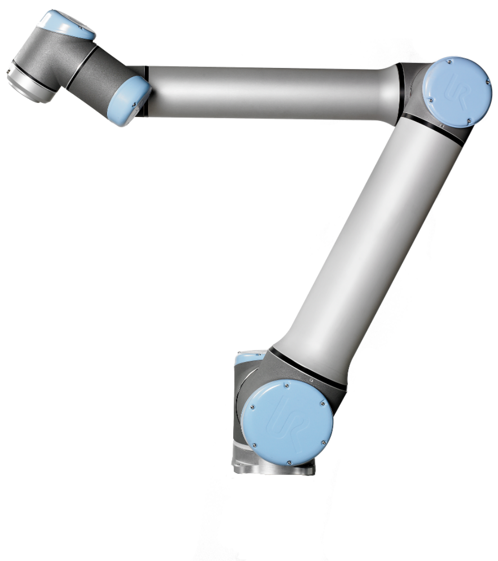
Chapter 1

Getting started

1.1 Introduction

Congratulations on the purchase of your new Universal Robot, UR10.

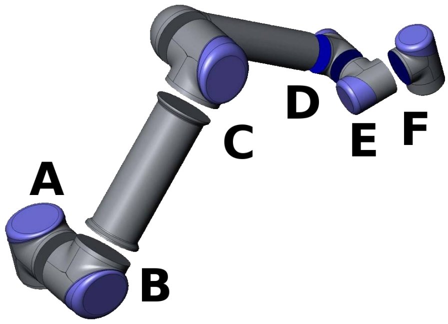


The robot is a machine that can be programmed to move a tool, and communicate with other machines using electrical signals. Using our patented programming interface, PolyScope, it is easy to program the robot to move the tool along a desired trajectory. PolyScope is described in the PolyScope Manual.

The reader of this manual is expected to be technically minded, to be familiar with the basic general concepts of programming, be able to connect a wire to a screw terminal, and be able to drill holes in a metal plate. No special knowledge about robots in general or Universal Robots in particular is required.

The rest of this chapter is an appetizer for getting started with the robot.

1.1.1 The Robot



The robot itself is an arm composed of extruded aluminum tubes and joints. The joints are named A:*Base*, B:*Shoulder*, C:*Elbow* and D,E,F:*Wrist 1,2,3*. The Base is where the robot is mounted, and at the other end (*Wrist 3*) the tool of the robot is attached. By coordinating the motion of each of the joints, the robot can move its tool around freely, with the exception of the area directly above and directly below the robot, and of course limited by the reach of the robot ($1300mm$ from the center of the base).

1.1.2 Programs

A program is a list of commands telling the robot what to do. The user interface *PolyScope*, described in the PolyScope manual, allows people with only little programming experience to program the robot. For most tasks, programming is done entirely using the touch panel without typing in any cryptic commands.

Since tool motion is such an important part of a robot program, a way of teaching the robot how to move is essential. In PolyScope, the motions of the tool are given using a series of *waypoints*. Each waypoint is a point in the robot's workspace.

Waypoints

A waypoint is a point in the workspace of the robot. A waypoint can be given by moving the robot to a certain position, or can be calculated by software. The robot performs a task by moving through a sequence of waypoints. Various options regarding how the robot moves between the waypoints can be given in the program.

Defining Waypoints, Moving the Robot. The easiest way to define a waypoint is to move the robot to the desired position. This can be done in two ways: 1) By simply pulling the robot, while pressing the 'Teach' button on the screen (see the PolyScope manual). 2) By using the touch screen to drive the tool linearly or to drive each joint individually.

Blends. Per default the robot stops at each waypoint. By giving the robot freedom to decide how to move near the waypoint, it is possible to drive through the desired path faster without stopping. This freedom is given by setting a *blend radius* for the waypoint, which means that once the robot comes within a certain distance of the waypoint, the robot can decide to deviate from the path. A blend radius of 5-10 cm usually gives good results.

Features

Besides moving through waypoints, the program can send I/O signals to other machines at certain points in the robot's path, and perform commands like `if..then` and `loop`, based on variables and I/O signals.

1.1.3 Safety Evaluation

The robot is a machine and as such a safety evaluation is required for each installation of the robot. Chapter 3.1 describes how to perform a safety evaluation.

1.2 Turning On and Off

How to turn the different parts of the robot system on and off is described in the following subsections.

1.2.1 Turning on the Controller Box

The controller box is turned on by pressing the power button, at the front side of the teach pendant. When the controller box is turned on, a lot of text will appear on the screen. After about 20 seconds, the Universal Robot's Logo will appear, with the text 'Loading'. After around 40 seconds, a few buttons appear on the screen and a popup will force the user to go to the initialization screen.

1.2.2 Turning on the Robot

The robot can be turned on if the controller box is turned on, and if all emergency stop buttons are not activated. Turning the robot on is done at the initialization screen, by touching the 'ON' button at the screen, and then pressing 'Start'. When a robot is started, a noise can be heard as the brakes unlock. After the robot has powereded up, it needs to be initialized before it can begin to perform work.

1.2.3 Initializing the Robot

After the robot is powered up, each of the robot's joints needs to find its exact position, in order to do so the joints need to move. The amount of motion needed depends on the joint position and type. Small joints need to move between 22.5° and 45°, large joints need to move half as much, the direction of rotation is unimportant. The Initialization screen, shown in figure 1.1, gives access to manual and semi-automatic driving of the robot's joints. The robot cannot automatically avoid collision with itself or the surrounds during this process. Therefore, caution should be exercised.

The *Auto* button near the top of the screen drives all joints until they are ready. When released and pressed again, all joints change drive direction. The *Manual* buttons permit manual driving of each joint.

A more detailed description of the initialization screen is found in the PolyScope manual.

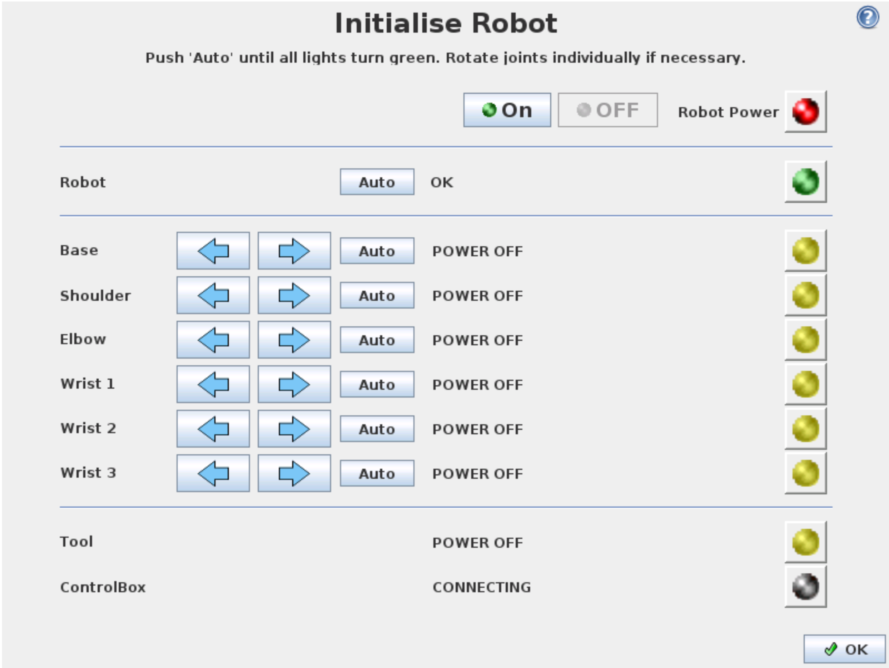


Figure 1.1: The initialization screen

1.2.4 Shutting Down the Robot

The power to the robot can be turned off by touching the 'OFF' button at the initialization screen. Most users do not need to use this feature since the robot is automatically turned off when the controller box is shutting down.

1.2.5 Shutting Down the Controller Box

Shut down the system by pressing the green power button on the screen, or by using the 'Shut Down' button on the welcome screen.

Shutting down by pulling the power cord out of the wall socket may cause corruption of the robot's file system, which may result in robot malfunction.

1.3 Quick start, Step by Step

To quickly set up the robot, perform the following steps:

1. Unpack the robot and the controller box.
2. Mount the robot on a sturdy surface.
3. Place the controller box on its foot.
4. Plug the robot cable into the connector at the bottom of the controller box.
5. Plug in the mains plug of the controller box.
6. Press the Emergency Stop button on the front side of the teach pendant.
7. Press the power button on the teach pendant.

8. Wait a minute while the system is starting up, displaying text on the touch screen.
9. When the system is ready, a popup will be shown on the touch screen, stating that the emergency stop button is pressed.
10. Touch the `OK` button at the popup.
11. Unlock the emergency stop buttons. The robot state then changes from 'Emergency Stopped' to 'Robot Power Off'.
12. Touch the `On` button on the touch screen. Wait a few seconds.
13. Touch the `Start` button on the touch screen. The robot now makes a noise and moves a little while unlocking the breaks.
14. Touch the blue arrows and move the joints around until every "light" at the right side of the screen turns green. Be careful not to drive the robot into itself or anything else.
15. All joints are now `OK`. Touch the OK button, bringing you the `Welcome` screen.
16. Touch the `PROGRAM Robot` button and select `Empty Program`.
17. Touch the `Next` button (bottom right) so that the `<empty>` line is selected in the tree structure on the left side of the screen.
18. Go to the `Structure` tab.
19. Touch the `Move` button.
20. Go to the `Command` tab.
21. Press the `Next` button, to go to the `Waypoint` settings.
22. Press the `Set this waypoint` button next to the `"?"` picture.
23. On the `Move` screen, move the robot by pressing the various blue arrows, or move the robot by holding the `Teach` button, placed on the backside of the teach pendant, while pulling the robot arm.
24. Press `OK`.
25. Press `Add waypoint before`.
26. Press the `Set this waypoint` button next to the `"?"` picture.
27. On the `Move` screen, move the robot by pressing the various blue arrows, or move the robot by holding the `Teach` button while pulling the robot arm.
28. Press `OK`.
29. Your program is ready. The robot will move between the two points when you press the 'Play' symbol. Stand clear, hold on to the emergency stop button and press 'Play'.
30. Congratulations! You have now produced your first robot program that moves the robot between the two given positions. Remember that you have to carry out a risk assessment and improve the overall safety condition before you really make the robot do some work.

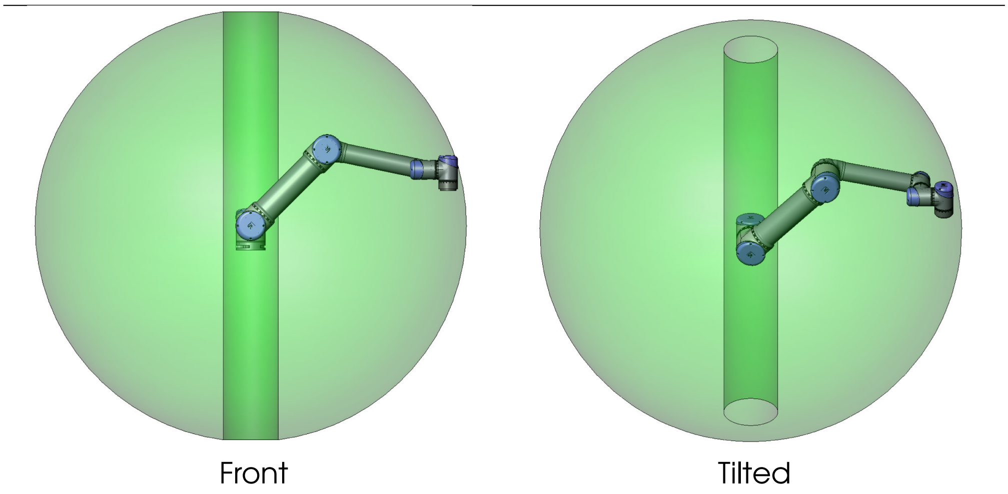


Figure 1.2: The workspace of the robot. The robot can work in an approximate sphere (Ø260cm) around the base, except for a cylindrical volume directly above and directly below the robot base.

1.4 Mounting Instructions

The robot consists essentially of six robot joints and two aluminum tubes, connecting the robot's *base* with the robot's *tool*. The robot is built so that the tool can be translated and rotated within the robot's workspace. The next subsections describes the basic things to know when mounting the different parts of the robot system.

1.4.1 The Workspace of the Robot

The workspace of the UR10 robot extends to 1300 mm from the base joint. The workspace of the robot is shown in figure 1.2. It is important to consider the cylindrical volume directly above and directly below the robot base when a mounting place for the robot is chosen. Moving the tool close to the cylindrical volume should be avoided if possible, because it causes the robot joints to move fast even though the tool is moving slowly.

1.4.2 Mounting the Robot

The robot is mounted using 4 M8 bolts, using the four $8.5mm$ holes on the robot's base. It is recommended to tighten these bolts with 20 Nm torque. If very accurate repositioning of the robot is desired, two Ø8 holes are provided for use with a pin. Also an accurate base counterpart can be purchased as accessory. Figure 1.3 shows where to drill holes and mount the screws.

1.4.3 Mounting the Tool

The robot tool flange has four holes for attaching a tool to the robot. A drawing of the tool flange is shown in figure 1.4.

Chapter 3

Safety

3.1 Introduction

This chapter gives a short introduction to the statutory documentation and important information about the risk assessment, followed by a section concerning emergency situations. Regarding safety in general all assembly instructions from 1.4 and 2.1 shall be followed. Technical specifications of the electrical safety interface, including performance level and safety categories, are found in section 2.3.

3.2 Statutory documentation

A robot installation within the EU shall comply with the machinery directive to insure its safety. This includes the following points.

1. Make sure that the product comply with all essential requirements.
2. Make a risk assessment.
3. Specify instructions for the operator.
4. Make a declaration of conformity.
5. Collect all information in a technical file.
6. Put a CE mark on the robot installation.

In a given robot installation, the integrator is responsible for the compliance with all relevant directives. Universal Robots takes responsibility for the robot itself complying with the relevant EU directives (See section 5.1).

Universal Robots provides a safety guide, available at http://www.universal-robots.com, for integrators with little or no experience in making the necessary documentation.

If the robot is installed outside EU, the robot integration shall comply with the local directives and laws of the specific country. The integrator is responsible for this compliance. It is always necessary to perform a risk assessment to ensure that the complete robot installation is sufficiently safe.

3.3 Risk assessment

One of the most important things that an integrator needs to do is to make a risk assessment. Universal Robots has identified the potential significant hazards listed below as hazards which must be considered by the integrator. Note that other significant hazards might be present in a specific robot installation.

1. Entrapment of fingers between robot foot and base (joint 0).
2. Entrapment of fingers between the arm and wrist (joint 4).
3. Penetration of skin by sharp edges and sharp points on tool or tool connector.
4. Penetration of skin by sharp edges and sharp points on obstacles near the robot track.
5. Bruising due to stroke from the robot.
6. Sprain or bone fracture due to strokes between a heavy payload and a hard surface.
7. Consequences due to loose bolts that holds the robot arm or tool.
8. Items falling out of tool. E.g. due to a poor grip or power interruption.
9. Electrical shock or fire due to malfunction of power supplies if the mains connection is not protected by a main fuse, a residual current device and a proper connection to earth. See section 1.4.7.
10. Mistakes due to different emergency stop buttons for different machines. Use common emergency stop function as descriped in section 2.3.1.

However, the UR10 is a very safe robot due to the following reasons:

1. Control system conforms to ISO 13849-1 performance level **d**.
2. The control system of the robot is redundant so that all dangerous failures forces the robot to enter a safe condition.
3. High level software generates a protective stop if the robot hits something. This stop force limit is lower than 150N.
4. Furthermore, low level software limits the torque generated by the joints, permitting only a small deviation from the expected torque.
5. The software prevents program execution when the robot is mounted differently than specified in the setup.
6. The weight of the robot is less than 28kg.
7. The robot shape is smooth, to reduces pressure (N/m^2) per force (N).
8. It is possible to move the joints of an unpowered robot. See section 3.4

The fact that the robot is very safe opens the possibility of either saving the safety guards or using safety guards with a low performance level. As a help in convincing customers and local authorities the UR10 robot has been certified by the Danish Technological Institute which is a Notified Body under the machinery directive in Denmark. The certification concludes that the robot complies with article 5.10.5 of the EN ISO 10218-1:2006. This standard is harmonized under the machinery directive and it specifically states that a robot can operate as a collaborative robot (i.e. without safety guards between the robot and the operator) if it is in compliance with the article 5.10.5. The risk assessment still needs to conclude that the overall robot installation is safe enough of course. A copy of the certification report can be requested from Universal Robots.

The standard EN ISO 10218-1:2006 is valid untill the 1st of January 2013. In the meantime the newer version EN ISO 10218-1:2011 and the corrosponding EN ISO 10218-2:2011 addressed to the integrators are also valid. Where the EN ISO 10218-1:2006 specifically states that a maximum force of 150N combined with a supporting risk assesment is required for collaborative operation, the newer standards does not specify a specific maximum force but leaves this to the specific risk assesment. In general this means that regardless of the standard used a risk assesment shall confirm that the collaborative robot installation is sufficiently safe, and for most cases the combination of a well constructed robot installation and the maximum force of 150N is sufficient.

3.4 Emergency situations

In the unlikely event of an emergency situation where one or more robot joints needs to be moved and robot power is either not possible or unwanted, there are three different ways to force movements of the robot joints without powering the motors of the joints:

1. Active backdriving: If possible, power on the robot by pushing the "ON" button on the initializing screen. Instead of pushing the "break release" button to power up the joint motors, push the teach button on the backside of the teach pendant. A special backdrive mode is entered and the robot will loosen its breacks automatically while the robot is hand guided. Releasing the teach button re-locks the breaks.

2. Manual break release: Remove the joint cover by removing the few M3 screws that fix it. Release the break by pushing the plunger on the small electro magnet as shown in the picture below.

3. Forced backdriving: Force a joint to move by pulling hard in the robot arm. Each joint break has a friction clutch which enables movement during high forced torque. Forced backdriving is intended for urgent emergencies only and might damage the joint gears and other parts.

Do not turn any joints more than necessary and beware of gravity and heavy payloads.