset. This can be done by unplugging the power supply from the AC side, and then replugging it while holding the Power button on the robot's base for about ten seconds.
- 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:

$$\begin{aligned} Robot &: IP = 192.168.0.100,\ netmask = 255.255.255.0,\ gateway = 192.168.0.1 \\ Computer &: IP = 192.168.0.101,\ netmask = 255.255.255.0,\ gateway = 192.168.0.1 \end{aligned}$$

- If you are using DHCP, make sure to verify the robot's IP address through 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) using the following sequence:
  1. Power off the robot (e.g., by hitting the E-Stop on the power supply).
  2. Press the Power button on the robot base while powering on the robot (i.e., pressing the RESET button on the power supply) and keep the Power button pressed for about ten seconds until the red LED and the yellow LEDs on the robot base start to blink sequentially.

CAUTION
Never disassemble the robot. The robot requires no maintenance, and if you think it is damaged, stop using it immediately and contact us.

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

Whenever you contact our support team, please provide the serial number of your robot and the sequence of numbers displayed after "Meca500 R3" in the welcome message that appears in the log panel upon connection with the robot: [3000][Connected to Meca500 R3 v8.x.x]. This is the firmware version installed on your robot. You can also get that number by executing the command `GetFwVersion`.

13 Storing the robot in its shipping box

To put the Meca500 back into the foam insert of its original shipping box, send the command `MoveJoints(0,-60,60,0,0,0)`. Recall that you must never force the brakes on joints 1, 2 and 3, unless there is an emergency.

14 EC Declaration of Incorporation (original)

According to the European Commission's Machinery Directive 2006/42/EC, Annex II, Section 1B

The manufacturer	Mecademic Inc. 1300 Saint-Patrick St Montreal, QC H3K 1A4 Canada

hereby declares that the product described below

Product designation:	Extra-small six-axis industrial robot Meca500
Type:	Meca500-R3

meets the applicable basic safety requirements of the Machinery Directive 2006/42/EC. This partly completed machinery may not be put into operation until conformity of the machine into which it will be incorporated is declared in conformity with the provisions of the Machinery Directive 2006/42/EC, and with the regulations transposing it into national law. Compliance with all essential requirements of Directive 2006/42/EC relies on the specific robot installation and the final risk assessment.

The manufacturer agrees to forward on demand the relevant technical documentation, compiled according to Directive 2006/42/EC, Annex VII, Part B, to state authorities.

Additionally the manufacturer declares the product in conformity with the following directives, according to which the product is CE marked:

- 2014/30/EU — Electromagnetic Compatibility Directive (EMC)
- 2011/65/EU — Restriction of the use of certain hazardous substances (RoHS)

Person responsible for the documentation: Dr. Ilian Bonev.

Ilian Bonev

Montreal, QC, Canada
June 15, 2020

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