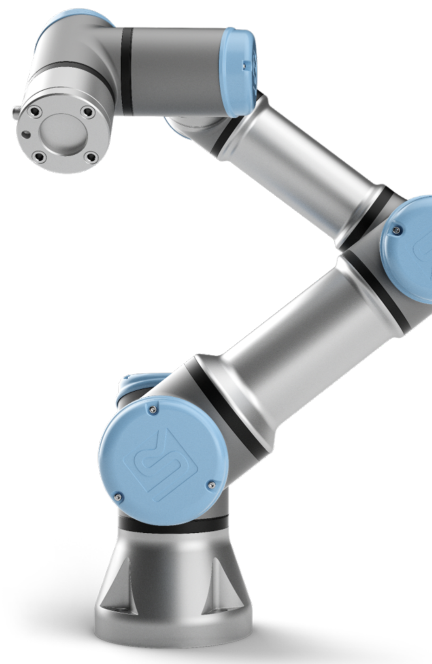
UNIVERSAL ROBOTS

Universal Robots e-Series User Manual



UR3e

Original instructions (en)

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Version 5.0.2

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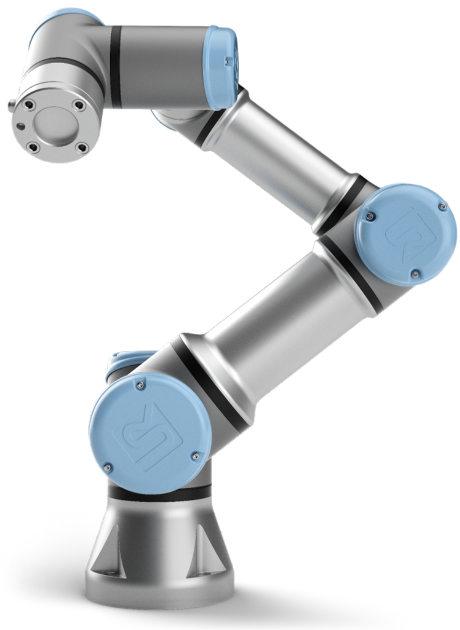
Contents

Preface



Congratulations on the purchase of your new Universal Robots e-Series robot, UR3e.

The robot can be programmed to move a tool, and communicate with other machines using electrical signals. It is an arm composed of extruded aluminium tubes and joints. Using our patented programming interface, PolyScope, it is easy to program the robot to move the tool along a desired trajectory.

With six joints and a wide scope of flexibility, Universal Robots e-Series collaborative robot arms are designed to mimic the range of motion of a human arm. Using our patented programming interface, PolyScope, it is easy to program the robot to move tools and communicate with other machines using electrical signals. Figure 1 illustrates the main components of the robot arm and can be used as a reference throughout the manual.

What Do the Boxes Contain

When you order a complete robot, you receive two boxes. One contains the robot arm, the other contains:

- Control Box with Teach Pendant
- Mounting bracket for the Control Box
- Mounting bracket for the Teach Pendant
- Key for opening the Control Box
- Mains cable or Power cable compatible to your region

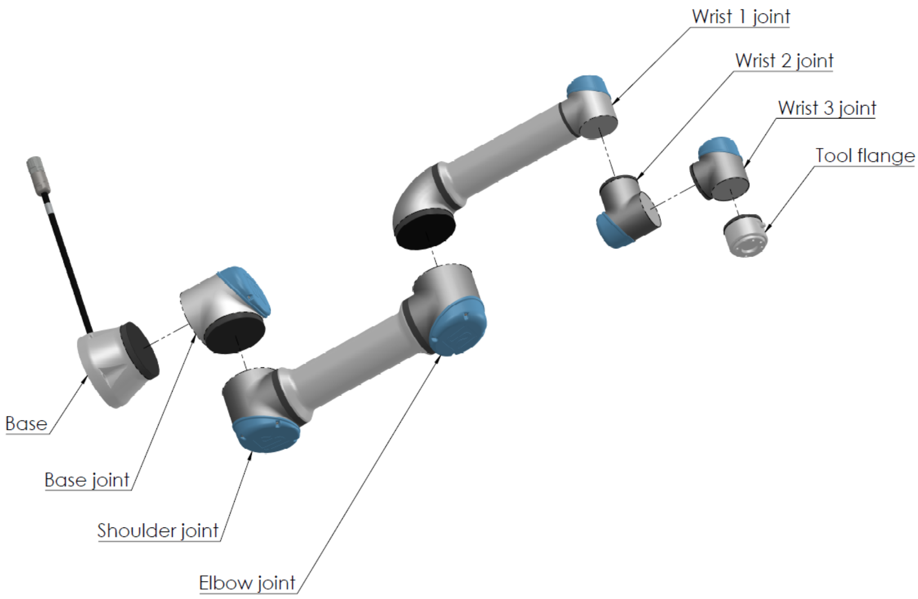


Figure 1: Klouby, základna a příruba nástroje ramene robota.

- Stylus pen with laser
- This manual

Important Safety Notice

The robot is **partly completed machinery** (see 8.4) and as such a risk assessment is required for each installation of the robot.
Note: You must follow all of the safety instructions in chapter 1.

How to Read This Manual

This manual contains instructions for installing and programming the robot. The manual is separated into two parts:

Hardware Installation Manual: The mechanical and electrical installation of the robot.

PolyScope Manual: Programming of the robot.

This manual is intended for the robot integrator who must have a basic level of mechanical and electrical training, as well as be familiar with elementary programming concepts.

Where to Find More Information

The support website (http://www.universal-robots.com/support) available to all UR distributors, contains additional information such as:

- Other language versions of this manual
- The **PolyScope Manual** updates after the PolyScope is upgraded to a new version

- The **Service Manual** with instructions for troubleshooting, maintenance and repair of the robot
- The **Script Manual** for advanced users
- The URCAPS an online platform for purchasing Universal Robots accessories and peripherals

Part I

Hardware Installation Manual

1 Safety

1.1 Introduction

This chapter contains important safety information, which must be read and understood by the integrator of Universal Robots e-Series robots **before** the robot is powered on for the first time.

In this chapter, the first subsections are general. The later subsections contain specific engineering data relevant to enable setting up and programming the robot. `Chapter 2` describes and defines safety-related functions particularly relevant for collaborative applications.
Instructions and guidance provided in `chapter 2` as well as in `section 1.7` are particularly important.

It is essential to observe and follow all assembly instructions and guidance provided in other chapters and parts of this manual.

Special attention shall be paid to text associated with warning symbols.

NOTE:
Universal Robots disclaims any and all liability if the robot (arm control box and/or teach pendant) is damaged, changed or modified in any way. Universal Robots cannot be held responsible for any damages caused to the robot or any other equipment due to programming errors or malfunctioning of the robot.

1.2 Validity and Responsibility

The information in this manual does not cover designing, installing and operating a complete robot application, nor does it cover all peripheral equipment that can influence the safety of the complete system. The complete system must be designed and installed in accordance with the safety requirements set forth in the standards and regulations of the country where the robot is installed.

The integrators of UR robots are responsible for ensuring that the applicable safety laws and regulations in the country concerned are observed and that any significant hazards in the complete robot application are eliminated.

This includes, but is not limited to:

- Performing a risk assessment for the complete robot system
- Interfacing other machines and additional safety devices if defined by the risk assessment
- Setting up the appropriate safety settings in the software
- Ensuring that the user will not modify any safety measures
- Validating that the total robot system is designed and installed correctly
- Specifying instructions for use
- Marking the robot installation with relevant signs and contact information of the integrator

- Collecting all documentation in a technical file; including the risk assessment and this manual

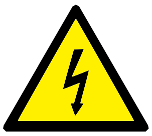
Guidance on how to find and read applicable standards and laws is provided on `http://universal-robots.com/support/`

1.3 Limitation of Liability

Any safety information provided in this manual must not be construed as a warranty, by UR, that the industrial manipulator will not cause injury or damage, even if industrial manipulator complies with all safety instructions.

1.4 Warning Symbols in this Manual

The symbols below define the captions specifying the danger levels used throughout this manual. The same warning signs are used on the product.



DANGER:
This indicates an imminently hazardous electrical situation which, if not avoided, could result in death or serious injury.

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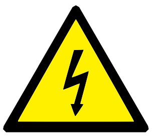
This indicates an imminently hazardous situation which, if not avoided, could result in death or serious injury.



WARNING:
This indicates a potentially hazardous electrical situation which, if not avoided, could result in injury or major damage to the equipment.

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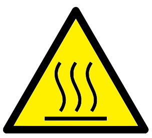
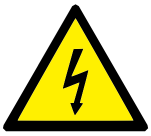


WARNING:
This indicates a potentially hazardous hot surface which, if touched, could result in injury.

CAUTION:
This indicates a situation which, if not avoided, could result in damage to the equipment.

1.5 General Warnings and Cautions

This section contains some general warnings and cautions that can be repeated or explained in different parts of this manual. Other warnings and cautions are present throughout this manual.

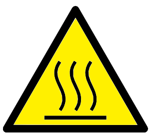


DANGER:
Make sure to install the robot and all electrical equipment according to the specifications and warnings found in chapters 4 and 5.

WARNING:

1. Make sure the robot arm and tool/end effector are properly and securely bolted in place.
2. Make sure the robot arm has ample space to operate freely.
3. Make sure that safety measures and/or robot safety configuration parameters have been set up to protect both programmers, operators and bystanders, as defined in the risk assessment.
4. Do not wear loose clothing or jewellery when working with the robot. Make sure long hair is tied back when working with the robot.
5. Never use the robot if it is damaged, for example if joint caps are loose, broken or removed.
6. If the software prompts an error, immediately press emergency stop, write down the conditions that led to the error, find the corresponding error codes on the log screen, and contact your supplier.
7. Do not connect any safety equipment to standard I/O. Use safety-related I/O only.
8. Make sure to use the correct installation settings (e.g. Robot mounting angle, mass in TCP, TCP offset, safety configuration). Save and load the installations file along with the program.
9. The freedrive function (Impedance/Backdrive) shall only be used in installations where the risk assessment allows it. Tool/end effectors and obstacles shall not have sharp edges or pinch points.
10. Make sure to warn people to keep their heads and faces outside the reach of the operating robot or robot about to start operating.
11. Be aware of robot movement when using the teach pendant.
12. If determined by the risk assessment, do not enter the safety range of the robot or touch the robot when the system is in operation.

13. Collisions can release high levels of kinetic energy, which are significantly higher at high speeds and with high payloads. (Kinetic Energy = $\frac{1}{2}$Mass · Speed^2)
14. Combining different machines can increase hazards or create new hazards. Always make an overall risk assessment for the complete installation. Depending on the assessed risk, different levels of functional safety can apply; as such, when different safety and emergency stop performance levels are needed, always choose the highest performance level. Always read and understand the manuals for all equipment used in the installation.
15. Never modify the robot. A modification might create hazards that are unforeseen by the integrator. All authorized reassembling shall be done according to the newest version of all relevant service manuals.
16. If the robot is purchased with an extra module (e.g. euromap67 interface) then look up that module in the respective manual.
17. Make sure the users of the robot are informed of the location of the emergency stop button(s) and are instructed to activate the emergency stop in case of emergency or abnormal situations.



WARNING:

1. The robot and its controller box generate heat during operation. Do not handle or touch the robot while in operation or immediately after operation as prolonged contact can cause discomfort. To cool the robot down, power off the robot and wait one hour.
2. Never stick fingers behind the internal cover of the controller box.

CAUTION:

1. When the robot is combined, or working, with machines capable of damaging the robot, it is highly recommended to test all functions and the robot program separately. It is also recommended to test the robot program using temporary waypoints outside the workspace of other machines.
2. Do not expose the robot to permanent magnetic fields. Very strong magnetic fields can damage the robot.

1.6 Intended Use

UR robots are industrial robots intended to handle tools/end effectors and fixtures, or to process or transfer components or products. For details about the environmental conditions under which the robot should operate, see appendices B and D.

UR robots are equipped with special safety-related features, which are purposely designed to enable collaborative operation, where the robot system operates without fences and/or together with a human.

Collaborative operation is only intended for non-hazardous applications, where the complete application, including tool/end effector, work piece, obstacles and other machines, is without any significant hazards according to the risk assessment of the specific application.

Any use or application deviating from intended use is deemed to be impermissible misuse. This includes, but is not limited to:

- Use in potentially explosive environments
- Use in medical and life critical applications
- Use before performing a risk assessment
- Use outside of stated specifications
- Use as a climbing aid
- Operation outside the permissible operating parameters

1.7 Risk Assessment

One of the most important things that an integrator needs to do is to perform a risk assessment. In many countries this is required by law. The robot itself is partly completed machinery, as the safety of the robot installation depends on how the robot is integrated (E.g. tool/end effector, obstacles and other machines).

It is recommended that the integrator uses ISO 12100 and ISO 10218-2 to conduct the risk assessment. Additionally the integrator can choose to use the Technical Specification ISO/TS 15066 as additional guidance.

The risk assessment that the integrator conducts shall consider all work tasks throughout the lifetime of the robot application, including but not limited to:

- Teaching the robot during set-up and development of the robot installation
- Troubleshooting and maintenance
- Normal operation of the robot installation

A risk assessment must be conducted **before** the robot arm is powered on for the first time. A part of the risk assessment conducted by the integrator is to identify the proper safety configuration settings, as well as the need for additional emergency stop buttons and/or other protective measures required for the specific robot application.

Identifying the correct safety configuration settings is a particularly important part of developing collaborative robot applications. See `chapter 2` and `part II` for detailed information.

Some safety-related features are purposely designed for collaborative robot applications. These features are configurable through the safety configuration settings and are particularly relevant when addressing specific risks in the risk assessment conducted by the integrator:

- **Force and power limiting**: Used to reduce clamping forces and pressures exerted by the robot in the direction of movement in case of collisions between the robot and the operator.
- **Momentum limiting**: Used to reduce high transient energy and impact forces in case of collisions between robot and operator by reducing the speed of the robot.
- **Joint, elbow and tool/end effector position limiting**: Particularly used to reduce risks associated with certain body parts. E.g. to avoid movement towards head and neck.
- **Tool/end effector orientation limiting**: Particularly used to reduce risks associated with certain areas and features of the tool/end effector and work-piece. E.g. to avoid sharp edges to be pointed towards the operator.
- **Speed limitation**: Particularly used to ensure a low speed of the robot arm.

The integrator must prevent unauthorized access to the safety configuration by using password protection.
A collaborative robot application risk assessment for contacts that are intentional and/or due to reasonably foreseeable misuse is required and must address:

- Severity of individual potential collisions
- Likeliness of occurrence of individual potential collisions
- Possibility to avoid individual potential collisions

If the robot is installed in a non-collaborative robot application where hazards cannot be reasonably eliminated or risks cannot be sufficiently reduced by use of the built-in safety-related functions (e.g. when using a hazardous tool/end effector), then the risk assessment conducted by the integrator must conclude the need for additional protective measures (e.g. an enabling device to protect the operator during set-up and programming).

Universal Robots identifies the potential significant hazards listed below as hazards that must be considered by the integrator.
Note: Other significant hazards can be present in a specific robot installation.

1. Penetration of skin by sharp edges and sharp points on tool/end effector or tool/end effector connector.
2. Penetration of skin by sharp edges and sharp points on obstacles near the robot track.

3. Bruising due to contact with the robot.
4. Sprain or bone fracture due to strokes between a heavy payload and a hard surface.
5. Consequences due to loose bolts that hold the robot arm or tool/end effector.
6. Items falling out of tool/end effector, e.g. due to a poor grip or power interruption.
7. Mistakes due to different emergency stop buttons for different machines.
8. Mistakes due to unauthorized changes to the safety configuration parameters.

Information on stopping times and stopping distances are found in `chapter 2` and `appendix A`.

1.8 Pre-Use Assessment

The following tests must be conducted before using the robot for the first time or after any modifications are made. Verify that all safety input and output are appropriately and correctly connected. Test that all connected safety input and output, including devices common to multiple machines or robots, are functioning. As such you must:

- Test that emergency stop buttons and input stop the robot and engage brakes.
- Test that safeguard input stop the robot motion. If safeguard reset is configured, check that it needs to be activated before motion can be resumed.
- Examine the initialization screen to test that reduced mode can switch the safety mode to reduced mode.
- Test that the operational mode switches the operational mode, see icon in top right corner of user interface.
- Test that the 3-position enabling device must be pressed to enable motion in manual mode and that the robot is under reduced speed control.
- Test that System Emergency Stop outputs are actually capable of bringing the whole system to a safe state.
- Test that the system connected to Robot Moving output, Robot Not Stopping output, Reduced Mode output, or Not Reduced Mode output can actually detect the output changes

1.9 Emergency Stop

Activate the emergency stop push-button to immediately stop all robot motion.

Note: According to IEC 60204-1 and ISO 13850, emergency devices are not safeguards. They are complimentary protective measures and are not intended to prevent injury.

The risk assessment of the robot application shall conclude if additional emergency stop buttons are need. Emergency stop push-buttons must comply with IEC 60947-5-5 `(see section 5.4.2)`.

1.10 Movement Without Drive Power

In the unlikely event of an emergency, you can use **forced back-driving** where you must move robot joint/s, but robot power is either impossible or unwanted.
To perform **forced back-driving** you must push, or pull, the robot arm hard to move the joint. Each joint brake has a friction clutch that enables movement during high forced torque.
Note: In a service situation, the brake on the joints can be released without connected power.

WARNING:

- Moving the robot arm manually is intended for urgent emergency purposes only and might damage the robot joints.

2 Safety-related Functions and Interfaces

2.1 Introduction

Universal Robots e-Series robots are equipped with a range of built-in safety functions as well as safety I/O, digital and analog control signals to or from the electrical interface, to connect to other machines and additional protective devices. Each safety function and I/O is constructed according to EN ISO13849-1:2008 (see chapter 8 for certifications) with Performance Level d (PLd) using a category 3 architecture.

See chapter 13 in part II for configuration of the safety functions, inputs and outputs in the user interface. See chapter 5 for descriptions on how to connect safety devices to I/O.

NOTE:

1. The use and configuration of safety functions and interfaces must follow the risk assessment procedures for each robot application. (see chapter 1 section 1.7)
2. If the robot discovers a fault or violation in the safety system (e.g. if one of the wires in the Emergency Stop circuit is cut or a safety limit is violated) then a Stop Category 0 is initiated.
3. The stopping time should be taken into account as part of the application risk assessment

DANGER:

1. The use of safety configuration parameters different from those determined by the risk assessment can result in hazards that are not reasonably eliminated or risks that are not sufficiently reduced
2. Ensure tools and grippers are connected appropriately so if there is an interruption of power, no hazards occurl
3. Use caution with 12V, since an error made by the programmer can cause the voltage to change to 24V, which might damage the equipment and cause a fire
4. The end effector is not protected by the UR safety system. The functioning of the end effector and/or connection cable is not monitored

2.2 Stop Categories

Depending on the circumstances, the robot can initiate three types of stop categories defined according to IEC 60204-1). These categories are defined in the following table.

Stop Category	Description
0	Stop the robot by immediate removal of power.
1	Stop the robot in an orderly, controlled manner. Power is removed once the robot is stopped.
2	*Stop the robot with power available to the drives, while maintaining the trajectory. Drive power is maintained after the robot is stopped.

Note: *Universal Robots robots' Category 2 stops are further described as SS1 or as SS2 type stops according to IEC 61800-5-2.

2.3 Safety Functions

Universal Robots robot safety functions, as listed in the table below, are in the robot but are meant to control the robot system i.e. the robot with its attached tool/end effector. The robot safety functions are used to reduce robot system risks determined by the risk assessment. Positions and speeds are relative to the base of the robot.

Safety Function	Description
Joint Position Limit	Sets upper and lower limits for the allowed joint positions.
Joint Speed Limit	Sets an upper limit for joint speed.
Safety Planes	Defines planes, in space, that limit robot position. Safety planes limit either the tool/end effector alone or both the tool/end effector and the elbow.
Tool Orientation	Defines allowable orientation limits for the tool.
Speed Limit	Limits maximum robot speed. The speed is limited at the elbow, at the tool/end effector flange, and at the center of the user-defined tool/end effector positions.
Force Limit	Limits maximum force exerted by the robot tool/end effector and elbow in clamping situations. The force is limited at the tool/end effector, elbow flange and center of the user-defined tool/end effector positions.
Momentum Limit	Limits maximum momentum of the robot.
Power Limit	Limits mechanical work performed by the robot.
Stopping Time Limit	Limits maximum time the robot uses for stopping after a protective stop is initiated.
Stopping Distance Limit	Limits maximum distance travelled by the robot after a protective stop is initiated.

The robot also has the following safety inputs:

Safety Input	Description
Emergency Stop Button	Performs a Stop Category 1 informing other machines using the *System Emergency Stop* output, if that output is defined.
Robot Emergency Stop	Performs a Stop Category 1 via Control Box input, informing other machines using the *System Emergency Stop* output, if that output is defined.
System Emergency Stop	Performs a Stop Category 1 on robot only.
Safeguard Stop	Performs a Stop Category 2.
Safeguard Reset	Returns from the *Safeguard Stop* state, when an edge on the Safeguard Reset input occurs.
Reduced Mode	Transitions the safety system to use the *Reduced mode* limits.
3-Position Enabling Device	Initiates a *Safeguard Stop* when the enabling device is fully compressed or fully released. When this happens, the enabling device inputs are high.
Operational Mode	Mode to switch, when needed. NOTE: required when a 3-Position Enabling Device is used.

For interfacing with other machines, the robot is equipped with the following safety outputs:

Safety Output	Description
System Emergency Stop	While this signal is logic low, the *Robot Emergency Stop* input is logic low or the Emergency Stop button is pressed.
Robot Moving	While this signal is logic high, no single joint of the robot moves more than 0.1 rad.
Robot Not Stopping	Logic high when the robot is stopped or in the process of stopping due to an Emergency Stop or Safeguard Stop. Otherwise it will be logic low.
Reduced Mode	Logic low when the safety system is in Reduced Mode.
Not Reduced Mode	Logic low when the system is not in Reduced Mode.

All safety I/O are dual channel, meaning they are safe when low (e.g., the Emergency Stop is active when the signals are low).

2.4 Safety Function

The safety system acts by monitoring if any of the safety limits are violated or if an Emergency Stop or a Safeguard Stop is initiated.
The reactions of the safety system are:

Trigger	Reaction
Emergency Stop	Stop Category 1.
Safeguard Stop	Stop Category 2.
Limit Violation	Stop Category 0.
Fault Detection	Stop Category 0.

When performing the application risk assessment, it is necessary to take into account the motion of the robot after a stop has been initiated. In order to ease this process, the safety functions *Stopping Time Limit* and *Stopping Distance Limit* can be used. These safety functions dynamically reduces the speed of the robot motion such that it can always be stopped within the limits. It is important to note that the joint position limits, the safety planes and the tool/end effector orientation limits take the expected stopping distance travel into account i.e. the robot motion will slow down before the limit is reached.

The functional safety can be summarized as:

Safety Function	Tolerance	Performance Level	Category
Emergency Stop	–	d	3
Safeguard Stop	–	d	3
Joint Position Limit	$5\,^{\circ}$	d	3
Joint Speed Limit	$1.15\,^{\circ}/\mathrm{s}$	d	3
Safety Planes	40 mm	d	3
Tool Orientation	$3\,^{\circ}$	d	3
Speed Limit	$50\,\mathrm{mm/s}$	d	3
Force Limit	25 N	d	3
Momentum Limit	$3\,\mathrm{kg\,m/s}$	d	3
Power Limit	10 W	d	3
Stopping Time Limit	50 ms	d	3
Stopping Distance Limit	40 mm	d	3

WARNING:
There are two exceptions to the force limiting function that are important when designing an application (Figure 2.1). As the robot stretches out, the knee-joint effect can give high forces in the radial direction (away from the base) at low speeds. Similarly, the short leverage arm, when the tool/end effector is close to the base and moving around the base, can cause high forces at low speeds. Pinching hazards can be avoided by removing obstacles in these areas, placing the robot differently, or by using a combination of safety planes and joint limits to eliminate the hazard by preventing the robot moving into this region of its workspace.

WARNING:
If the robot is used in manual hand-guiding applications with linear movements, the speed limit must be set to maximum $250\,\mathrm{mm/s}$ for the tool/end effector and elbow unless a risk assessment shows that higher speeds are acceptable. This will prevent fast movements of the robot elbow near singularities.

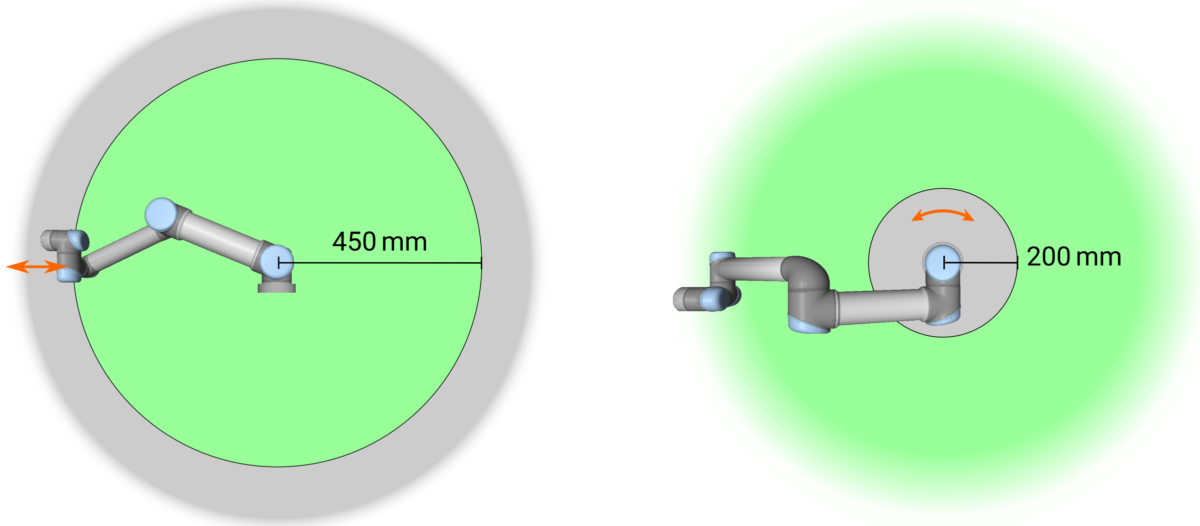


Figure 2.1: Due to the physical properties of the robot arm, certain workspace areas require attention regarding pinching hazards. One area (left) is defined for radial motions when the wrist 1 joint is at least 450 mm from the base of the robot. The other area (right) is within 200 mm of the base of the robot, when moving tangentially.

2.5 Modes

Normal and Reduced Mode The safety system has two configurable Modes: **Normal** and **Reduced**. Safety limits can be configured for each of these two modes. Reduced Mode is active when the robot tool/end effector is positioned on the Reduced Mode side of a **Trigger Reduced Mode** plane or when triggered by a safety input.

Using a plane to trigger Reduced Mode: When the robot moves from the Reduced Mode side of the trigger plane, back to the Normal Mode side, there is a 20mm area around the trigger plane where both Normal and Reduced Mode limits are allowed. It prevents the Safety Mode from flickering if the robot is right at the limit.

Using an input to trigger Reduced Mode: When an input is used (to either start or stop Reduced Mode), up to 500ms can elapse before the new mode limit values are applied. This could happen either when changing Reduced Mode to Normal Mode OR changing Normal Mode to Reduced Mode. It allows the robot to adapt e.g. the speed to the new safety limits.

Recovery Mode When a safety limit is violated, the safety system must be restarted. If the system is outside a safety limit at start-up (e.g. outside a joint position limit),the special Recovery Mode is entered. In Recovery Mode, it is not possible to run programs for the robot, but the robot arm can be manually moved back within limits either by using Freedrive Mode or by using the Move tab in PolyScope `(see part II PolyScope Manual)`. The safety limits of Recovery Mode are:

Safety Function	Limit
Joint Speed Limit	30 $^{\circ}/_{s}$
Speed Limit	250 $^{mm}/_{s}$
Force Limit	100 N
Momentum Limit	10 $^{kg\,m}/_{s}$
Power Limit	80 W

The safety system issues a Stop Category 0 if a violation of these limits appears.

WARNING:
Notice that limits for the joint positions, the safety planes, and the tool/end effector orientation are disabled in Recovery Mode. Take caution when moving the robot arm back within the limits.

3 Transportation

As supplied on the pallet, the robot and Control Box are a calibrated set. Do not separate them as this would require recalibration.

Only transport the robot in its original packaging. Save the packaging material in a dry place if you want to move the robot later.

When moving the robot from its packaging to the installation space, hold both tubes of the robot arm at the same time. Hold the robot in place until all mounting bolts are securely tightened at the base of the robot.

Lift the Control Box by its handle.

WARNING:

1. Make sure not to overload your back or other bodyparts when lifting the equipment. Use proper lifting equipment. All regional and national lifting guidelines shall be followed. Universal Robots cannot be held responsible for any damage caused by transportation of the equipment.
2. Make sure to mount the robot according to the instructions in `chapter 4`.

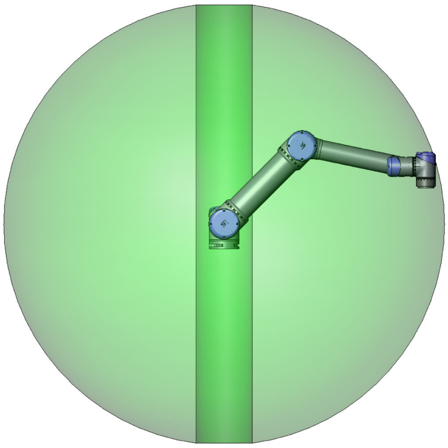
4 Mechanical Interface

4.1 Introduction

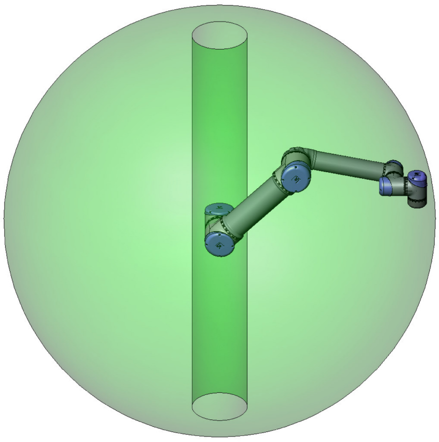
This chapter describes the basics of mounting the parts of the robot system. Electrical installation instructions in chapter 5 must be observed.

4.2 Workspace of the Robot

The workspace of the UR3e robot extends 500 mm from the base joint. It is important to consider the cylindrical volume directly above and directly below the robot base when choosing a mounting place for the robot. Moving the tool close to the cylindrical volume should be avoided because it causes the joints to move fast even when the tool is moving slowly, which causes the robot to work inefficiently and makes it difficult to conduct a risk assessment.



Front



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4.3 Mounting

Robot Arm The Robot Arm is mounted using four 8.8 strength, M6 bolts and four 6.6 mm mounting holes at the base. The bolts must be tightened with 9 N m torque.
Use the two Ø5 holes provided, with a pin, to accurately reposition Robot Arm. Note: You can purchase an accurate base counterpart as an accessory. Figure 4.1 shows where to drill holes and mount the screws.

Mount the robot on a sturdy, vibration-less, surface that can withstand at least ten times the full torque of the base joint and at least five times the weight of the Robot Arm. If the robot is mounted on a linear axis, or a moving platform, then the acceleration of the moving mounting base is very low. A high acceleration might cause the robot to make a safety stop.

DANGER:
Make sure the Robot Arm is properly and securely bolted in place.
Unstable mounting can lead to accidents.

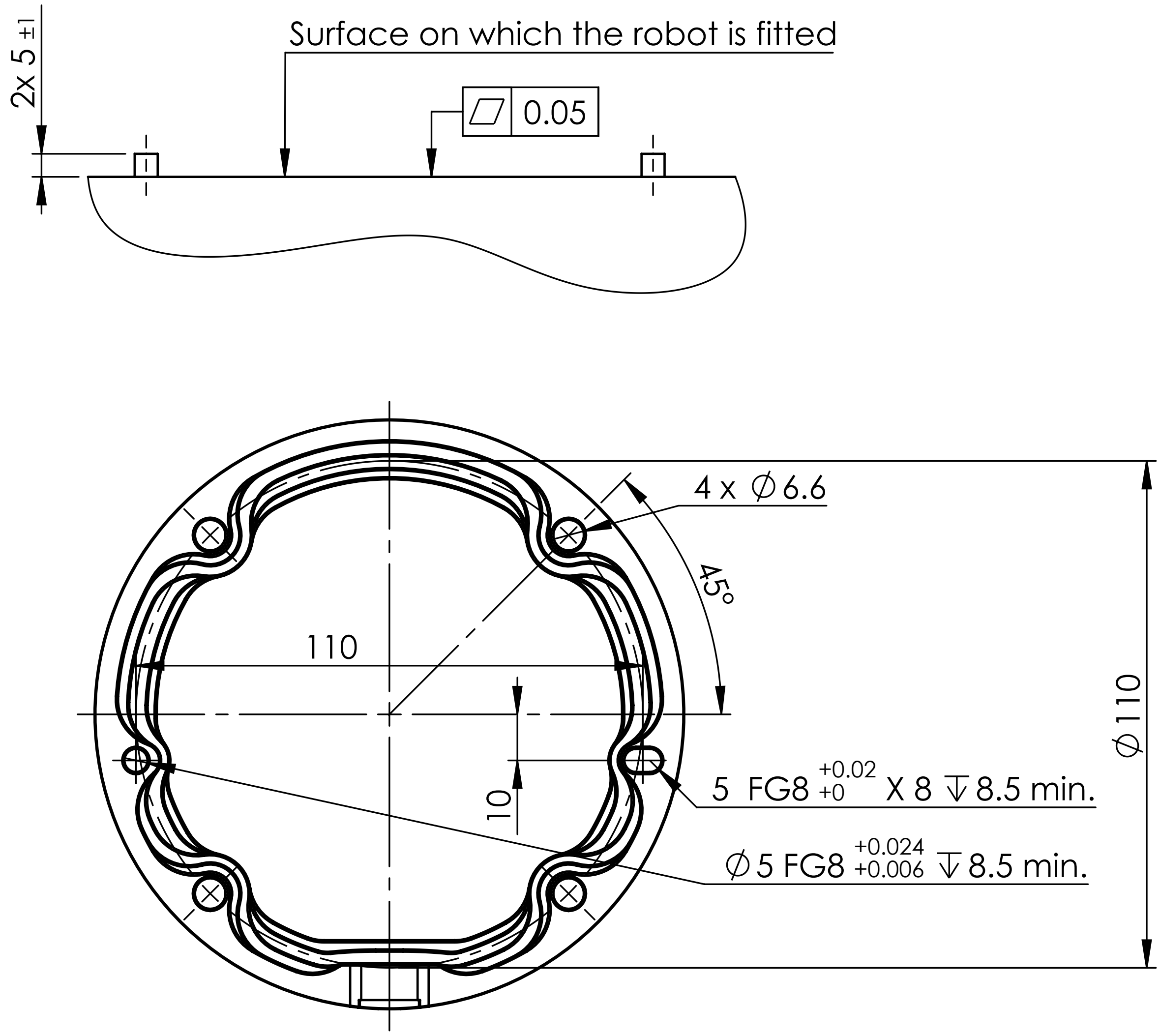


Figure 4.1: Holes for mounting the robot. Use four M6 bolts. All measurements are in mm.

CAUTION:
Mount the robot in an environment suited for the IP rating. The robot must not be operated in enviroments that exceed those corresponding to the IP ratings of the robot (IP54), Teach Pendant (IP54) and Control Box (IP44)

Tool The robot tool flange has four M6 thread holes for attaching a tool to the robot. The M6 bolts must be tightened with 8 N m, strength class 8.8. For accurate tool repositioning, use a pin in the Ø6 hole provided. Figure 4.2 shows dimensions and hole pattern of the tool flange. It is recommended to use a radially slotted hole for the pin to avoid over-constraining, while keeping precise position.

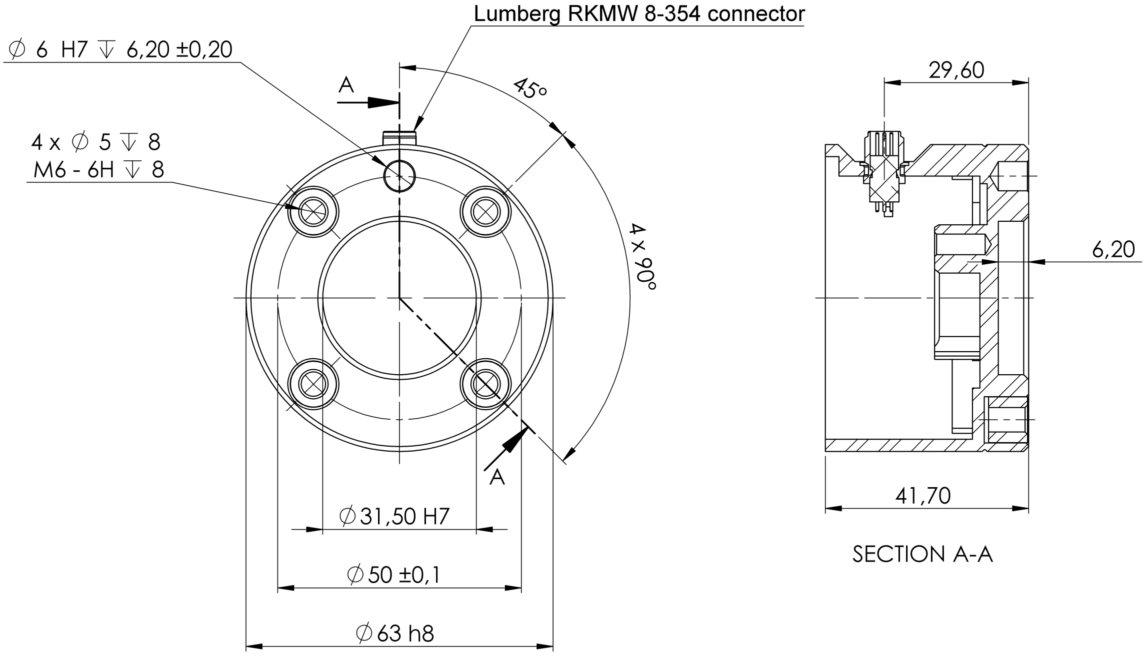


Figure 4.2: The tool output flange (ISO 9409-1-50-4-M6) is where the tool is mounted at the tip of the robot. All measures are in mm.

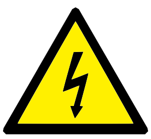
DANGER:

1. Ensure the tool is properly and securely bolted in place.
2. Ensure the tool is constructed such that it cannot create a hazardous situation by dropping a part unexpectedly.

Control Box The Control Box can be hung on a wall or placed on the ground. A clearance of 50 mm on each side of the Control Box is needed for sufficient airflow.

Teach Pendant The Teach Pendant can be hung on a wall or on the Control Box. Verify that the cable does not cause tripping hazard.

Note: you can buy extra brackets for mounting the Control Box and Teach Pendant.



DANGER:

1. Make sure the Control Box, Teach Pendant and cables do not come into contact with liquids. A wet Control Box could cause fatal injury.
2. Place the Teach Pendant (IP54) and Control Box (IP44) in an environment suited for the IP rating.

4.4 Maximum Payload

The maximum allowed payload of the Robot Arm depends on the *center of gravity offset*, see Figure 4.3. The center of gravity offset is defined as the distance between the center of the tool output flange and the center of gravity of the attached payload.

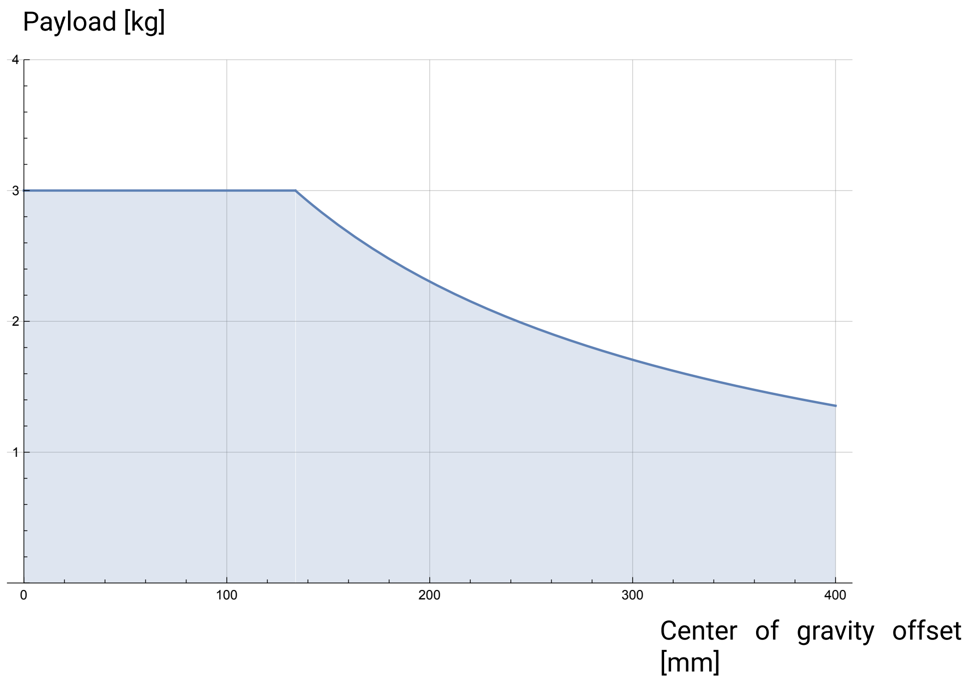


Figure 4.3: The relationship between the maximum allowed payload and the center of gravity offset.

5 Electrical Interface

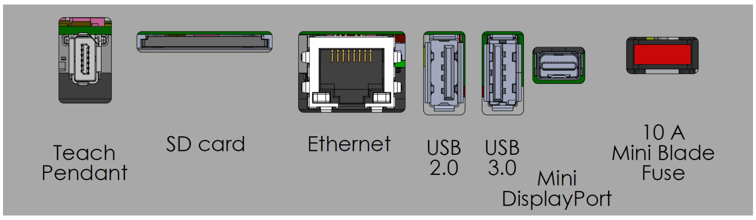
5.1 Introduction

This chapter describes electrical interface groups for the Robot Arm in the Control Box. Examples are given for most types of **I/O**. The term **I/O** refers to both digital and analog control signals to or from the electrical interface groups listed below.

- Mains connection
- Robot connection
- Controller I/O
- Tool I/O
- Ethernet

5.1.1 Control Box Bracket

On the underside of the I/O interface groups, there is a bracket with ports that allows for additional connections (illustrated below). The base of the Control Box has a capped opening for easy connection (see 5.2).



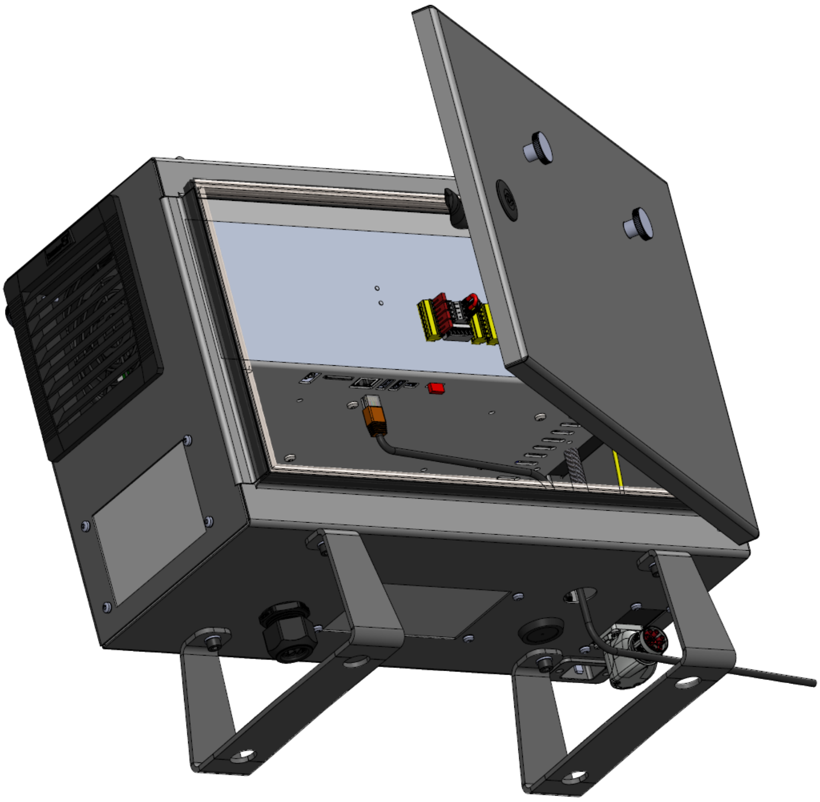
Note: The Fuse must be UL marked, Mini Blade type with maximum current rating: 10A and minimum voltage rating: 32V

5.2 Ethernet

The Ethernet interface can be used for:

- MODBUS, EtherNet/IP and PROFINET (see part II).
- Remote access and control.

To connect the Ethernet cable by passing it through the hole at the base of the Control Box, and plugging it into the Ethernet port on the underside of the bracket.
Replace the cap at the base of the Control Box with an appropriate cable gland to connect the cable to the Ethernet port.



The electrical specifications are shown in the table below.

Parameter	Min	Typ	Max	Unit
Communication speed	10	-	1000	Mb/s

5.3 Electrical Warnings and Cautions

Observe the following warnings for all the aforementioned interface groups, in addition to when the robot application is designed and installed.

DANGER:

1. Never connect safety signals to a PLC which is not a safety PLC with the correct safety level. Failure to follow this warning could result in serious injury or death as the safety functions could be overridden. It is important to keep safety interface signals separated from the normal I/O interface signals.
2. All safety-related signals are constructed redundantly (two independent channels). Keep the two channels separate so that a single fault cannot lead to loss of the safety function.
3. Some I/Os inside the Control Box can be configured for either normal or safety-related I/O. Read and understand the complete section 5.4.

DANGER:

1. Make sure all equipment not rated for water exposure remain dry. If water is allowed to enter the product, lockout-tagout all power and then contact your local Universal Robots service provider for assistance.
2. Only use the original cables supplied with the robot only. Do not use the robot for applications where the cables are subject to flexing. Contact your local Universal Robots service if longer or flexible cables are needed.
3. Negative connections are referred to as Ground (GND) and are connected to the casing of the robot and the Control Box. All mentioned GND connections are only for powering and signalling. For PE (Protective Earth) use the M6-size screw connections marked with earth symbols inside the Control Box. The grounding conductor shall have at least the current rating of the highest current in the system.
4. Use caution when installing interface cables to the robot I/O. The metal plate in the bottom is intended for interface cables and connectors. Remove the plate before drilling holes. Make sure that all shavings are removed before reinstalling the plate. Remember to use correct gland sizes.

CAUTION:

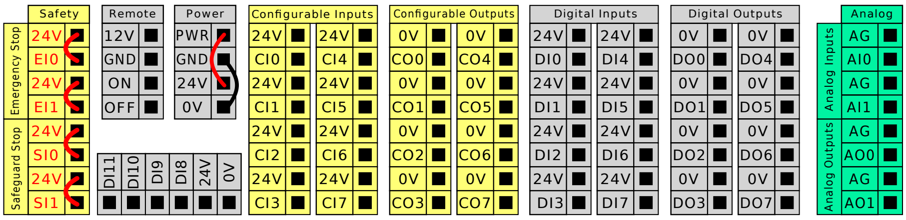
1. The robot has been tested according to international IEC standards for **ElectroMagnetic Compatibility (EMC)**. Disturbing signals with levels higher than those defined in the specific IEC standards can cause unexpected behaviors from the robot. Very high signal levels or excessive exposure can damage the robot permanently. EMC problems are found to happen usually in welding processes and are normally prompted by error messages in the log. Universal Robots cannot be held responsible for any damages caused by EMC problems.
2. I/O cables going from the Control Box to other machinery and factory equipment may not be longer than 30m, unless additional tests are performed.

NOTE:
All voltages and currents are in Direct Current (DC) unless otherwise specified.

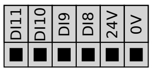
5.4 Controller I/O

You can use the **I/O** inside the Control Box for a wide range of equipment including pneumatic relays, PLCs and emergency stop buttons.

The illustration below shows the layout of electrical interface groups inside the Control Box.



Note: You can use the horizontal Digital Inputs block (DI8-DI11), illustrated below, for quadrature encoding Conveyor Tracking (see 5.4.1) for these types of input.



The meaning of the color schemes listed below must be observed and maintained.

Yellow with red text	Dedicated safety signals
Yellow with black text	Configurable for safety
Gray with black text	General purpose digital I/O
Green with black text	General purpose analog I/O

In the GUI, you can set up **configurable I/O** as either **safety-related I/O** or **general purpose I/O** (see part II).

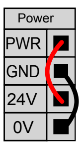
5.4.1 Common specifications for all digital I/O

This section defines electrical specifications for the following 24V digital I/O of the Control Box.

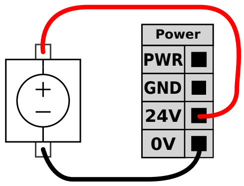
- Safety I/O.
- Configurable I/O.
- General purpose I/O.

Install the robot according to the electrical specifications which are the same for all three inputs.

It is possible to power the digital I/O from an internal 24V power supply or from an external power source by configuring the terminal block called **Power**. This block consists of four terminals. The upper two (PWR and GND) are 24V and ground from the internal 24V supply. The lower two terminals (24V and 0V) in the block are the 24V input to supply the I/O. The default configuration uses the internal power supply (see below).



Note: If more current is needed, connect an external power supply as shown below.



The electrical specifications for both the internal and external power supply are shown below.

Terminals	Parameter	Min	Typ	Max	Unit
Internal 24V power supply					
[PWR - GND]	Voltage	23	24	25	V
[PWR - GND]	Current	0	-	2	A
External 24V input requirements					
[24V - 0V]	Voltage	20	24	29	V
[24V - 0V]	Current	0	-	6	A

The digital I/O are constructed in compliance with IEC 61131-2. The electrical specifications are shown below.

Terminals	Parameter	Min	Typ	Max	Unit
Digital Outputss					
[COx / DOx]	Current*	0	-	1	A
[COx / DOx]	Voltage drop	0	-	0.5	V
[COx / DOx]	Leakage current	0	-	0.1	mA
[COx / DOx]	Function	-	PNP	-	Type
[COx / DOx]	IEC 61131-2	-	1A	-	Type
Digital Inputss					
[EIx/SIx/CIx/DIx]	Voltage	-3	-	30	V
[EIx/SIx/CIx/DIx]	OFF region	-3	-	5	V
[EIx/SIx/CIx/DIx]	ON region	11	-	30	V
[EIx/SIx/CIx/DIx]	Current (11-30V)	2	-	15	mA
[EIx/SIx/CIx/DIx]	Function	-	PNP +	-	Type
[EIx/SIx/CIx/DIx]	IEC 61131-2	-	3	-	Type

*For resistive loads or inductive loads of maximum 1H.

NOTE:
The word **configurable** is used for I/O that is configured as either safety-related I/O or normal I/O. These are the yellow terminals with black text.

5.4.2 Safety I/O

This section describes dedicated safety input (Yellow terminal with red text) and configurable I/O (Yellow terminals with black text) when configured as safety I/O. Follow the Common specifications for all digital I/O in section 5.4.1.
Safety devices and equipment must be installed according to the safety instructions and the risk assessment in chapter 1.

All safety I/O are paired (redundant) and must be kept as two separate branches. A single fault does not cause loss of the safety function.

There are two permanent safety input types:

- **Robot Emergency Stop** for emergency stop equipment only
- **Safeguard Stop** for other safety-related protective equipment.

The functional difference is shown below.

	Emergency Stop	**Safeguard Stop**
Robot stops moving	Yes	Yes
Program execution	Pauses	Pauses
Robot power	Off	On
Reset	Manual	Automatic or manual
Frequency of use	Infrequent	Every cycle to infrequent
Requires re-initialization	Brake release only	No
Stop Category (IEC 60204-1)	1	2
Performance level of monitoring function (ISO 13849-1)	PLd	PLd

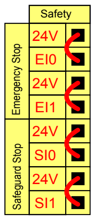
Use the configurable I/O to set up additional safety I/O functionality, e.g. Emergency Stop Output. Configuring a set of configurable I/O for safety functions are done through the GUI, (see `part II`).

DANGER:

1. Never connect safety signals to a PLC that is not a safety PLC with the correct safety level. Failure to follow this warning could result in serious injury or death as the safety functions could be overridden. It is important to keep safety interface signals separated from the normal I/O interface signals.
2. All safety-related I/O are constructed redundantly (two independent channels). Keep the two channels separate so that a single fault cannot lead to loss of the safety function.
3. Safety functions must be verified before putting the robot into operation. Safety functions must be tested regularly.
4. The robot installation shall conform to these specifications. Failure to do so could result in serious injury or death as the safety function could be overridden.

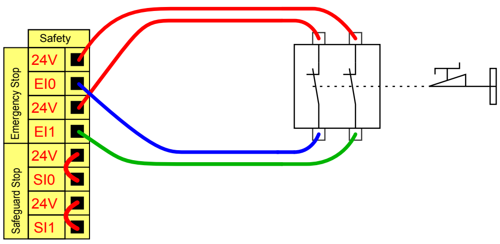
Default safety configuration

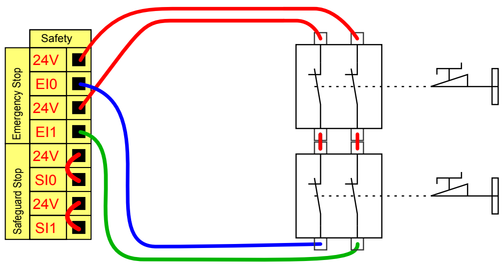
The robot is delivered with a default configuration, which enables operation without any additional safety equipment (see illustration below).



Connecting emergency stop buttons

Most applications require one or more extra emergency stop buttons. The illustration below shows how one or more emergency stop buttons can be connected.



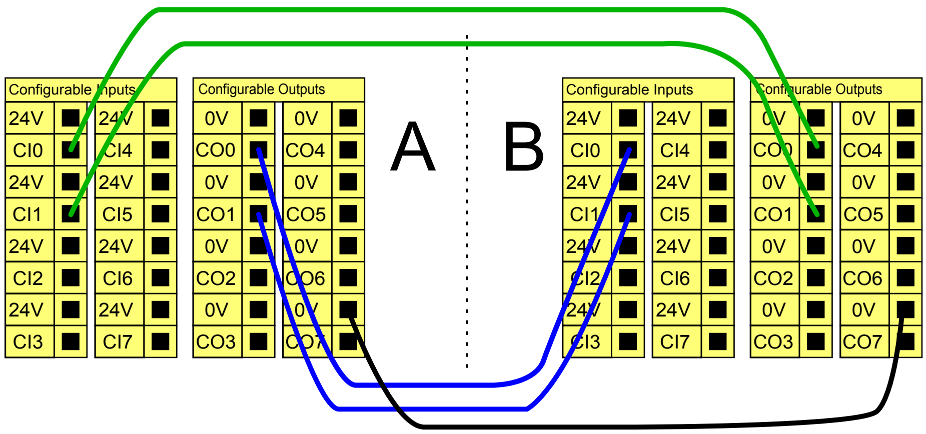


Sharing the Emergency Stop with other machines

You can set up a shared emergency stop function between the robot and other machines by configuring the following I/O functions via the GUI. The Robot Emergency Stop Input cannot be used for sharing purposes. If more than two UR robots or other machines need to be connected, a safety PLC must be used to control the emergency stop signals.

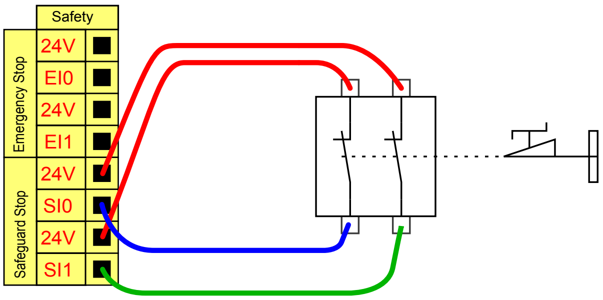
- Configurable input pair: External emergency stop.
- Configurable output pair: System emergency stop.

The illustration below shows how two UR robots share their emergency stop functions. In this example the configured I/Os used are CI0-CI1 and CO0-CO1.



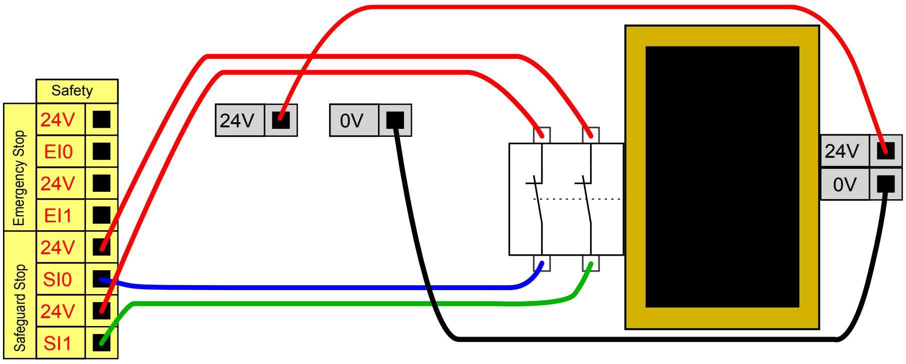
Safeguard stop with automatic resume

An example of a basic safeguard stop device is a door switch where the robot is stopped when a door is opened (see illustration below).



This configuration is only intended for applications where the operator cannot go through the door and close it behind him. The configurable I/O is used to setup a reset button outside the door to reactivate robot motion.

Another example where automatic resume is appropriate is when using a safety mat or a safety-related laser scanner (see below).

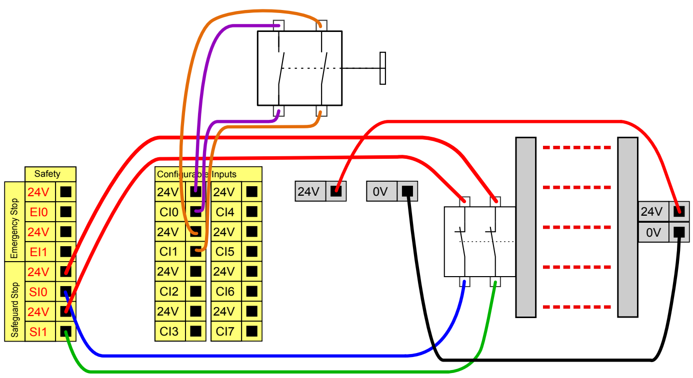


DANGER:

1. The robot resumes movement automatically when the signal is re-established. Do not use this configuration if signal can be re-established from the inside of the safety perimeter.

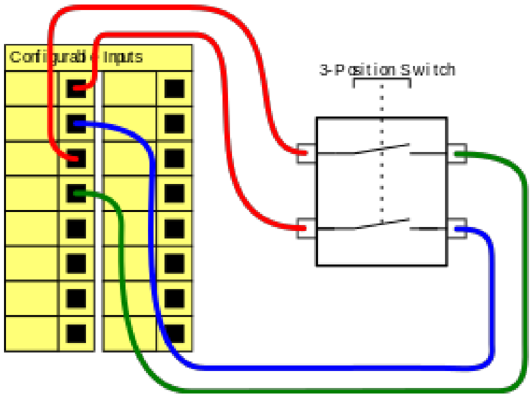
Safeguard Stop with reset button

If the safeguard interface is used to interact with a light curtain, a reset outside the safety perimeter is required. The reset button must be a two channel type. In this example the I/O configured for reset is CI0-CI1 (see below).



3-Position Enabling Device

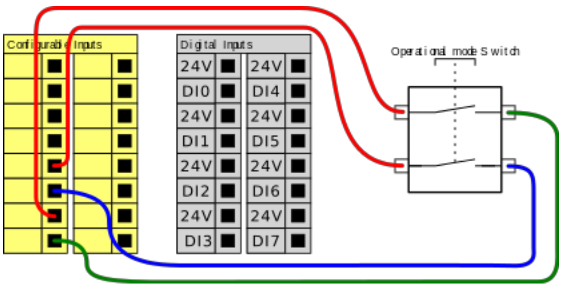
The illustration below shows how to connect a Three-Position Enabling Device. See section 12.2 for more about 3-Position Enabling Device.



NOTE:
The Universal Robots safety system does not support multiple 3-Position Enabling Devices.

Operational Mode Switch

The illustration below shows an Operational Mode Switch. See section 12.1 for more about operational Modes.



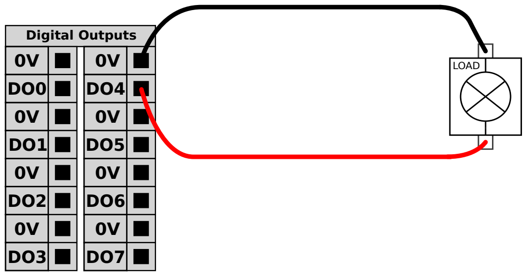
5.4.3 General purpose digital I/O

This section describes the general purpose 24V I/O (Gray terminals) and the configurable I/O (Yellow terminals with black text) when not configured as safety I/O. The common specifications in section 5.4.1 must be observed.

The general purpose I/O can be used t o drive equipment like pneumatic relays directly or for communication with other PLC systems. All Digital Outputss can be disabled automatically when program execution is stopped, see part II. In this mode, the output is always low when a program is not running. Examples are shown in the following subsections. These examples use regular Digital Outputss but any configurable outputs could also have be used if they are not configured to perform a safety function.

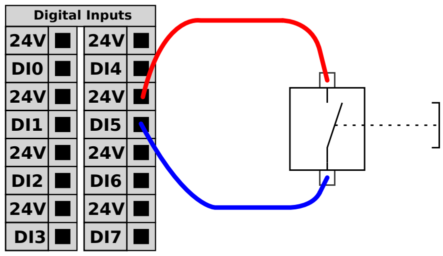
Load controlled by a Digital Outputs

This example shows how a load is controlled from a Digital Outputs when connected.



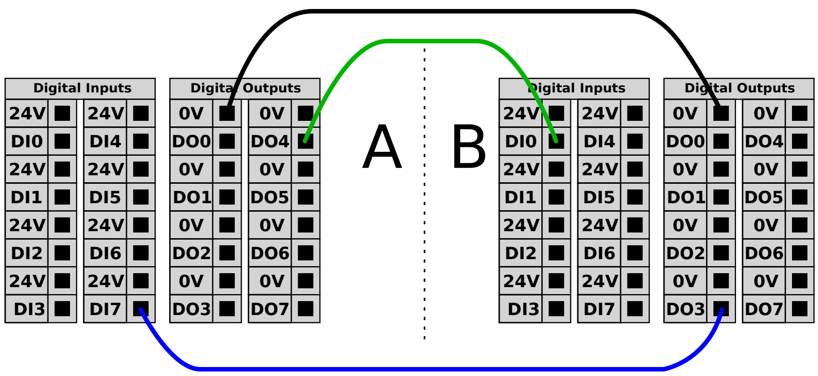
5.4.4 Digital Inputs from a button

This example illustrates connecting a simple button to a Digital Inputs.



5.4.5 Communication with other machines or PLCs

You can use the digital I/O to communicate with other equipment if a common GND (0V) is established and if the machine uses PNP technology, see below.



5.4.6 General purpose analog I/O

The analog I/O interface is the green terminal. It is used to set or measure voltage (0-10V) or current (4-20mA) to and from other equipment.

The following directions is recommended to achieve the highest accuracy.

- Use the AG terminal closest to the I/O. The pair share a common mode filter.
- Use the same GND (0V) for equipment and Control Box. The analog I/O is not galvanically isolated from the Control Box.
- Use a shielded cable or twisted pairs. Connect the shield to the GND terminal at the terminal called **Power**.

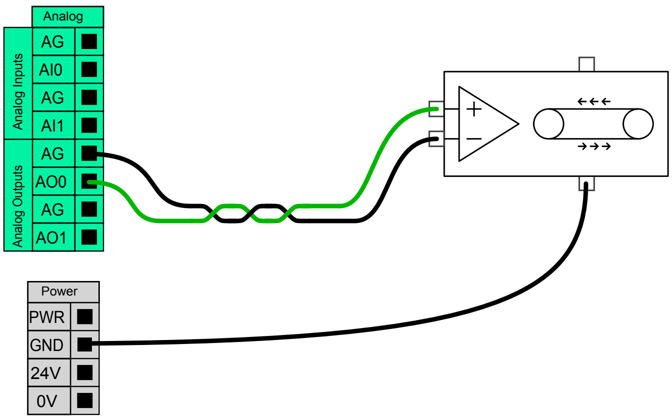
- Use equipment that works in current mode. Current signals are less sensitive to interferences.

In the GUI you can select input modes `(see part II)`. The electrical specifications are shown below.

Terminals	Parameter	Min	Typ	Max	Unit
Analog Input in current mode					
`[AIx - AG]`	Current	4	-	20	mA
`[AIx - AG]`	Resistance	-	20	-	ohm
`[AIx - AG]`	Resolution	-	12	-	bit
Analog Input in voltage mode					
`[AIx - AG]`	Voltage	0	-	10	V
`[AIx - AG]`	Resistance	-	10	-	Kohm
`[AIx - AG]`	Resolution	-	12	-	bit
Analog Output in current mode					
`[AOx - AG]`	Current	4	-	20	mA
`[AOx - AG]`	Voltage	0	-	10	V
`[AOx - AG]`	Resolution	-	12	-	bit
Analog Output in voltage mode					
`[AOx - AG]`	Voltage	0	-	10	V
`[AOx - AG]`	Current	-20	-	20	mA
`[AOx - AG]`	Resistance	-	1	-	ohm
`[AOx - AG]`	Resolution	-	12	-	bit

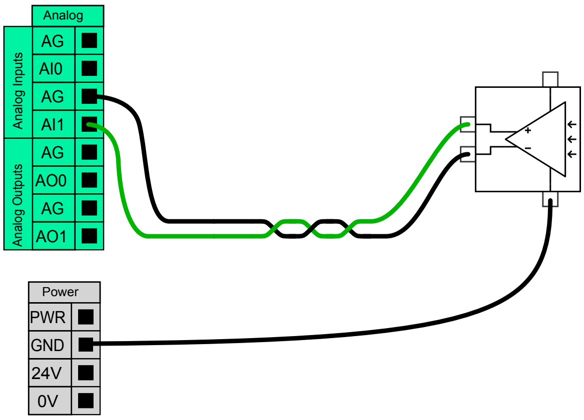
Using an Analog Output

This example illustrates controlling a conveyor belt with an analog speed control input.



Using an Analog Input

This example illustrates connecting an analog sensor.



5.4.7 Remote ON/OFF control

Use remote **ON/OFF** control to turn the Control Box on and off without using the Teach Pendant. It is typically used:

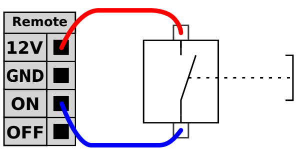
- When the Teach Pendant is inaccessible.
- When a PLC system must have full control.
- When several robots must be turned on or off at the same time.

The remote **ON/OFF** control provides a auxiliary 12V supply, kept active when the Control Box is turned off. The **ON** input is intended only for short time activation and works in the same way as the **POWER** button. The **OFF** input can be held down as desired. The electrical specifications are shown below. Note: Use a software feature to load and start programs automatically `(see part II)`.

Terminals	Parameter	Min	Typ	Max	Unit
`[12V - GND]`	Voltage	10	12	13	V
`[12V - GND]`	Current	-	-	100	mA
`[ON / OFF]`	Inactive voltage	0	-	0.5	V
`[ON / OFF]`	Active voltage	5	-	12	V
`[ON / OFF]`	Input current	-	1	-	mA
`[ON]`	Activation time	200	-	600	ms

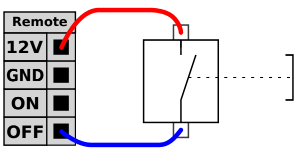
Remote ON button

This example illustrates connecting a remote **ON** button.



Remote OFF button

This example illustrates connecting a remote **OFF** button.

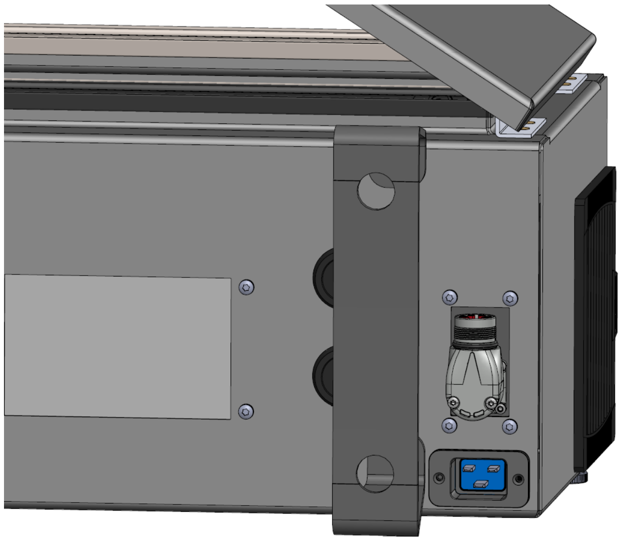


CAUTION:
Do not press and hold the **ON** input or the **POWER** button as it switches off the Control Box without saving. You must use the **OFF** input for remote off control as this signal allows the Control Box to save open files and shut down correctly.

5.5 Mains Connection

The mains cable from the Control Box has a standard IEC plug at the end. Connect a country specific mains plug, or cable, to the IEC plug.

In order to energize the robot, the Control Box must be connected to the mains via the standard IEC C20 plug at the bottom of the Control Box, through a corresponding IEC C19 cord (see illustration below).



The mains supply is equipped with the following:

- Connection to ground
- Main fuse
- Residual current device

It is recommended to install a main switch to power off all equipment in the robot application as an easy means for lockout-tagout under service. The electrical specifications are shown in the table below.

Parameter	Min	Typ	Max	Unit
Input voltage	100	-	265	VAC
External mains fuse (@ 100-200V)	8	-	16	A
External mains fuse (@ 200-265V)	8	-	16	A
Input frequency	47	-	63	Hz
Stand-by power	-	-	<1.5	W
Nominal operating power	90	150	325	W

DANGER:

1. Ensure the robot is grounded correctly (electrical connection to ground). Use the unused bolts associated with grounding symbols inside the Control Box to create common grounding of all equipment in the system. The grounding conductor shall have at least the current rating of the highest current in the system.
2. Ensure the input power to the Control Box is protected with a Residual Current Device (RCD) and a correct fuse.
3. Lockout-tagout all power for the complete robot installation during service. Other equipment shall not supply voltage to the robot I/O when the system is locked out.
4. Ensure all cables are connected correctly before the Control Box is powered. Always use the original power cord.

5.6 Robot Connection

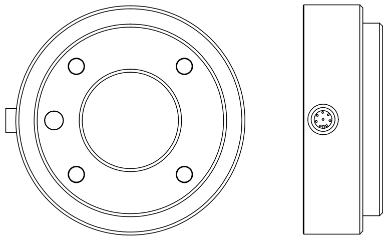
Plug and lock the cable from the robot into the connector at the bottom of the Control Box (see illustration below). Twist the connector twice to ensure it is properly locked before turning on the Robot Arm.
Turn the connector to the right to make it easier to lock after the cable is plugged in.

CAUTION:

1. Do not disconnect Robot Cable when Robot Arm is turned on.
2. Do not extend or modify original cable.

5.7 Tool I/O

Adjacent to the tool flange on Wrist #3, there is an eight-pinned connector that provides power and control signals for different grippers and sensors that can be attached to the robot. Lumberg KKMV 8-354 is a suitable industrial cable. Each of the eight wires inside the cable have different colors representing different functions.



This connector provides power and control signals for grippers and sensors used on a specific robot tool. The industrial cable listed below is suitable:

- Lumberg RKMV 8-354.

The eight wires inside the cable have different colors that designate different functions. See table below:

Color	Signal	Description
Red	GND	Ground
Gray	PWR	0V/12V/24V
Blue	DO0	Digital Outputs 0
Pink	DO1	Digital Outputs 1
Yellow	DI0	Digital Inputs 0
Green	DI1	Digital Inputs 1
White	AI2 / RS485+	Analog in 2 or RS485+
Brown	AI3 / RS485-	Analog in 3 or RS485-

Set the internal power supply to 0V, 12V or 24V in the I/O tab of the GUI (see part II). The electrical specifications are shown below:

Parameter	Min	Type	Max	Unit
Supply voltage in 24V mode	23.5	24	24.8	V
Supply voltage in 12V mode	11.5	12	12.5	V
Supply current in both modes*	-	600	2000**	mA

*It is highly recommended to use a protective diode for inductive loads
**2000 mA for max 1 second. Duty cycle max: 10%. Average current must not exceed 600 mA

The following sections describe the different tool I/O.

NOTE:
The tool flange is connected to GND (same as the red wire).

5.7.1 Tool Digital Outputs

Digital Outputs are implemented as NPN. When Digital Outputs is activated, the corresponding connection is driven to GND and when it is deactivated the corresponding connection is open (open-collector/open-drain). The electrical specifications are shown below:

Parameter	Min	Typ	Max	Unit
Voltage when open	-0.5	-	26	V
Voltage when sinking 1A	-	0.08	0.09	V
Current when sinking	0	600	1000	mA
Current through GND	0	600	3000*	mA

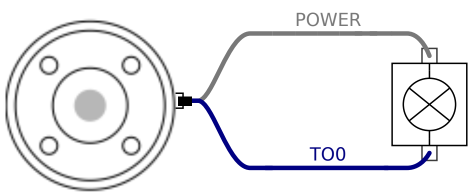
*3000 mA for max 1 second. Duty cycle max: 10%. Average current must not exceed 600 mA

CAUTION:

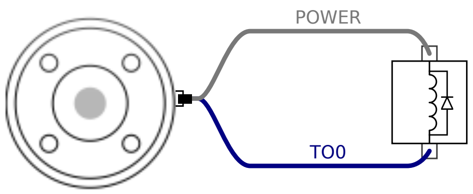
1. The Digital Outputs in the tool are not current-limited. Overriding the specified data can cause permanent damage.

Using Tool Digital Outputs

This example illustrates turning on a load using the internal 12V or 24V power supply. The output voltage at the I/O tab must be define. There is voltage between the POWER connection and the shield/ground, even when the load is turned off.



It is recommended to use a protective diode for inductive loads, as shown below.



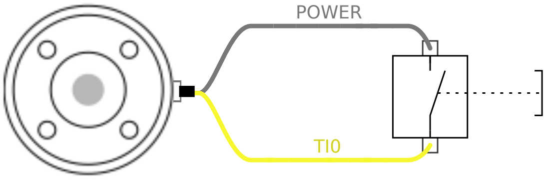
5.7.2 Tool Digital Inputs

The Digital Inputs are implemented as PNP with weak pull-down resistors. This means that a floating input always reads as low. The electrical specifications are shown below.

Parameter	Min	Type	Max	Unit
Input voltage	-0.5	-	26	V
Logical low voltage	-	-	2.0	V
Logical high voltage	5.5	-	-	V
Input resistance	-	47k	-	Ω

Using the Tool Digital Inputs

This example illustrates connecting a simple button.



5.7.3 Tool Analog Input

Tool Analog Input are nondifferential and can be set to either voltage (0-10V) or current (4-20mA) on the I/O tab (see `part II`). The electrical specifications are shown below.

Parameter	Min	Type	Max	Unit
Input voltage in voltage mode	-0.5	-	26	V
Input resistance @ range 0V to 10V	-	10.7	-	kΩ
Resolution	-	12	-	bit
Input voltage in current mode	-0.5	-	5.0	V
Input current in current mode	-2.5	-	25	mA
Input resistance @ range 4mA to 20mA	-	182	188	Ω
Resolution	-	12	-	bit

Two examples of using Analog Input are shown in the following subsections.

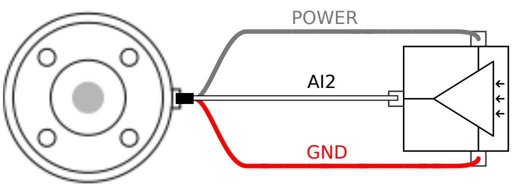
CAUTION:

1. Analog Inputs are not protected against overvoltage in current mode. Exceeding the limit in the electrical specification can cause permanent damage to the input.

Using Tool Analog Inputs, Nondifferential

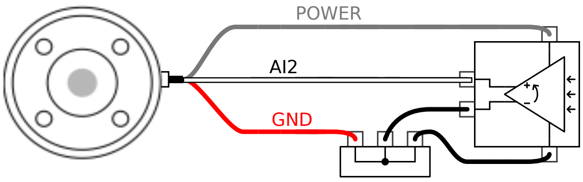
This example shows an analog sensor connection with a nondifferential output. The sensor output can be either current or voltage, as long as the input mode of that Analog Input is set to the same on the I/O tab.

Note: You can check that a sensor with voltage output can drive the internal resistance of the tool, or the measurement might be invalid.



Using Tool Analog Inputs, Differential

This example shows an analog sensor connection with a differential output. Connecting the negative output part to GND (0V), works in the same way as a nondifferential sensor.



5.7.4 Tool Communication I/O

- **Signal requests** The RS485 signals use internal fail-safe biasing. If the attached device does not support this fail-safe, signal biasing must either be done in the attached tool, or added externally by adding pull-up resistors to RS485+ and pull-down to RS485-.
- **Latency** The latency of messages sent via the tool connector ranges from 2ms to 4ms, from the time the message is written on the PC to the start of the message on the RS485. A buffer stores data sent to the tool connector until the line goes idle. Once 1000 bytes of data have been received, the message is written on the device.

Baud Rates	9.6k, 19.2k, 38.4k, 57.6k, 115.2k, 1M, 2M, 5M
Stop Bits	1, 2
Parity	None, Odd, Even

6 Maintenance and Repair

You must perform maintenance and repair work in compliance with all safety instructions in this manual.

You must perform maintenance, calibration and repair work according to the latest versions of Service Manuals on the support website `http://www.universal-robots.com/support`.

Only authorized system integrators, or Universal Robots, shall perform repairs.

All parts returned to Universal Robots shall be returned according to the service manual.

6.1 Safety Instructions

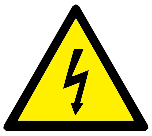
After maintenance and repair work, checks must be done to ensure the required safety level. Checks must adhere to valid national or regional work safety regulations. The correct functioning of all safety functions shall also be tested.

The purpose of maintenance and repair work is to ensure that the system is kept operational or, in the event of a fault, to return the system to an operational state. Repair work includes troubleshooting in addition to the actual repair itself.

When working on the robot arm or control box, you must observe the procedures and warnings below.

DANGER:

1. Do not change anything in the safety configuration of the software (e.g. the force limit). The safety configuration is described in the PolyScope Manual. If any safety parameter is changed, the complete robot system shall be considered new, meaning that the overall safety approval process, including risk assessment, shall be updated accordingly.
2. Replace faulty components using new components with the same article numbers or equivalent components approved by Universal Robots for this purpose.
3. Reactivate any deactivated safety measures immediately after the work is completed.
4. Document all repairs and save this documentation in the technical file associated with the complete robot system.



DANGER:

1. Remove the mains input cable from the bottom of the control box to ensure that it is completely unpowered. Deenergize any other source of energy connected to the robot arm or control box. Take necessary precautions to prevent other persons from energizing the system during the repair period.
2. Check the earth connection before re-powering the system.
3. Observe ESD regulations when parts of the robot arm or control box are disassembled.
4. Avoid disassembling the power supplies inside the control box. High voltages (up to 600 V) can be present inside these power supplies for several hours after the control box has been switched off.
5. Prevent water and dust from entering the robot arm or control box.

7 Disposal and Environment

Universal Robots e-Series robots must be disposed of in accordance with the applicable national laws, regulations and standards.

Universal Robots e-Series robots are produced with restricted use of hazardous substances to protect the environment; as defined by the European RoHS directive 2011/65/EU. These substances include mercury, cadmium, lead, chromium VI, polybrominated biphenyls and polybrominated diphenyl ethers.

Fee for disposal and handling of electronic waste of Universal Robots e-Series robots sold on the Danish market is prepaid to DPA-system by Universal Robots A/S. Importers in countries covered by the European WEEE Directive 2012/19/EU must make their own registration to the national WEEE register of their country. The fee is typically less than 1€/robot. A list of national registers can be found here: `https://www.ewrn.org/national-registers`.

The following symbols are affixed on the robot to indicate conformity with the above legislations:

8 Certifications

This chapter presents certificates and declarations prepared for the product.

8.1 Third Party Certification

Third party certification is voluntary. However, to provide the best service to robot integrators, UR chooses to certify our robots at the following recognized test institutes:

TÜV NORD Universal Robots e-Series robots are safety approved by TÜV NORD, a notified body under the machinery directive 2006/42/EC in EU. You can find a copy of the TÜV NORD safety approval certificate in `appendix B`.

DELTA URUniversal Robots e-Series robots are performance tested by DELTA. You can find electromagnetic compatibility (EMC) and environmental test certificates in `appendix B`.

CHINA RoHS Universal Robots e-Series robots conform to CHINA RoHS management methods for controlling pollution by electronic information products.

8.2 Supplier Third Party Certification

Environment As provided by our suppliers, Universal Robots e-Series robots shipping pallets comply with the ISMPM-15 Danish requirements for producing wood packaging material and are marked in accordance with this scheme.

8.3 Manufacturer Test Certification

UR Universal Robots e-Series robots undergo continuous internal testing and end of line test procedures. UR testing processes undergo continuous review and improvement.

8.4 Declarations According to EU directives

Although they are primarily relevant for Europe, some countries outside Europe recognize and/or require **EU declarations**. European directives are available on the official homepage: `http://eur-lex.europa.eu`.

UR robots are certified according to the directives listed below.

2006/42/EC — Machinery Directive (MD)

According to the Machinery Directive 2006/42/EC, Universal Robots e-Series robots are **partly completed machinery**, as such a **CE** mark is not affixed.

If the UR robot is used in a pesticide application, you must note the presence of directive 2009/127/EC.

The declaration of incorporation according to 2006/42/EC annex II 1.B. is shown in `appendix B`.

2006/95/EC — Low Voltage Directive (LVD)

2004/108/EC — Electromagnetic Compatibility (EMC)

2011/65/EU — Restriction of the use of certain Hazardous Substances (RoHS)

2012/19/EU — Waste of Electrical and Electronic Equipment (WEEE)

In the Declaration of Incorporation in `appendix B`, declarations of conformity with the above directives are listed.

A **CE** mark is affixed according to the **CE** marking directives above. Information on both electric and electronic equipment waste is in `chapter 7`.

Information on standards applied during the development of the robot is in `appendix C`.

9 Warranties

9.1 Product Warranty

Without prejudice to any claim the user (customer) may have in relation to the dealer or retailer, the customer shall be granted a manufacturer's Warranty under the conditions set out below:

In the case of new devices and their components exhibiting defects resulting from manufacturing and/or material faults within 12 months of entry into service (maximum of 15 months from shipment), Universal Robots shall provide the necessary spare parts, while the user (customer) shall provide working hours to replace the spare parts, either replace the part with another part reflecting the current state of the art, or repair the said part. This Warranty shall be invalid if the device defect is attributable to improper treatment and/or failure to comply with information contained in the user guides. This Warranty shall not apply to or extend to services performed by the authorized dealer or the customer themselves (e.g. installation, configuration, software downloads). The purchase receipt, together with the date of purchase, shall be required as evidence for invoking the Warranty. Claims under the Warranty must be submitted within two months of the Warranty default becoming evident. Ownership of devices or components replaced by and returned to Universal Robots shall vest in Universal Robots. Any other claims resulting out of or in connection with the device shall be excluded from this Warranty. Nothing in this Warranty shall attempt to limit or exclude a Customer's Statutory Rights nor the manufacturer's liability for death or personal injury resulting from its negligence. The duration of the Warranty shall not be extended by services rendered under the terms of the Warranty. Insofar as no Warranty default exists, Universal Robots reserves the right to charge the customer for replacement or repair. The above provisions do not imply a change in the burden of proof to the detriment of the customer. In case of a device exhibiting defects, Universal Robots shall not be liable for any indirect, incidental, special or consequential damages, including but not limited to, lost profits, loss of use, loss of production or damage to other production equipment.

In case of a device exhibiting defects, Universal Robots shall not cover any consequential damage or loss, such as loss of production or damage to other production equipment.

9.2 Disclaimer

Universal Robots continues to improve reliability and performance of its products, and therefore reserves the right to upgrade the product without prior warning. Universal Robots takes every care that the contents of this manual are precise and correct, but takes no responsibility for any errors or missing information.

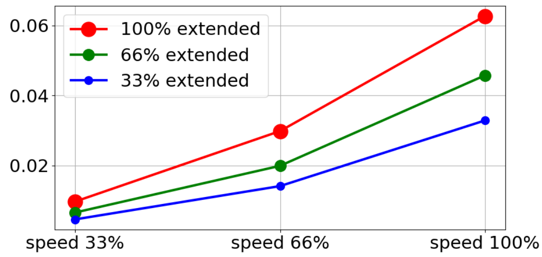
A Stopping Time and Stopping Distance

The graphical data provided for **Joint 0 (base)**, **Joint 1 (shoulder)** and **Joint 2 (elbow)** is valid for stopping distance and stopping time:

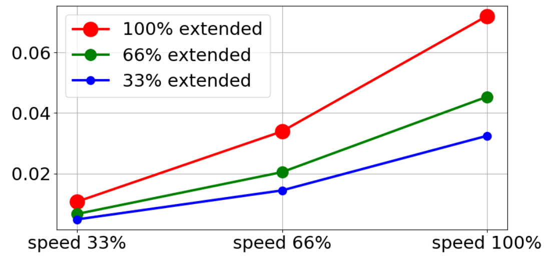
- Category 0
- Category 1
- Category 2

Note: These values represent a worst case scenario; your values will be different.

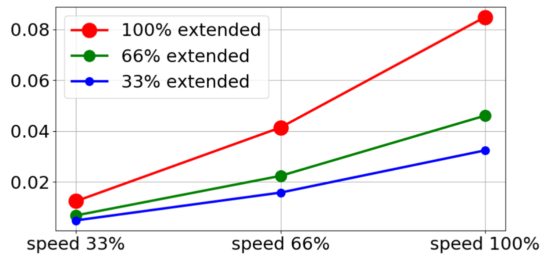
The **Joint 0** test was carried out by performing a horizontal movement, where the rotational axis was perpendicular to the ground.
During the **Joint 1** and **Joint 2** tests, the robot followed a vertical trajectory, where the rotational axes were parallel to the ground, and the stop was performed while the robot was moving downward.



(a) Stopping distance in meters for 33% of maximum payload

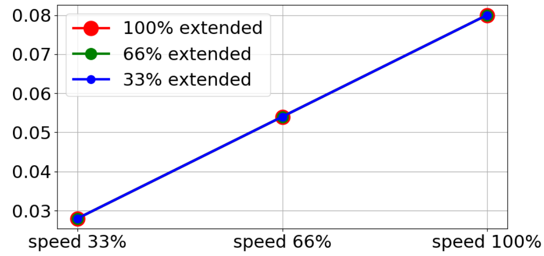


(b) Stopping distance in meters for 66% of maximum payload

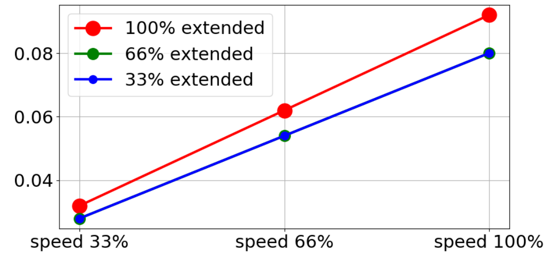


(c) Stopping distance in meters for maximum payload

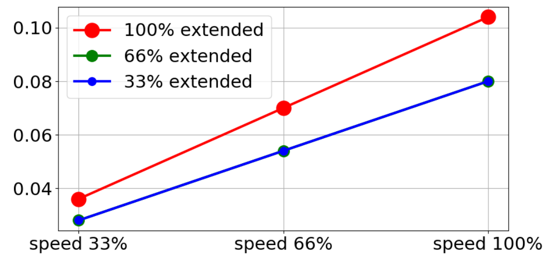
Figure A.1: Stopping distance for joint 0 (BASE)



(a) Stopping time in seconds for 33% of maximum payload

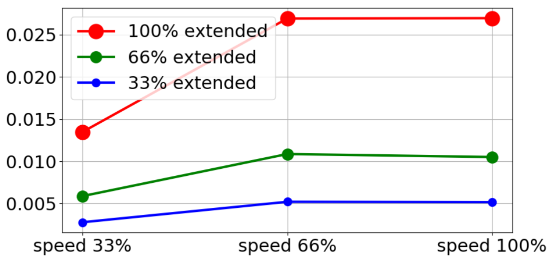


(b) Stopping time in seconds for 66% of maximum payload

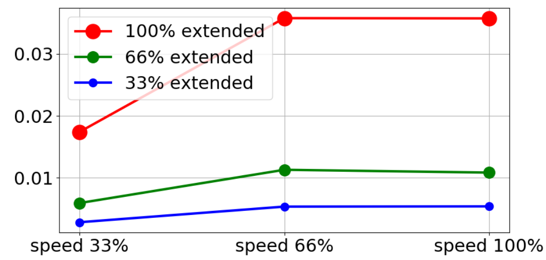


(c) Stopping time in seconds for maximum payload

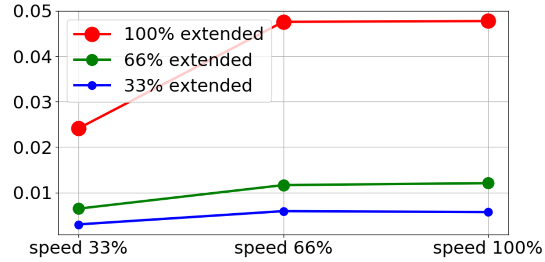
Figure A.2: Stopping time for joint 0 (BASE)



(a) Stopping distance in meters for 33% of maximum payload

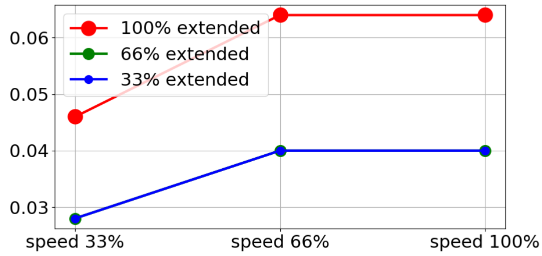


(b) Stopping distance in meters for 66% of maximum payload

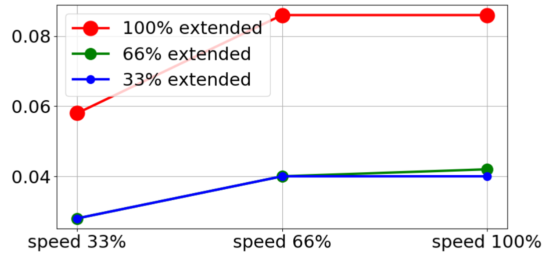


(c) Stopping distance in meters for maximum payload

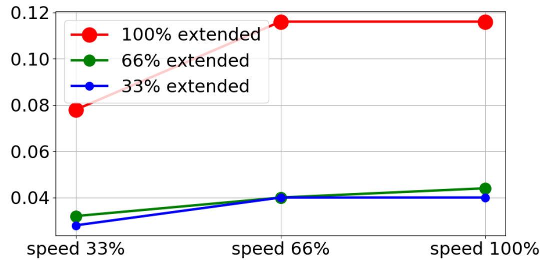
Figure A.3: Stopping distance for joint 1 (SHOULDER)



(a) Stopping time in seconds for 33% of maximum payload

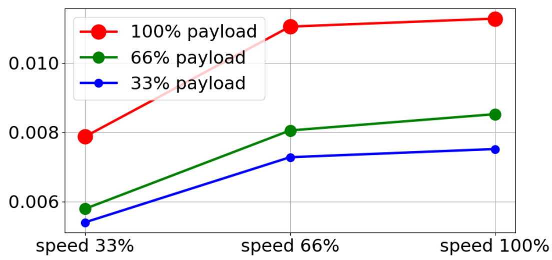


(b) Stopping time in seconds for 66% of maximum payload

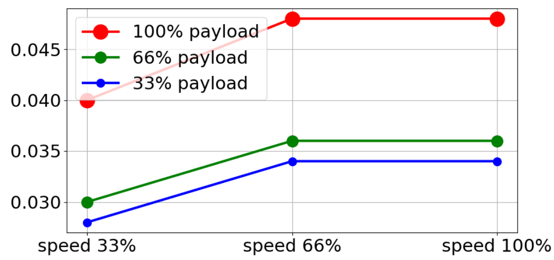


(c) Stopping time in seconds for maximum payload

Figure A.4: Stopping time for joint 1 (SHOULDER)



(a) Stopping distance in meters for all payloads



(b) Stopping time in seconds for all payloads

Figure A.5: Stopping distance and time for joint 2 (ELBOW)

B Declarations and Certificates

B.1 CE/EU Declaration of Incorporation (original)

According to European Directive 2006/42/EC annex II 1.B.

The manufacturer Universal Robots A/S
Energivej 25
5260 Odense S
Denmark

hereby declares that the product described below

Industrial robot UR3e/CB3

may not be put into service before the machinery in which it will be incorporated is declared in conformity with the provisions of Directive 2006/42/EC, as amended by Directive 2009/127/EC, and with the regulations transposing it into national law.

The safety features of the product are prepared for compliance with all essential requirements of Directive 2006/42/EC under the correct incorporation conditions, see product manual. Compliance with all essential requirements of Directive 2006/42/EC relies on the specific robot installation and the final risk assessment.

Relevant technical documentation is compiled according to Directive 2006/42/EC annex VII part B and available in electronic form to national authorities upon legitimate request. Undersigned is based on the manufacturer address and authorised to compile this documentation.

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

2014/35/EU — Low Voltage Directive (LVD)
2014/30/EU — Electromagnetic Compatibility Directive (EMC)
2011/65/EU — Restriction of the use of certain hazardous substances (RoHS)

A complete list of applied harmonized standards, including associated specifications, is provided in the product manual.

Odense, April 20th, 2016

R&D
David Brandt
Technology Officer

B.2 Safety System Certificate

ZERTIFIKAT
CERTIFICATE

Hiermit wird bescheinigt, dass die Firma / *This certifies that the company*

Universal Robots A/S
Energivej 25
DK-5260 Odense S
Denmark

berechtigt ist, das unten genannte Produkt mit dem abgebildeten Zeichen zu kennzeichnen
is authorized to provide the product mentioned below with the mark as illustrated

Fertigungsstätte *Manufacturing plant*	**Universal Robots A/S** **Energivej 25** **DK-5260 Odense S** **Denmark**
Beschreibung des Produktes (Details s. Anlage 1) *Description of product* *(Details see Annex 1)*	**Industrial robot UR10e, UR5e and UR3e**
Geprüft nach *Tested in accordance with*	**EN ISO 10218-1:2011**

TÜV NORD CERT GmbH Type Tested

Registrier-Nr. / *Registered No.* 44 780 14097607
Prüfbericht Nr. / *Test Report No.* . 3520 4429, 3522 2109
Aktenzeichen / *File reference* 8000484576

Gültigkeit / Validity
von / *from* 2018-05-14
bis / *until* 2023-05-13

Zertifizierungsstelle der
TÜV NORD CERT GmbH

Essen, 2018-05-14

TÜV NORD CERT GmbH Langemarckstraße 20 45141 Essen www.tuev-nord-cert.de technology@tuev-nord.de

Bitte beachten Sie auch die umseitigen Hinweise
Please also pay attention to the information stated overleaf

TÜV NORD

ZERTIFIKAT
CERTIFICATE

Hiermit wird bescheinigt, dass die Firma / *This is to certify, that the company*

Universal Robots A/S
Energivej 25
DK-5260 Odense S
Denmark

berechtigt ist, das unten genannte Produkt mit dem abgebildeten Zeichen zu kennzeichnen.
is authorized to provide the product described below with the mark as illustrated.

Fertigungsstätte: *Manufacturing plant:*	**Universal Robots A/S** **Energivej 25** **DK-5260 Odense S** **Denmark**
Beschreibung des Produktes (Details s. Anlage 1) *Description of product* *(Details see Annex 1)*	**Universal Robots Safety System G5** **for UR10e, UR5e and UR3e robots**
Geprüft nach: *Tested in accordance with:*	**EN ISO 13849-1:2015, Cat.3, PL d**

TÜV NORD
TÜV NORD CERT GmbH
Approved Safety Function
acc. to applied safety standards
EN ISO 13849-1
PL 'd'

Registrier-Nr. / *Registered No.* 44 207 14097610
Prüfbericht Nr. / *Test Report No.* 3520 1327 / 3522 2247
Aktenzeichen / *File reference* 8000484576

Gültigkeit / Validity
von / *from* 2018-05-14
bis / *until* 2023-05-13

Zertifizierungsstelle der TÜV NORD CERT GmbH
Certification body of TÜV NORD CERT GmbH

Essen, 2018-05-14

TÜV NORD CERT GmbH   Langemarckstraße 20   45141 Essen   www.tuev-nord-cert.de   technology@tuev-nord.de

Bitte beachten Sie auch die umseitigen Hinweise
Please also pay attention to the information stated overleaf

B.3 Environmental Test Certificate

Climatic and mechanical assessment

DELTA A PART OF FORCE TECHNOLOGY

Client	Force Technology project no.
Universal Robots A/S Energivej 25 5260 Odense S Denmark	117-32120

Product identification

UR 3 robot arms
UR 3 control boxes with attached Teach Pendants.
UR 5 robot arms
UR5 control boxes with attached Teach Pendants.
UR10 robot arms:
UR10 control boxes with attached Teach Pendants.
See reports for details.

Force Technology report(s)

DELTA project no. 117-28266, DANAK-19/18069
DELTA project no. 117-28086, DANAK-19/17068

Other document(s)

Conclusion

The three robot arms UR3, UR5 and UR10 including their control boxes and Teach Pendants have been tested according to the below listed standards. The test results are given in the Force Technology reports listed above. The tests were carried out as specified and the test criteria for environmental tests were fulfilled in general terms with only a few minor issues (see test reports for details).

IEC 60068-2-1, Test Ae; -5 ℃, 16 h
IEC 60068-2-2, Test Be; +35°C, 16h
IEC 60068-2-2, Test Be; +50℃, 16 h
IEC 60068-2-64, Test Fh; 5 – 10 Hz: +12 dB/octave, 10-50 Hz 0.00042 g²/Hz, 50 – 100 Hz: -12 dB/octave, 1,66 grms, 3 x 1½ h
IEC 60068-2-27, Test Ea, Shock; 11 g, 11 ms, 3 x 18 shocks

Date	Assessor
Hørsholm, 25 August 2017	Andreas Wendelboe Højsgaard M.Sc.Eng.

DELTA – a part of FORCE Technology - Venlighedsvej 4 - 2970 Hørsholm - Denmark - Tel. +45 72 19 40 00 - Fax +45 72 19 40 01 - www.delta.dk

B.4 EMC Test Certificate

DELTA

A PART OF FORCE TECHNOLOGY

Attestation of Conformity

AoC no. 1645

Project / task no. 117-29565

DELTA has performed compliance test on electrical products since 1967. DELTA is an accredited test house according to EN17025 and participates in the international standardisation organisation CEN/CENELEC, IEC/CISPR and ETSI. This attestation of conformity with the below mentioned standards and/or normative documents is based on accredited tests and/or technical assessments carried out at DELTA – a part of FORCE Technology.

Client

Universal Robots A/S
Energivej 25
5260 Odense
Denmark

Product identification (type(s), serial no(s).)
UR robot generation 5, G5 for models UR3, UR5, and UR10

Manufacturer
Universal Robots A/S

Technical report(s)
EMC test of UR robot generation 5, DELTA project no.117-29565-1 DANAK 19/18171

Standards/Normative documents
EMC Directive 2014/30/EU, Article 6
EN 61326-3-1:2008 Industrial locations SIL 2
EN/(IEC) 61000-6-1:2007
EN/(IEC) 61000-6-2:2005
EN/(IEC) 61000-6-3:2007+A1
EN/(IEC) 61000-6-4:2007+A1
EN/(IEC) 61000-3-2:2014
EN/(IEC) 61000-3-3:2013

The product identified above has been assessed and complies with the specified standards/normative documents. The attestation does not include any market surveillance. It is the responsibility of the manufacturer that mass-produced apparatus have the same properties and quality. This attestation does not contain any statements pertaining to the requirements pursuant to other standards, directives or laws other than the above mentioned.

DELTA – a part of
FORCE Technology
Venlighedsvej 4
2970 Hørsholm
Denmark

Tel. +45 72 19 40 00
Fax +45 72 19 40 01
www.delta.dk
VAT No. 55117314

Hørsholm, 15 August 2017

Michael Nielsen
Specialist, Product Compliance

20aoctest-uk-j

C Applied Standards

This section describes relevant standards applied under the development of the robot arm and control box. Whenever a European Directive number is noted in brackets, it indicates that the standard is harmonized according to that Directive.

A standard is not a law. A standard is a document developed by stakeholders within a given industry, defining the normal safety and performance requirements for a product or product group.

Abbreviations mean the following:

ISO	International Standardization Organization
IEC	International Electrotechnical Commission
EN	European Norm
TS	Technical Specification
TR	Technical Report
ANSI	American National Standards Institute
RIA	Robotic Industries Association
CSA	Canadian Standards Association

Conformity with the following standards is only guaranteed if all assembly instructions, safety instructions and guidance in this manual are followed.

ISO 13849-1:2006 [PLd]
ISO 13849-1:2015 [PLd]
ISO 13849-2:2012
EN ISO 13849-1:2008 (E) [PLd – 2006/42/EC]
EN ISO 13849-2:2012 (E) (2006/42/EC)

Safety of machinery – Safety-related parts of control systems

Part 1: General principles for design

Part 2: Validation

The safety control system is designed as Performance Level d (PLd) according to the requirements of these standards.

ISO 13850:2006 [Stop Category 1]
ISO 13850:2015 [Stop Category 1]
EN ISO 13850:2008 (E) [Stop Category 1 - 2006/42/EC]
EN ISO 13850:2015 [Stop Category 1 - 2006/42/EC]

Safety of machinery – Emergency stop – Principles for design

The emergency stop function is designed as a Stop Category 1 according to this standard. Stop Category 1 is a controlled stop with power to the motors to achieve the stop and then removal of power when the stop is achieved.

ISO 12100:2010
EN ISO 12100:2010 (E) [2006/42/EC]

Safety of machinery – General principles for design – Risk assessment and risk reduction

UR robots are evaluated according to the principles of this standard.

ISO 10218-1:2011
EN ISO 10218-1:2011(E) [2006/42/EC]

Robots and robotic devices – Safety requirements for industrial robots

Part 1: Robots

This standard is intended for the robot manufacturer, not the integrator. The second part (ISO 10218-2) is intended for the robot integrator, as it deals with the installation and design of the robot application.

ANSI/RIA R15.06-2012

Industrial Robots and Robot Systems – Safety Requirements

This American standard is the ISO standards ISO 10218-1 and ISO 10218-2 combined into one document. The language is changed from British English to American English, but the content is the same.

Note that part two (ISO 10218-2) of this standard is intended for the integrator of the robot system, and not Universal Robots.

CAN/CSA-Z434-14

Industrial Robots and Robot Systems – General Safety Requirements

This Canadian standard is the ISO standards ISO 10218-1 (see above) and -2 combined into one document. CSA added additional requirements for the user of the robot system. Some of these requirements might need to be addressed by the robot integrator.

Note that part two (ISO 10218-2) of this standard is intended for the integrator of the robot system, and not Universal Robots.

IEC 61000-6-2:2005
IEC 61000-6-4/A1:2010
EN 61000-6-2:2005 [2004/108/EC]
EN 61000-6-4/A1:2011 [2004/108/EC]

Electromagnetic compatibility (EMC)

Part 6-2: Generic standards - Immunity for industrial environments

Part 6-4: Generic standards - Emission standard for industrial environments

These standards define requirements for the electrical and electromagnetic disturbances. Conforming to these standards ensures that the UR robots perform well in industrial environments and that they do not disturb other equipment.

IEC 61326-3-1:2008
EN 61326-3-1:2008

Electrical equipment for measurement, control and laboratory use - EMC requirements

Part 3-1: Immunity requirements for safety-related systems and for equipment intended to perform safety-related functions (functional safety) - General industrial applications

This standard defines extended EMC immunity requirements for safety-related functions. Conforming to this standard ensures that the safety functions of UR robots provide safety even if other equipment exceeds the EMC emission limits defined in the IEC 61000 standards.

IEC 61131-2:2007 (E)
EN 61131-2:2007 [2004/108/EC]

Programmable controllers

Part 2: Equipment requirements and tests

Both normal and safety-rated 24V I/Os are constructed according to requirements of this standard to ensure reliable communication with other PLC systems.

ISO 14118:2000 (E)
EN 1037/A1:2008 [2006/42/EC]

Safety of machinery – Prevention of unexpected start-up

These two standards are very similar. They define safety principles for avoiding unexpected start-up, both as a result of unintended repowering during maintenance or repair, and as a result of unintended start-up commands from a control perspective.

IEC 60947-5-5/A1:2005
EN 60947-5-5/A11:2013 [2006/42/EC]

Low-voltage switchgear and controlgear

Part 5-5: Control circuit devices and switching elements - Electrical emergency stop device with mechanical latching function

The direct opening action and the safety lock mechanism of the emergency stop button comply with requirements in this standard.

IEC 60529:2013
EN 60529/A2:2013

Degrees of protection provided by enclosures (IP Code)

This standard defines enclosure ratings regarding protection against dust and water. UR robots are designed and classified with an IP code according to this standard, see robot sticker.

IEC 60320-1/A1:2007
IEC 60320-1:2015
EN 60320-1/A1:2007 [2006/95/EC]
EN 60320-1:2015

Appliance couplers for household and similar general purposes

Part 1: General requirements

The mains input cable complies with this standard.

ISO 9409-1:2004 [Type 50-4-M6]

Manipulating industrial robots – Mechanical interfaces

Part 1: Plates

The tool flange on UR robots conforms to type 50-4-M6 of this standard. Robot tools should also be constructed according to this standard to ensure proper fitting.

ISO 13732-1:2006
EN ISO 13732-1:2008 [2006/42/EC]

Ergonomics of the thermal environment – Methods for the assessment of human responses to contact with surfaces

Part 1: Hot surfaces

The UR robots are designed so that the surface temperature is kept under the ergonomic limits defined in this standard.

IEC 61140/A1:2004
EN 61140/A1:2006 [2006/95/EC]

Protection against electric shock – Common aspects for installation and equipment

UR robots are constructed in compliance with this standard to provide protection against electrical shock. A protective earth/ground connection is mandatory, as defined in the Hardware Installation Manual.

IEC 60068-2-1:2007
IEC 60068-2-2:2007
IEC 60068-2-27:2008
IEC 60068-2-64:2008
EN 60068-2-1:2007
EN 60068-2-2:2007
EN 60068-2-27:2009
EN 60068-2-64:2008

Environmental testing

Part 2-1: Tests - Test A: Cold

Part 2-2: Tests - Test B: Dry heat

Part 2-27: Tests - Test Ea and guidance: Shock

Part 2-64: Tests - Test Fh: Vibration, broadband random and guidance

UR robots are tested according to the test methods defined in these standards.

IEC 61784-3:2010
EN 61784-3:2010 [SIL 2]

Industrial communication networks – Profiles

Part 3: Functional safety fieldbuses – General rules and profile definitions

This standards defines requirements for safety-rated communication buses.

IEC 60204-1/A1:2008
EN 60204-1/A1:2009 [2006/42/EC]

Safety of machinery – Electrical equipment of machines

Part 1: General requirements

The general principles of this standard are applied.

IEC 60664-1:2007
IEC 60664-5:2007
EN 60664-1:2007 [2006/95/EC]
EN 60664-5:2007

Insulation coordination for equipment within low-voltage systems

Part 1: Principles, requirements and tests

Part 5: Comprehensive method for determining clearances and creepage distances equal to or less than 2 mm

The electrical circuitry of UR robots is designed in compliance with this standard.

EUROMAP 67:2015, V1.11

Electrical Interface between Injection Molding Machine and Handling Device / Robot

UR robots equipped with the E67 accessory module to interface injection molding machines comply with this standard.

D Technical Specifications

Robot type	UR3e
Weight	11.1 kg / 24.5 lb
Maximum payload (see section 4.4)	3 kg / 6.6 lb
Reach	500 mm / 19.7 in
Joint ranges	Unlimited rotation of tool flange, ± 360 ° for all other joints
Speed	All wrist joints: Max 360 °/s Other joints: Max 180 °/s. Tool: Approx. 1 m/s / Approx. 39.4 in/s.
System Update Frequency	500 Hz
Force Torque Sensor Accuracy	3.5 N
Pose Repeatability	± 0.03 mm / ± 0.0011 in (1.1 mils)
Footprint	Ø128 mm / 5.0 in
Degrees of freedom	6 rotating joints
Control box size (W × H × D)	460 mm × 445 mm × 260 mm / 18.2 in × 17.6 in × 10.3 in
Control box I/O ports	16 digital in, 16 digital out, 2 analog in, 2 analog out
Tool I/O ports	2 digital in, 2 digital out, 2 analogue in
I/O power supply	24 V 2 A in Control Box and 12 V/24 V 600 mA in tool
Communication	TCP/IP 1000 Mbit: IEEE 802.3ab, 1000BASE-T Ethernet socket, MODBUS TCP & EtherNet/IP Adapter, Profinet
Programming	PolyScope graphical user interface on 12” touchscreen
Noise	70 dB(A)
IP classification	IP54
Cleanroom classification	Robot Arm: ISO Class 5 Control Box: ISO Class 6
Power consumption	Approx. 150 W using a typical program
Collaboration operation	17 advanced safety functions. In compliance with: EN ISO 13849-1:2008, PLd, Cat.3 and EN ISO 10218-1:2011, clause 5.10.5
Materials	Aluminium, PP plastic
Temperature	The robot can work in an ambient temperature range of -5-50 °C At high continuous joint speed, the maximum ambient temperature specification is derated.
Power supply	100-240 VAC, 47-440 Hz
Cabling	Cable between robot and Control Box (6 m / 236 in) Cable between touchscreen and Control Box (4.5 m / 177 in)

Part II

PolyScope Manual

10 Introduction

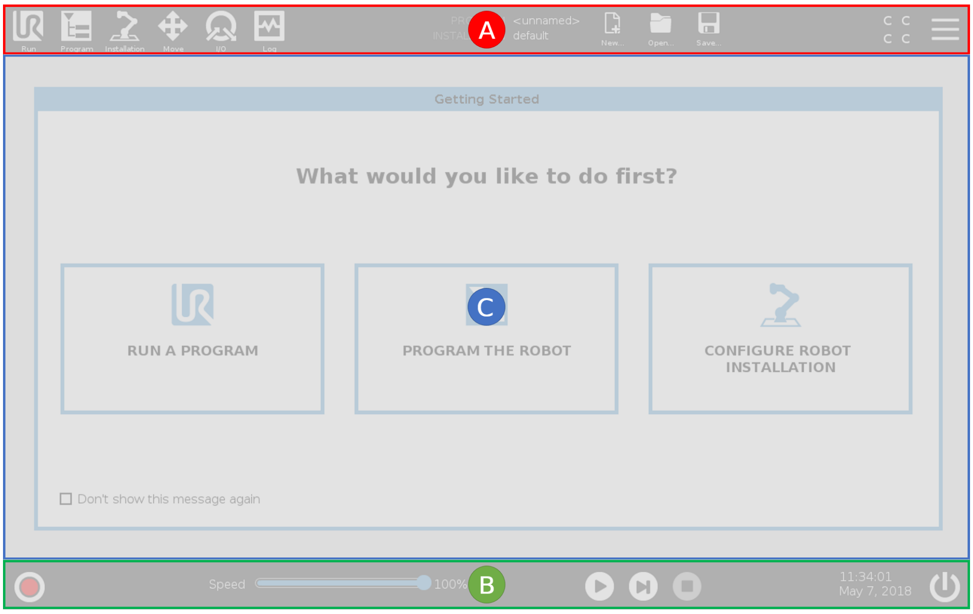
10.1 PolyScope Basics

The **PolyScope** or robot user interface is the touch screen on your **Teach Pendant** panel. It is the graphical user interface (GUI) that operates the robot arm and control box, executes and creates robot programs. PolyScope comprises three zones:

A : **Header** with tabs/icons that make interactive screens available to you.

B : **Footer** with buttons that control your loaded program/s.

C : **Screen** with fields that manage and monitor robot actions.



Note: On start up a Cannot Proceed dialogue can appear. You must select **Go to initialization screen** to turn on robot.

10.1.1 Header Icons/Tabs

Run is a simple means of operating the robot using pre-written programs.


Initialize manages robot state. This icon changes color depending on robot state: green (normal), yellow (idle) and red (stopped).

Program creates and/or modifies robot programs.

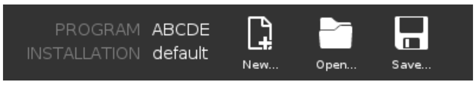
Installation configures robot arm settings and external equipment e.g. mounting and safety.

Move controls and/or regulates robot movement.

I/O monitors and sets live Input/Output signals to and from robot control box.

Log indicates robot health as well as any warning or error messages.

Note: File Path, New, Open and Save make up the File Manager.



File Path displays active robot Program and Installation.

New... creates a new Program or Installation.

Open... opens a previously created and saved Program or Installation.

Save... saves a Program, Installation or both at the same time.

Note: Automatic mode and Manual mode icons only appear in the Header if you set a operational mode password.


Automatic indicates that the robot has Automatic environment loaded. Click it to switch to Manual environment.


Manual indicates that the robot has Manual environment loaded. Click it to switch to Automatic environment.

Safety Checksum displays the active safety configuration.


Hamburger Menu accesses PolyScope Help, About and Settings.

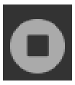
10.1.2 Footer Buttons

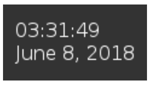
Speed Slider shows in real time the relative speed at which the robot arm moves, taking safety settings into account.

Note: Play Stop and Start make up Automove.


Play starts current loaded robot Program.


Step allows a Program to be run single-stepped.

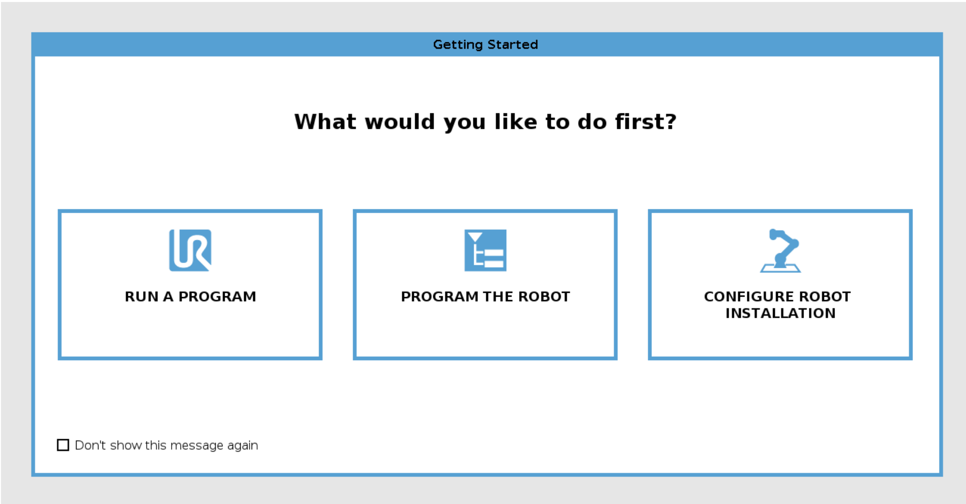
 **Stop** halts current loaded robot Program.



Clock displays real time and date.

 **Shutdown** allows the robot to be powered off or restarted.

10.2 Getting Started Screen



Run a Program, Program the Robot or Configure Robot Installation.
Note: When you power on for the first time, if a Cannot Proceed dialog appears, you can **Go to the initialization screen** or select **Not now** to remain on the Getting Started screen.

11 Quick Start

11.1 Robot Arm Basics

The Universal Robot arm is composed of tubes and joints. You use the PolyScope to coordinate the motion of these joints, moving the robot and positioning its tool as desired - except for the area directly above and directly below the base.

Base is where the robot is mounted.

Shoulder and Elbow make larger movements.

Wrists 1 and 2 make finer movements.

Wrist 3 is where you attach the robot tool.

NOTE:
Before powering on the robot for the first time, your designated UR robot integrator must:

1. Read and understand the safety information in the Hardware Installation Manual.
2. Set the safety configuration parameters defined by the risk assessment (see chapter 13).

11.1.1 Installing the Robot Arm and Control Box

You can use PolyScope, once the robot arm is installed and control box is installed and switched on. Note: a risk assessment is required before using the robot arm to do any work.

1. Unpack the **Robot arm** and the **Control box**.

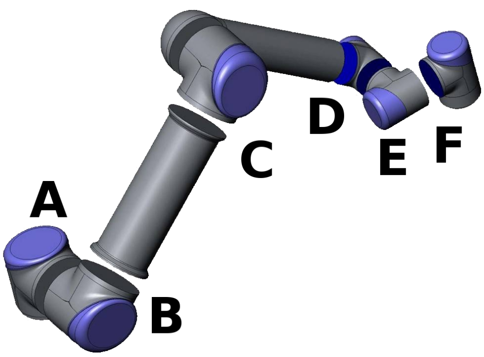


Figure 11.1: Joints of the robot. A: *Base*, B: *Shoulder*, C: *Elbow* and D, E, F: *Wrist 1, 2, 3*

2. Mount the **Robot arm** on a sturdy and vibration-free surface.
3. Place the **Control box** on its **Foot**.
4. Connect the cable to the robot and the control box.
5. Plug in the main control box plug.

DANGER:
Tipping hazard. If the robot is not securely placed on a sturdy surface, the robot can fall over and cause injury.

`See Hardware Installation Manual` for detailed installation instructions.

11.1.2 Turning Control Box On/Off

The control box mainly contains the physical electrical Input/Output that connects the robot arm, the Teach Pendant and any peripherals. You must turn on the control box to be able to power on the robot arm.`(see 15)`.

1. On your **Teach Pendant**, press the power button to turn on control box.
2. Wait as text from the underlying operating system, followed by buttons, appear on the screen.
3. When a Cannot Proceed dialog appears, select **Go to initialization screen** to access **Initialize Robot** screen.

11.1.3 Turning Robot Arm On/Off

Once you turn on the control box and are directed to the **Initialize Robot** screen `(see 15)`, you can power on the robot arm.

1. On the Initialize Robot screen tap **ON**.
2. Observe the on-screen changes and tap **START**. Robot arm start up is accompanied by sound and slight movements as joint brakes are released.
3. You can power off the robot arm by tapping **OFF**.

Note: Robot arm is also powered off automatically when control box is shut down.

11.2 Quick System Start-up

Before using the PolyScope, verify that the robot arm and control box are correctly installed.

1. On the **Teach Pendant**, press the emergency stop button.
2. On the Teach Pendant, press the power button and allow the system to start, displaying text on the **PolyScope**.
3. A popup appears on the touch screen indicating that the system is ready and that the robot must be initialized.
4. In the popup dialog, touch the button to access the initialization screen.

5. When the **Confirmation of applied Safety Configuration** dialog appears, press the **Confirm Safety Configuration** button to apply an initial set of safety parameters. These must be adjusted based on a risk assessment.
6. Unlock the emergency stop button to change robot state from **Emergency Stopped** to **Power off**.
7. Step outside the reach (workspace) of the robot.
8. On the **Initialize Robot** screen, touch the **ON** button and allow robot state to change to **Idle**.
9. In the **Current Payload** field, verify that payload mass and selected mounting are correct. You are alerted if the mounting detected, based on sensor data, does not match the selected mounting.
10. On the **Initialize Robot** screen, touch the **Start** button, for the robot to release its brake system.
    Note: Robot vibrates and makes clicking sounds indicating it is ready to be programmed

NOTE:
You can learn to program your robot on Universal Robots Academy at `www.universal-robots.com/academy/`

12 Operational Mode Selection

12.1 Operational Modes

Operational Modes are enabled when you configure a 3-Postition Enabling Device, or set a password.

Automatic Mode Once activated, the robot can only perform pre-defined tasks. The Move Tab and Freedrive Mode are unavailable. You cannot modify or save programs and installations.

Manual Mode Once activated, you can program the robot using the Move Tab, Freedrive Mode and Speed Slider. You can modify or save programs and installations.

Operational mode	Manual	Automatic
Freedrive	x	*
Move robot with arrows on MoveTab	x	*
Speed Slider	x	x**
Edit & save program & installation	x	
Execute Programs	Reduced speed*	x

*Only when a 3-position enabling device is configured
** It is possible via the Installation to specify that the Speed Slider is enabled/visible in the run screen

NOTE:

- A Universal Robots robot is not equipped with a 3-Position Enabling Device. If the risk assessment requires the device, it must be attached before the robot is used.
- If a 3-Position Enabling Device is not configured, both Freedrive and Move Tab are enabled. Speed is not reduced in Manual Mode.

WARNING:

- Any suspended safeguards must be returned to full functionality before selecting Automatic Mode.
- Wherever possible, the Manual Mode of operatio shall be performed with all persons outside the safeguard space.
- The device used to switch the robot to Operational Mode must be placed outside the safeguarded space.
- The user must not enter the safeguarded space when robot is in Automatic Mode.

The three methods for configuring Operational Mode selection are described in the following subsections. Each method is exclusive, meaning that using one method, makes the other two methods inactive.

Using Operational Mode Safety Input

1. In the Installation Tab, select Safety I/O.
2. Configure the Operational Mode Input. The option to configure appears in the drop-down menu once the 3-Position Enabling Device input is configured.
3. The robot is in Automatic Mode when the Operational Mode Input is low and in Manual Mode when the Operational Mode Input is high.

NOTE:

- The physical mode selector, if used, must completely adhere to ISO 10218-1: article 5.7.1 for selection.
- Before defining an operational input, you must define a 3-Position Enabling Device.

Using PolyScope

1. In PolyScope, select an Operational Mode.
2. To switch between modes, in the Header, select the profile icon.

See 22.3.2 for more information on setting a PolyScope password.

Note: PolyScope is automatically in Manual Mode when the Safety I/O configuration with 3-Position Enabling Device is enabled.

Using Dashboard Server

1. Connect to the Dashboard server.
2. Use the **Set Operational Mode** commands.
   - Set Operational Mode Automatic
   - Set Operational Mode Manual
   - Clear Operational Mode

See `http://universal-robots.com/support/` for more on using the Dashboard server.

12.2 3-Position Enabling Device

When a 3-Position Enabling Device is configured and the **Operational Mode** is in Manual Mode, the robot can only be moved by pressing the 3-Position Enabling Device.
When the **Operational Mode** is in Automatic Mode, the 3-Position Enabling Device has no effect.

NOTE:
The 3-Position Device, its behavior, its performance characteristics and operation must thoroughly comply with ISO 10218-1: article 5.8.3 for an enabling device.

12.2.1 Manual High Speed

When the input is low, the robot is in Safeguard Stop. The Speed Slider is set to an initial value that corresponds to 250 mm/s and can be incrementally increased for higher speed. The speed slider is reset to the low value whenever the 3-Position Enabling Device input goes from low to high.

NOTE:
Use safety joint limits (See 13.2.4) or safety planes (see 13.2.5)to restrict the space the robot can move in while utilizing manual high speed.

13 Safety Configuration

13.1 Safety Settings Basics

This section covers how to access the robot safety settings. It is made up of items that help you set up the robot Safety Configuration.

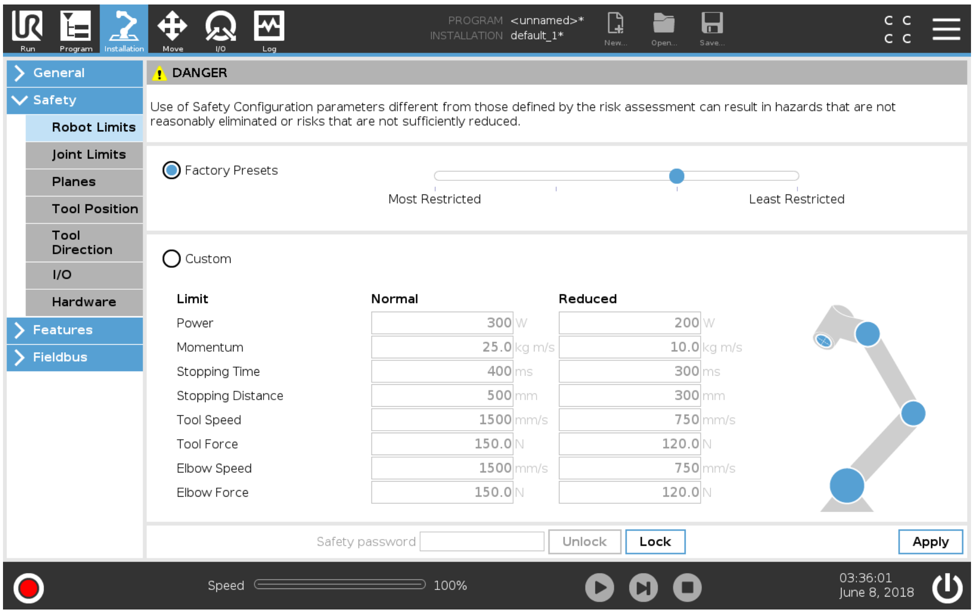
DANGER:
Before you configure your robot safety settings, your integrator must conduct a risk assessment to guarantee the safety of personnel and equipment around the robot. A risk assessment is an evaluation of all work procedures throughout the robot lifetime, conducted in order to apply correct safety configuration settings (see Hardware Installation Manual). You must set the following in accordance with the integrator's risk assessment.

1. The integrator must prevent unauthorized persons from changing the safety configuration e.g. installing password protection.
2. Use and configuration of the safety-related functions and interfaces for a specific robot application (see Hardware Installation Manual).
3. Safety configuration settings for set-up and teaching before the robot arm is powered on for the first time.
4. All safety configuration settings accessible on this screen and sub-tabs.
5. The integrator must ensure that all changes to the safety configuration settings comply with the risk assessment.

13.1.1 Accessing Safety Configuration

Note: Safety Settings are password protected and can only be configured once a password is set and subsequently used.

1. In your PolyScope header, press the **Installation** icon.
2. On the left of the screen, in the action menu, press **Safety**.
3. Observe that the **Robot Limits** screen displays, but settings are inaccessible.
4. If a **Safety password** was previously set, enter the password and press **Unlock** to make settings accessible. Note: Once Safety settings are unlocked, all settings are now active.
5. Press **Lock** tab or navigate away from the Safety menu to lock all Safety item settings again.



You can find more safety system information in the `Hardware Installation Manual`.

13.1.2 Setting a Safety Password

You must set a password to Unlock all safety settings that make up your Safety Configuration. Note: If no safety password is applied, you are prompted to set it up.

1. In your PolyScope header right corner, press the **Hamburger** menu and select **Settings**.
2. On the left of the screen, in the blue menu, press **Password** and select **Safety**.
3. In **New password**, type a password.
4. Now, in **Confirm new password**, type the same password and press **Apply**.
5. In the bottom left of the blue menu, press Exit to return to previous screen.

Note: You can press the **Lock** tab to lock all Safety settings again or simply navigate to a screen outside of the Safety menu.

13.1.3 Changing the Safety Configuration

Changes to the Safety Configuration settings must comply with the risk assessment conducted by the integrator `(see Hardware Installation Manual)`.

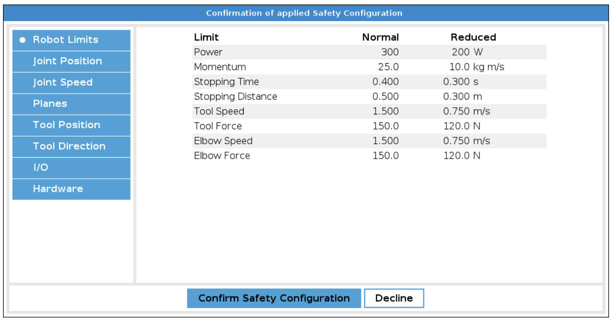
Recommended procedure:

1. Verify that changes comply with the risk assessment conducted by the integrator.
2. Adjust safety settings to the appropriate level defined by the risk assessment conducted by the integrator.
3. Verify that the settings are applied.
4. Place following text in the operators' manuals:

"Before working near the robot, make sure that the safety configuration is as expected. This can be verified e.g. by inspecting the safety checksum in the top right corner of PolyScope for any changes."

13.1.4 Applying New Safety Configuration

The robot is powered off while you make changes to the configuration. Your changes only take effect after you hit the **Apply** button. The robot cannot be powered on again until you either **Apply and Restart** or **Revert Changes**. The former allows you to visually inspect your robot Safety Configuration which, for safety reasons, is displayed in SI Units in a popup. When your visual inspection is complete you can **Confirm Safety Configuration** and the changes are automatically saved as part of the current robot installation.



13.1.5 Safety Checksum

The **Safety Checksum** icon displays your applied robot safety configuration and is read from top to bottom, left to right e.g. BF4B. Different text and/or colors indicate changes to the applied safety configuration.

Note:

- The **Safety Checksum** changes if you change the **Safety Functions** settings, because the **Safety Checksum** is only generated by the safety settings.
- You must apply your changes to the **Safety Configuration** for the **Safety Checksum** to reflect your changes.

13.2 Safety Menu Settings

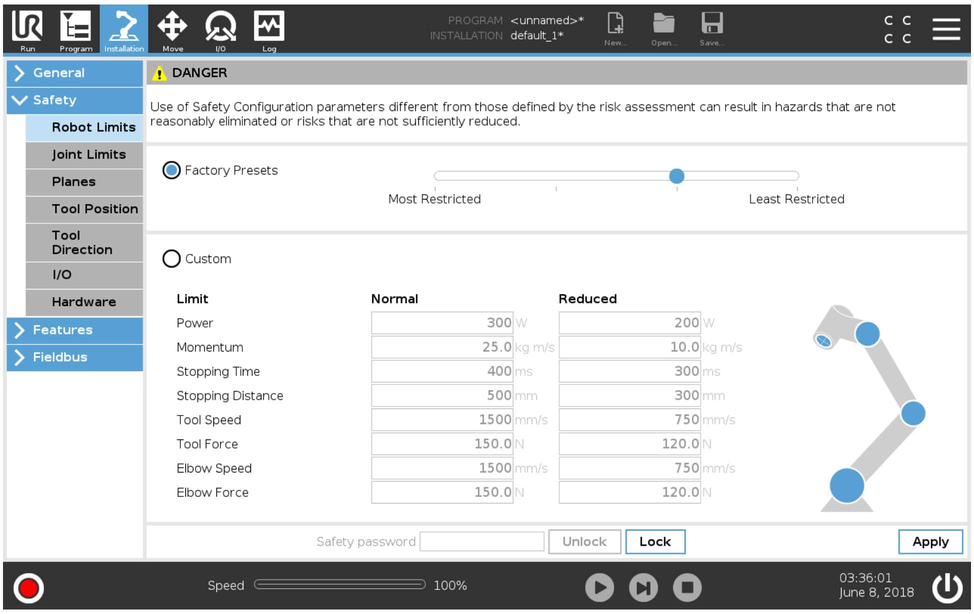
This section defines Safety menu settings that make up your robot Safety configuration.

13.2.1 Robot Limits

Robot Limits allow you to restrict general robot movements. The Robot Limits screen has two configuration options: **Factory Presets** and **Custom**.

1. Factory Presets is where you can use the slider to select a predefined safety setting . The values in the table are updated to reflect the preset values ranging from **Most Restricted** to **Least Restricted**

   Note: Slider values are only suggestions and do not substitute a proper risk assessment.



2. Custom is where you can set Limits on how the robot functions and monitor the associated Tolerance.

   Power limits maximum mechanical work produced by the robot in the environment.
   Note: this limit considers the payload a part of the robot and not of the environment.

   Momentum limits maximum robot momentum.

   Stopping Time limits maximum time it takes the robot to stop e.g. when an emergency stop is activated.

   Stopping Distance limits maximum distance the robot tool or elbow can travel while stopping.

NOTE:
Restricting stopping time and distance affect overall robot speed. For example, if stopping time is set to 300 ms, the maximum robot speed is limited allowing the robot to stop within 300 ms.

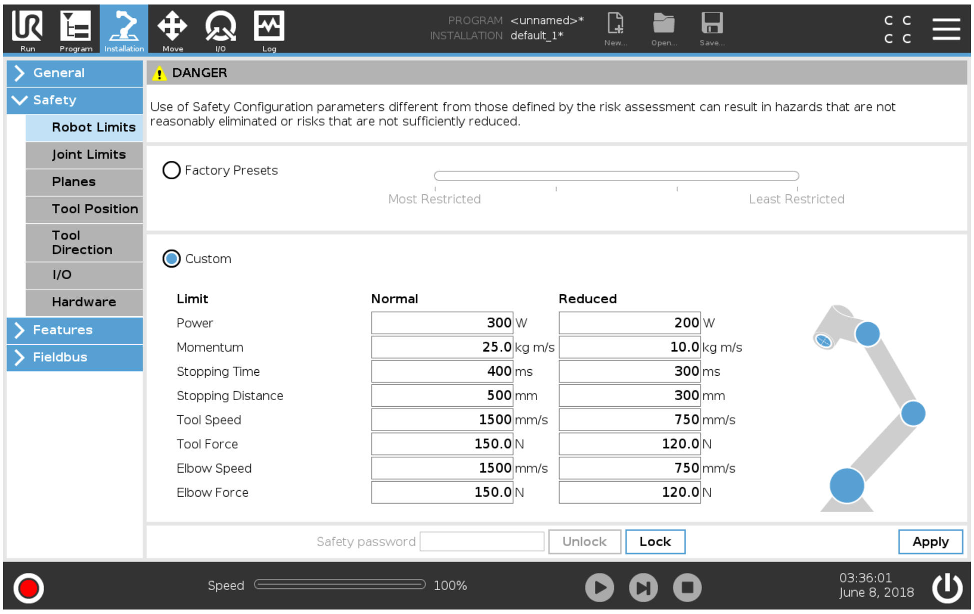
Tool Speed limits maximum robot tool speed.

Tool Force limits the maximum force exerted by the robot tool in clamping situations.

Elbow Speed limits maximum robot elbow speed.

Elbow Force limits maximum force that the elbow exerts on the environment.

The tool speed and force are limited at the tool flange and the center of the two user-defined tool positions, see 13.2.6.



NOTE:
You can switch back to **Factory Presets** for all robot limits to reset to their default settings.

13.2.2 Safety Modes

Under normal conditions, i.e. when no protective stop is in effect, the safety system operates in a Safety Mode associated with a set of safety limits:

Normal mode is the safety mode that is active by default

Reduced mode is active when the robot **Tool Center Point** (TCP) is positioned beyond a Trigger Reduced mode plane (see 13.2.5), or when triggered using a configurable input (see 13.2.8)

Recovery mode activates when a safety limit from the active limit set is violated, the robot arm performs a Stop Category 0. If an active safety limit, such as a joint position limit or a safety boundary, is violated already when the robot arm is powered on, it starts up in **Recovery** mode. This makes it possible to move the robot arm back within the safety limits. While in Recovery mode, the movement of the robot arm is restricted by a fixed limit that you cannot customize. For details about Recovery mode limits (see Hardware Installation Manual).

WARNING:
Limits for **joint position**, **tool position** and **tool orientation** are disabled in Recovery mode, so take caution when moving the robot arm back within the limits.

The menu of the Safety Configuration screen enables the user to define separate sets of safety limits for Normal and Reduced mode. For the tool and joints, Reduced mode limits for speed and momentum are required to be more restrictive than their Normal mode counterparts.

13.2.3 Tolerances

In the Safety Configuration the safety system limits are specified. The *Safety System* receives the values from the input fields and detects any violation if any these values are exceeded. The robot controller attempts to prevent any violations by making a protective stop or by reducing the speed. This means that a program might not be able to perform motions very close to a limit.

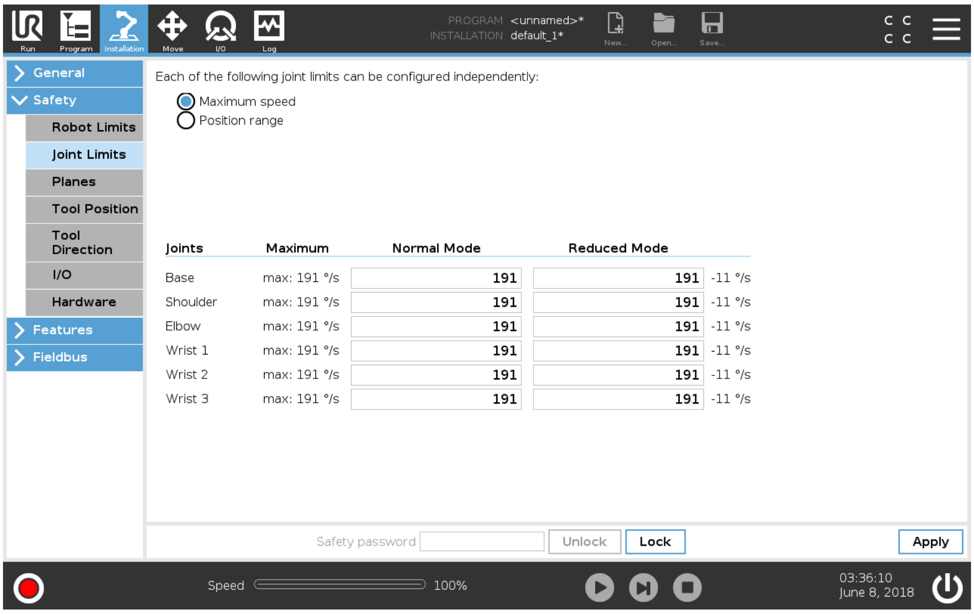
WARNING:
Tolerances are specific to Software version. Updating software may change tolerances. Consult the release notes for information about Software version changes.

13.2.4 Joint Limits

Joint Limits allow you to restrict individual robot joint movements in joint space i.e. joint rotational position and joint rotational speed. There are two Joint Limits options: **Maximum speed** and **Position range**.

1. Maximum speed is where you define the maximum angular velocity for each joint.

2. Position range is where you define the position range for each joint. Again, the input fields for Reduced mode are disabled if there is no safety plane or configurable input set to trigger it. This limit enables safety-rated soft axis limiting of the robot.



13.2.5 Planes

NOTE:
Configuring planes is entirely based on features. We recommend you create and name all features before editing the safety configuration, as the robot is powered off once the Safety Tab has been unlocked and moving the robot will be impossible.

Safety planes restrict robot workspace. You can define up to eight safety planes, restricting the robot tool and elbow. You can also restrict elbow movement for each safety plane and disable by deselecting the checkbox. Before configuring safety planes, you must define a feature in the robot installation (see 17.1.3). The feature can then be copied into the safety plane screen and configured.

WARNING:
Defining safety planes only limits the defined Tool spheres and elbow, not the overall limit for the robot arm. This means that specifying a safety plane, does not guarantee that other parts of the robot arm will obey this restriction.

Modes

You can configure each plane with restrictive **Modes** using the icons listed below.

Disabled The safety plane is never active in this state.

Normal When the safety system is in Normal mode, a normal plane is active and it acts as a strict limit on the position.

Reduced When the safety system is in Reduced mode, a reduced mode plane is active and it acts as a strict limit on the position.

Normal & Reduced When the safety system is either in Normal or Reduced mode, a normal and reduced mode plane is active and acts as a strict limit on the position.

Trigger Reduced Mode The safety plane causes the safety system to switch to Reduced mode if the robot Tool or Elbow is positioned beyond it.

Show Pressing this icon hides or shows the safety plane in the graphics pane.

Delete Deletes the created safety plane (note: there is no undo/redo action here so if a plane is deleted by mistake, it will have to be remade)

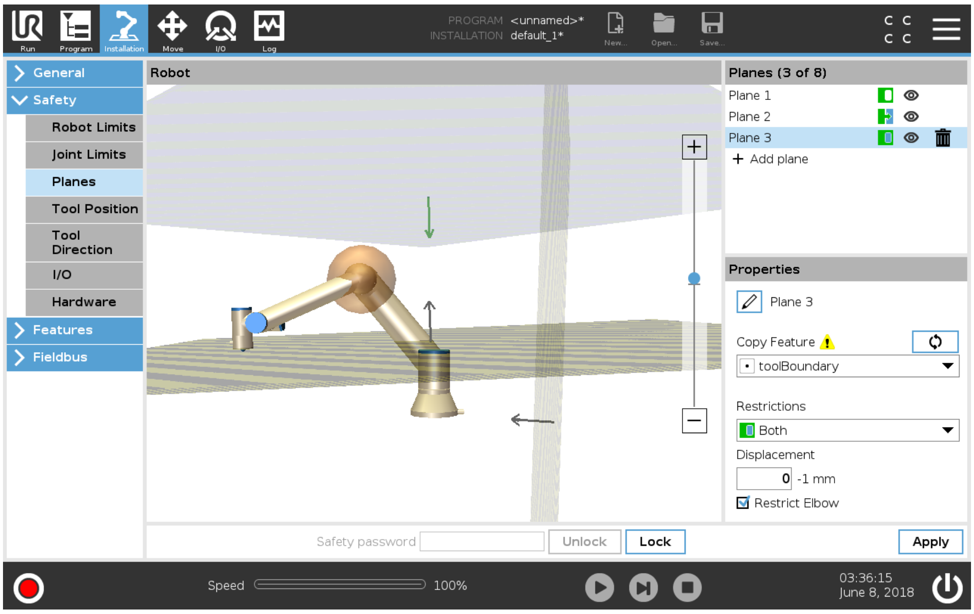
Rename Pressing this icon allows you to rename the plane.

Configuring Safety Planes

1. In your PolyScope header, tap **Installation**.
2. On the left, in the action menu, tap Safety and select **Planes**.
3. On the top right of the screen, in the Planes field, tap **Add plane**.

4. On the bottom right of the screen, in the **Properties** field, set up Name, Copy Feature and Restrictions. Note: In **Copy Feature**, only Undefined and Base are available. You can reset a configured safety plane by selecting **Undefined**

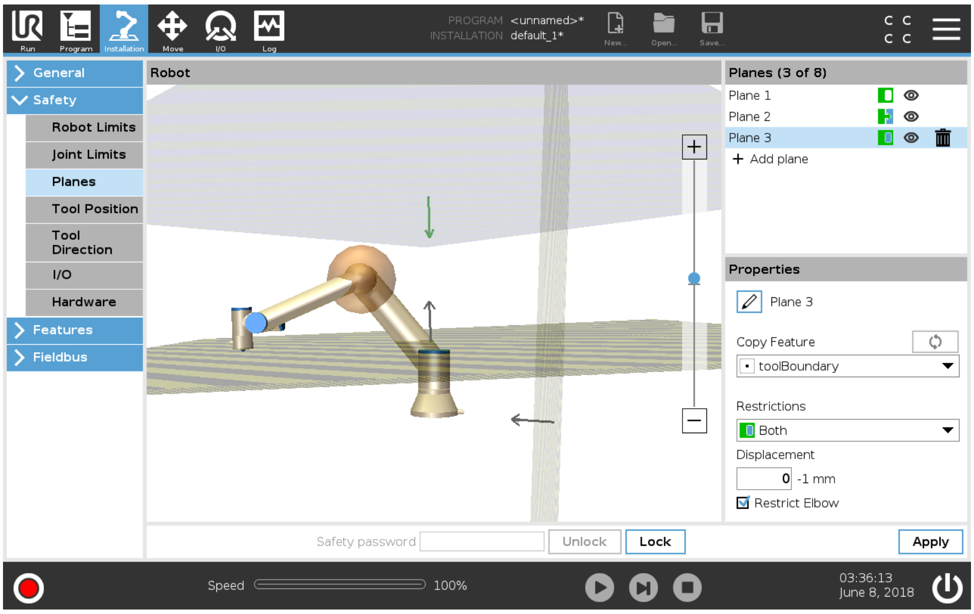
If the copied feature is modified in the Features screen, a warning icon appears to the right of the Copy Feature text. This indicates that the feature is out of sync i.e. the information in the properties card is not updated to reflect the modifications that may have been made to the Feature.



Elbow

You can enable **Restrict Elbow** to prevent robot elbow joint from passing through any of your defined planes. Disable Restrict Elbow for elbow to pass through planes.

Color Codes



Gray Plane is configured but disabled (A)

Yellow & Black Normal Plane (B)

Blue & Green Trigger Plane (C)

Black Arrow The side of the plane the tool and/or elbow is allowed to be on (For Normal Planes)

Green Arrow The side of the plane the tool and/or elbow is allowed to be on (For Trigger Planes)

Gray Arrow The side of the plane the tool and/or elbow is allowed to be on (For Disabled Planes)

Freedriving Robot

If the robot comes close to certain limits, while in Freedrive (see 18.6), you can experience a repelling force from the robot.

13.2.6 Tool Position

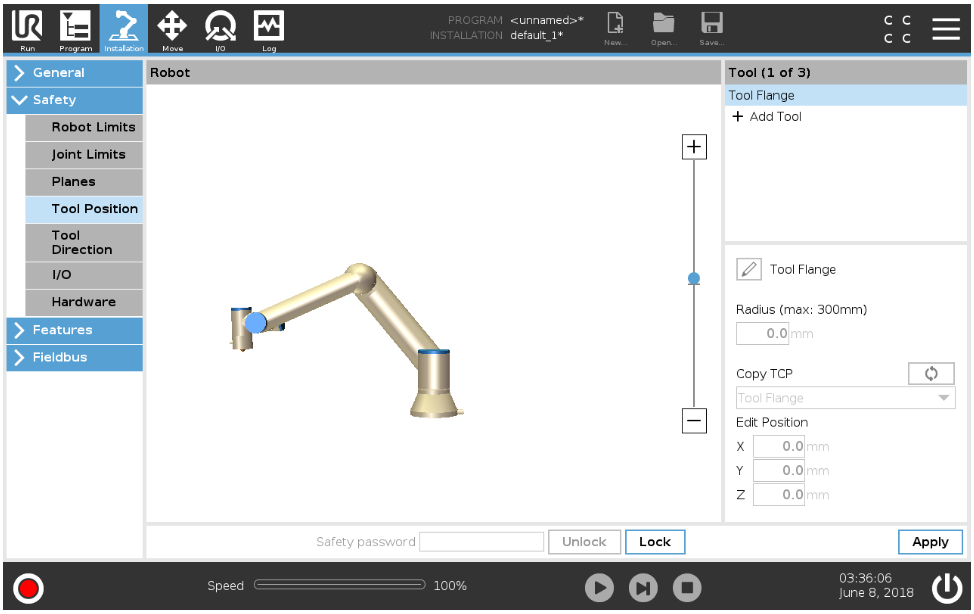
The Tool Position screen enables more controlled restriction of tools and/or accessories placed on the end of the robot arm.

Robot is where you can visualize your modifications.

Tool is where you can define and configure a tool up to two tools.

Tool_1 is the default tool defined with values x=0.0, y= 0.0, z=0.0 and radius=0.0. These values represent the robot tool flange.
Note:

- Under Copy TCP, you can also select **Tool Flange** and cause the tool values to go back to 0.
- A default sphere is defined at the tool flange.

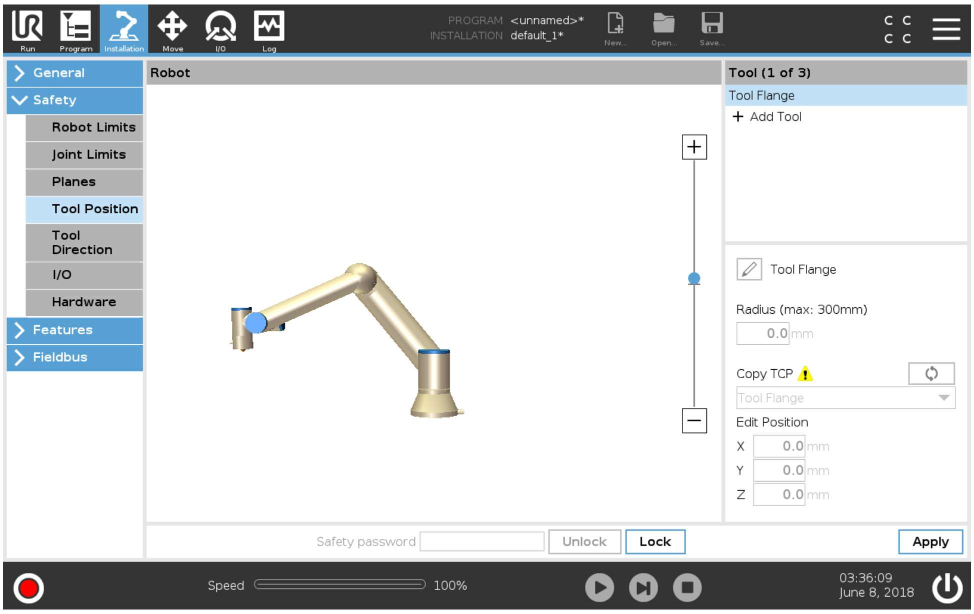


For the user defined tools, the user can change:

Radius to change the radius of the tool sphere. The radius is considered when using safety planes. When a point in the sphere passes a reduced mode trigger plane, the robot switches to *Reduced* mode. The safety system prevents any point on the sphere from passing a safety plane (see 13.2.5).

Position to change the position of the tool with respect to the tool flange of the robot. The position is considered for the safety functions for tool speed, tool force, stopping distance and safety planes.

You can use an existing Tool Center Point as a base for defining new tool positions. A copy of the existing TCP, predefined in General menu, in TCP screen, can be accessed in Tool Position menu, in Copy TCP drop-down list.
When you edit or adjust the values in the **Edit Position** input fields, the name of the TCP visible in the drop down menu changes to **custom**, indicating that there is a difference between the copied TCP and the actual limit input. The original TCP is still available in the drop down list and can be selected again to change the values back to the original position. The selection in the copy TCP drop down menu does not affect the tool name.
Once you apply your Tool Position screen changes, if you try to modify the copied TCP in the TCP configuration screen, a warning icon appears to the right of the Copy TCP text. This indicates that the TCP is out of sync i.e. the information in the properties field is not updated to reflect modifications that may have been made to the TCP. The TCP can be synced by pressing the sync icon `(see 17.1.1)`.
Note: the TCP does not have to be synced in order to define and use a tool successfully.
You can rename the tool by pressing the pencil tab next to the displayed tool name. You can also determine the Radius with an allowed range of 0-300 mm. The limit appears in the graphics pane as either a point or a sphere depending on radius size.

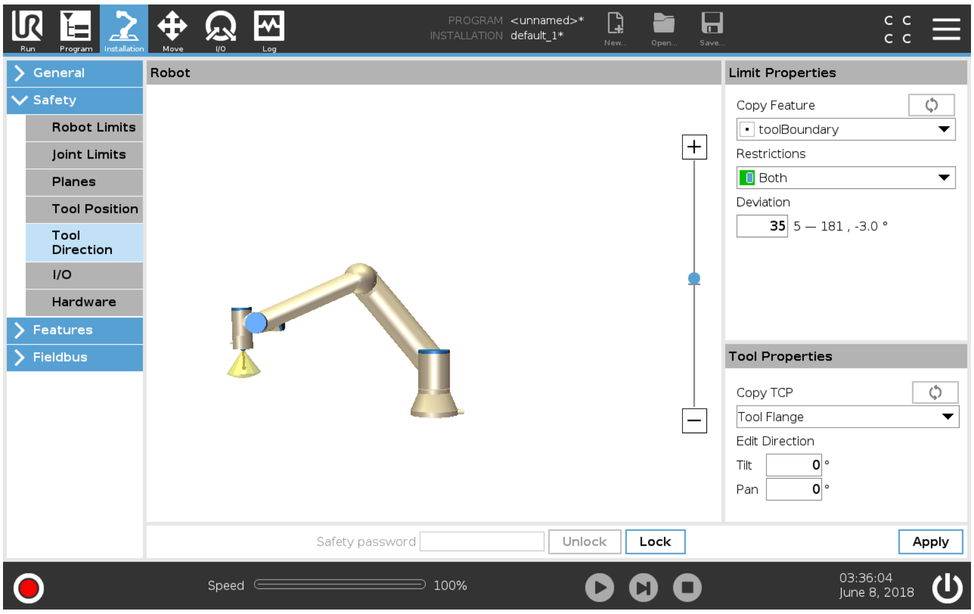


13.2.7 Tool Direction

The Tool Direction screen can be used to restrict the angle in which the tool is pointing. The limit is defined by a cone that has a fixed orientation with respect to the robot arm Base. As the robot arm moves around, tool direction is restricted so it remains within the defined cone. The default direction of the tool coincides with the Z-axis of the tool output flange. It can be customized by specifying tilt and pan angles.

Before configuring the limit, you must define a point or plane in the robot installation `(see 17.3)`. The feature can then be copied and its Z axis used as the center of the cone defining the limit.

NOTE:
Configuration of the tool direction is based on features. We recommend you create desired feature(s) before editing the safety configuration, as once the Safety Tab has been unlocked, the robot arm powers off making it impossible to define new features.



Limit Properties

The Tool Direction limit has three configurable properties:

1. **Cone center**: You can select a point or plane feature from the drop-down menu, to define the center of the cone. The Z axis of the selected feature is used as the direction around which the cone is centred.
2. **Cone angle**: You can define how many degrees the robot is allowed to deviate from center.

Disabled Tool direction limit is never active

Normal Tool direction limit is active only when safety system is in **Normal mode**.

Reduced Tool direction limit is active only when the safety system is in **Reduced mode**.

Normal & Reduced Tool direction limit is active when the safety system is in **Normal mode** as well as when it is in **Reduced mode**.

You can reset the values to default or undo the Tool Direction configuration by setting the copy feature back to ”Undefined”.

Tool Properties

By default, the tool points in the same direction as the Z axis of the tool output flange. This can be modified by specifying two angles:

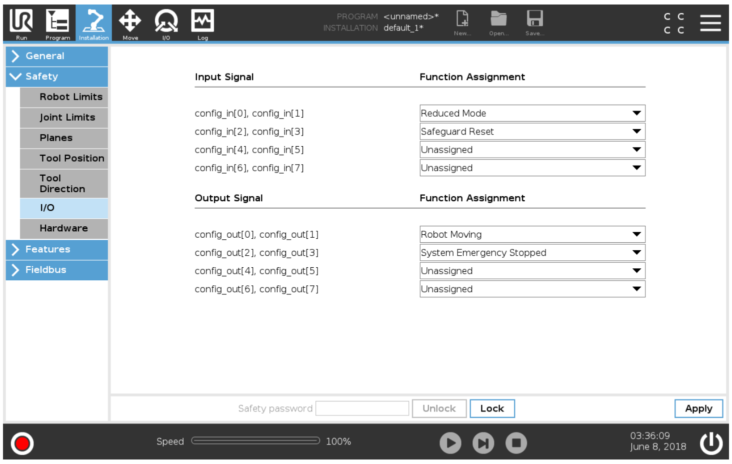
Tilt angle: How much to tile the Z axis of the output flange towards the X axis of the output flange

Pan angle: How much to rotate the tilted Z axis around the original output flange Z axis.

Alternatively, the Z axis of an existing TCP can be copied by selecting that TCP from the drop-down menu.

13.2.8 I/O

The I/O are divided between inputs and outputs and are paired up so that each function provides a Category 3 and PLd I/O.



Input Signals

The following Safety Functions can be used with the input signals:

System Emergency Stop This is an emergency stop button alternative to the one on the Teach Pendant, providing the same functionality if the device complies with ISO 13850.

Reduced Mode All safety limits can be applied in either Normal mode or Reduced mode (see 13.2.2). When configured, a low signal sent to the inputs causing the safety system to transition to Reduced mode. The robot arm decelerates to satisfy the Reduced mode limit set. The safety system guarantees that the robot is within Reduced mode limits less than 0.5s after the input is triggered. If the robot arm continues to violate any of the Reduced mode limits, it performs a Stop Category 0. Transition back to Normal mode occurs in the same way. Note: safety planes can also cause a transition to Reduced mode.

3-Position Enabling Device Defining a **3-Position Enabling Device** safety input makes it possible to define an **Operational Mode** safety input. When defined, the **3-Position Enabling Device** must be held down for a robot in **Manual Mode** to move.

Operational Mode When defined, this input can be used to switch between **Automatic Mode** or **Manual Mode** (see 12.1).

Safeguard Reset When a Safeguard Stop is configured, this output ensures that the Safeguard Stop state continues until a reset is triggered. The robot arm will not move when in a Safeguard Stopped state.

WARNING:
By default, the Safeguard Reset input function is configured for input pins 0 and 1. Disabling it altogether implies that the robot arm ceases to be Safeguard Stopped as soon as the Safeguard Stop input becomes high. In other words, without a Safeguard Reset input, the Safeguard Stop inputs SI0 and SI1 (`see the Hardware Installation Manual`) fully determine whether the Safeguard Stopped state is active or not.

Output Signals

You can apply the following Safety functions for output signals. All signals return to low when the state which triggered the high signal has ended:

System Emergency Stop Low signal is given when the safety system has been triggered into an Emergency Stopped state by the Robot Emergency Stop input or the Emergency Stop Button. To avoid deadlocks, if the Emergency Stopped state is triggered by the System Emergency Stop input, low signal will not be given.

Robot Moving Low signal if the robot is moving, otherwise high.

Robot Not Stopping high signal when the robot is stopped or in the process of stopping due to an emergency stop or safeguard stop. Otherwise it will be logic low.

Reduced Mode Sends a low signal when the robot arm is placed in Reduced mode or if the safety input is configured with a Reduced Mode input and the signal is currently low. Otherwise the signal is high.

Not Reduced Mode This is the inverse of the Reduced Mode defined above.

NOTE:
Any external machinery receiving its Emergency Stop state from the robot through the System Emergency Stop output must comply with ISO 13850. This is particularly necessary in setups where the Robot Emergency Stop input is connected to an external Emergency Stop device. In such cases, the System Emergency Stop output becomes high when the external Emergency Stop device is released. This implies that the emergency stop state at the external machinery will be reset with no manual action needed from the robot's operator. Hence, to comply with safety standards, the external machinery must require manual action in order to resume.

13.2.9 Hardware

You can use the robot without attaching the Teach Pendant. Removing the Teach Pendant requires defining another Emergency Stop source. You must specify if the Teach Pendant is attached to avoid triggering a safety violation.

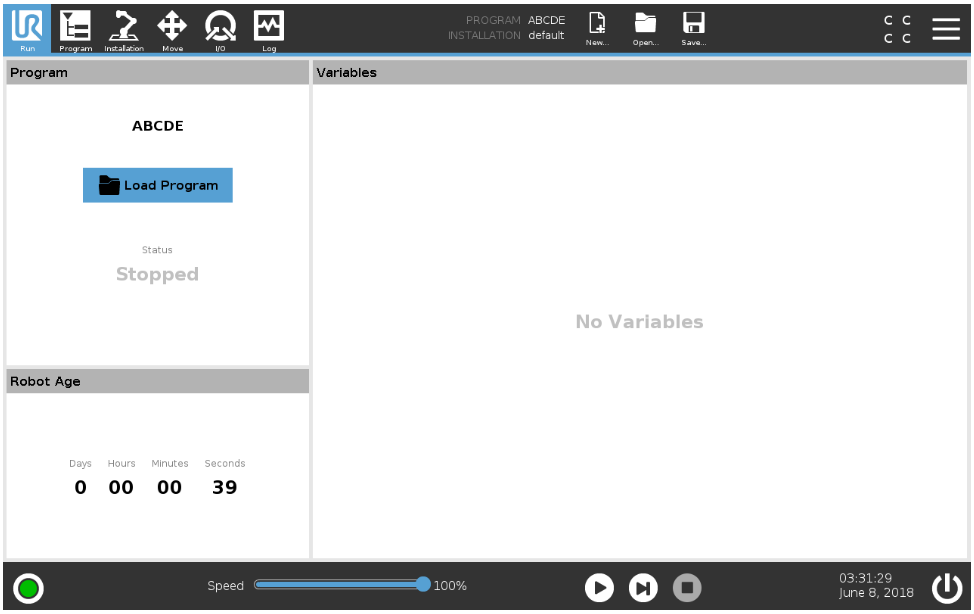
Selecting Available Hardware

The robot can be used without PolyScope as the programming interface.

1. In the Header tap **Installation**.
2. In the action menu on left tap **Safety** and select **Hardware**.
3. Input Safety password and **Unlock** the screen.
4. Deselect **Teach Pendant** to use robot without PolyScope interface.
5. Press **Save and restart** to implement changes.

CAUTION:
If the Teach Pendant is detached or disconnected from the robot, the Emergency Stop button is no longer active. You must remove the Teach Pendant from the vicinity of the robot.

14 Run Tab



The **Run** tab allows you to simply operate the robot arm and control box, using as few buttons and options as possible. You can combine simple operation with password protecting the programming part of PolyScope (see 22.3.2), to make the robot into a tool that can run exclusively pre-written programs.

On this screen you can automatically load and start default a program based on an external input signal edge transition (see 17.1.9).
Note: The combination of auto loading and starting of a default program and auto initialization on power up can, for instance, be used to integrate the robot arm into other machinery.

14.1 Program

The **Program** field, displays the name of the program that was loaded on to the robot and its current status. You can tap the **Load Program** tab to load a different program.

14.2 Variables

A robot program can make use of variables to store and update various values during runtime. Two kinds of variables are available:

Installation variables These can be used by multiple programs and their names and values are persisted together with the robot installation (see 17.1.8). Installation variables keep their value after the robot and control box has been rebooted.

Regular program variables These are available to the running program only and their values are lost as soon as the program is stopped.

The following variable types are available:

bool	A boolean variable whose value is either `True` or `False`.
int	A whole number in the range from -2147483648 to 2147483647 (32 bit).
float	A floating point number (decimal) (32 bit).
string	A sequence of characters.
pose	A vector describing the location and orientation in Cartesian space. It is a combination of a position vector (x, y, z) and a rotation vector (rx, ry, rz) representing the orientation, written `p[x, y, z, rx, ry, rz]`.
list	A sequence of variables.

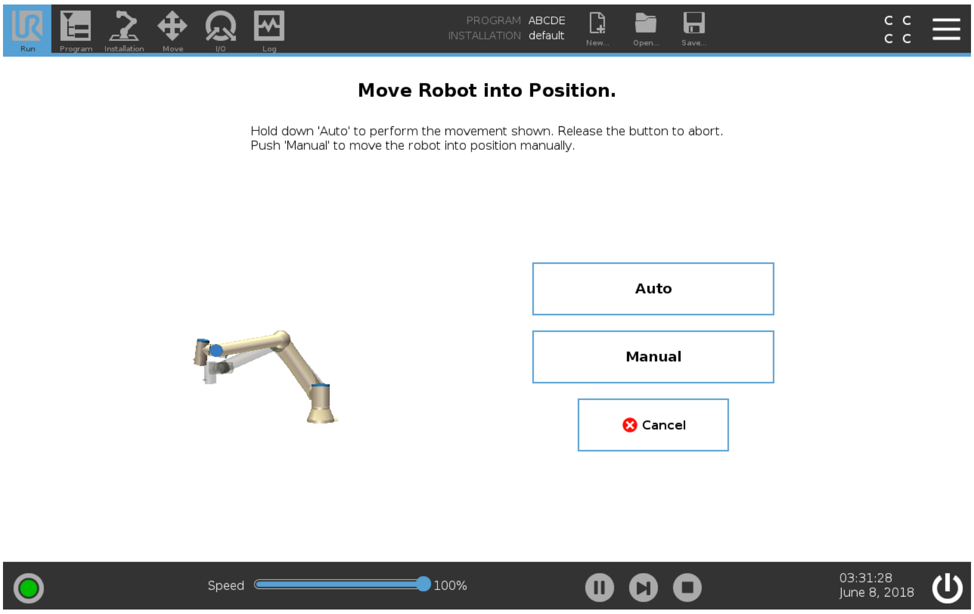
14.3 Robot Age

This field represents how long ago was the robot turned on for the first time.
Note: the numbers represented in this field are not associated with program run time.

14.4 Move Robot into Position

In the **Footer**, press the **Play** button to access the **Move Robot into Position** screen when you have to move your robot into a specific position in its workspace. For example: when the robot arm has to move to a particular start position before running a program, or when moving to a waypoint while modifying a program.

Note: **Automove** is a function made up of three buttons in the Footer: **Play**, **Step** and **Stop**.



Auto

Hold down the **Auto** tab to move the robot arm to its start position.
Note: You can release the button to stop the motion at any time.

Animation

The animation shows the movement the robot arm is about to perform when you hold down the **Auto** tab.

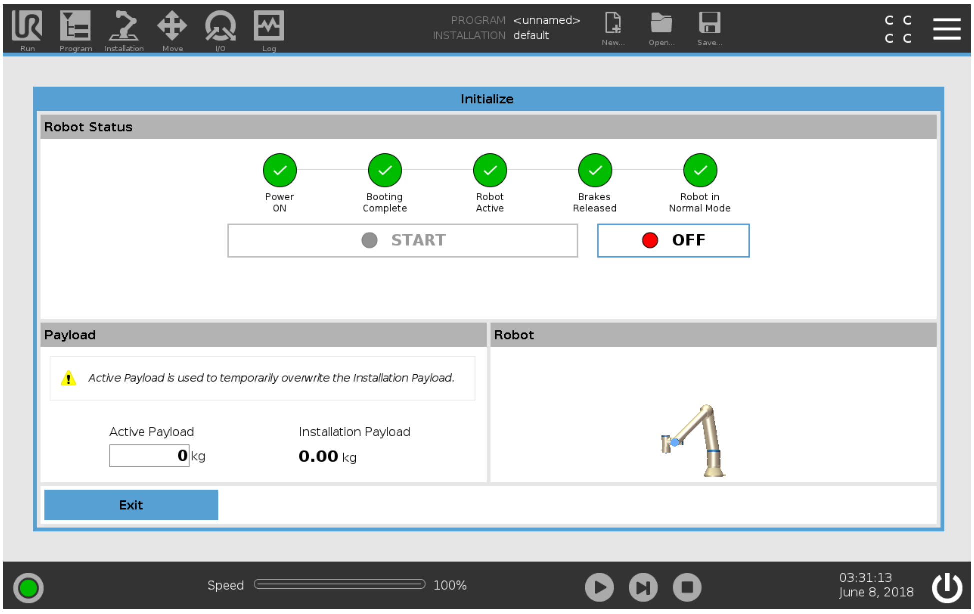
CAUTION:

1. Compare the animation with the position of the real robot arm and make sure that the robot arm can safely perform the movement without hitting any obstacles.
2. The Automove function moves the robot along the shadow trajectory. Collision might damage the robot or other equipment.

Manual

Push the **Manual** tab to access the **Move** icon screen where the robot arm can be moved manually. This is only needed if you do not prefer the animation's movement.

15 Initialize Tab



15.1 Robot Arm State Indicator

Located in the Header, the Initialize icon includes a status LED indicating Robot arm running state.

- **Red** indicates theRobot arm is in a stopped state due to different possible reasons.
- **Yellow** indicates the Robot arm is powered on, but it is not ready for normal operation.
- **Green** indicates the Robot arm is powered on and ready for normal operation.

On the **Initialize Robot** screen, the text next to the LED further specifies Robot arm state.

15.2 Active Payload and Installation

When the Robot arm is powered on, the payload mass used by the controller is shown in the **Current Payload** text field. Tap the text field to modify the current payload value. Setting this value does not modify the robot's installation payload (see 17.1.1), but only the payload mass used by the controller. Similarly, the installation file name is shown in the **Installation file** text field and in the Header. The active installation file name is also displayed in the Header, File Path next to **Installation**.

Before starting up the Robot arm, it is important to verify both the active payload and the active installation correspond to the situation of the Robot arm.

15.3 Initializing the Robot Arm

DANGER:
Always verify the actual payload and installation are correct before starting up the Robot arm. If these settings are incorrect, the Robot arm and Control Box will not function correctly and may become dangerous to people or equipment.

CAUTION:
Great caution should be taken if the Robot arm is touching an obstacle or table since driving the Robot arm into the obstacle might damage a joint gearbox.

On the Initialize Robot screen, the ON button with the green LED serves to perform the initialization of the Robot arm. The text on the ON button changes to START, and the action it performs, change depending on Robot arm state.

- When the controller PC boots up, tap the ON button once to power the Robot arm on. The Robot State then turns to yellow to indicate the power is on and in **Idle**.
- When the Robot arm state is **Idle**, tap the START button to start Robot arm. At this point, sensor data is checked against the configured mounting of the Robot arm. If a mismatch is found (with a tolerance of 30°), the button is disabled and an error message is displayed below it. If the mounting is verified, tapping the button releases all joint brakes (break release is accompanied by clicking and slight movement) and the Robot arm is ready for normal operation.
- If the Robot arm violates one of the safety limits after it starts up, it operates in **Recovery mode**. In this mode, tapping the button switches to a Recovery Mode screen where the Robot arm can be moved back within the safety limits.
- If a fault occurs, the Controller can be restarted using the ON button.
- If the Controller is not running, tap the ON button starts it.

On the Initialize Robot screen, tap the OFF button with the red LED to power off the Robot arm.

15.4 Installation File

The Robot Installation covers all aspects of how the Robot arm and Control Box are placed in the working environment. It includes the mechanical mounting of the Robot arm, electrical connections to other equipment and options on which the robot program depends. It does not include the program itself.

These settings can be set using the various screens under the **Installation** tab, except for the I/O domains which are set in the **I/O** tab (see 19).

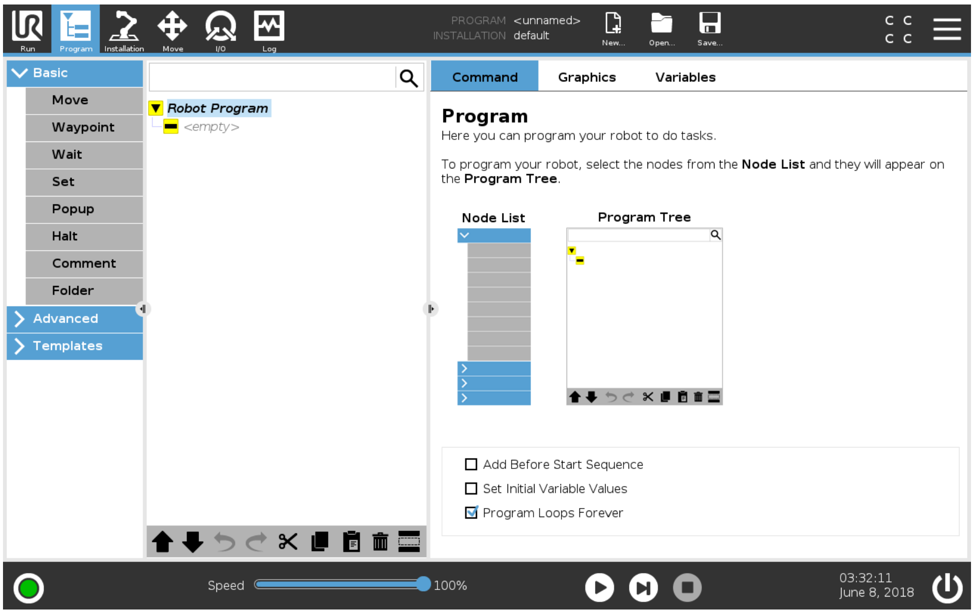
It is possible to have more than one installation file for the robot. Created programs created use the active installation and load this installation automatically when used.

Any changes to an installation must be saved to be preserved after power down. If there are unsaved changes in the installation, a floppy disk icon is shown next to the **Load/Save** text on the left side of the **Installation** tab.

You can save an installation by pressing the **Save...** or **Save As...** button. Alternatively, saving a program also saves the active installation. To load a different installation file, use the **Load** button. In the Robot Installation the **Create New** button resets all of the settings to their factory defaults.

CAUTION:
Using the robot with an installation loaded from a USB drive is not recommended. To use an installation stored on a USB drive, first load it and then save it in the local programs folder using the **Save As...** button.

16 Program Tab



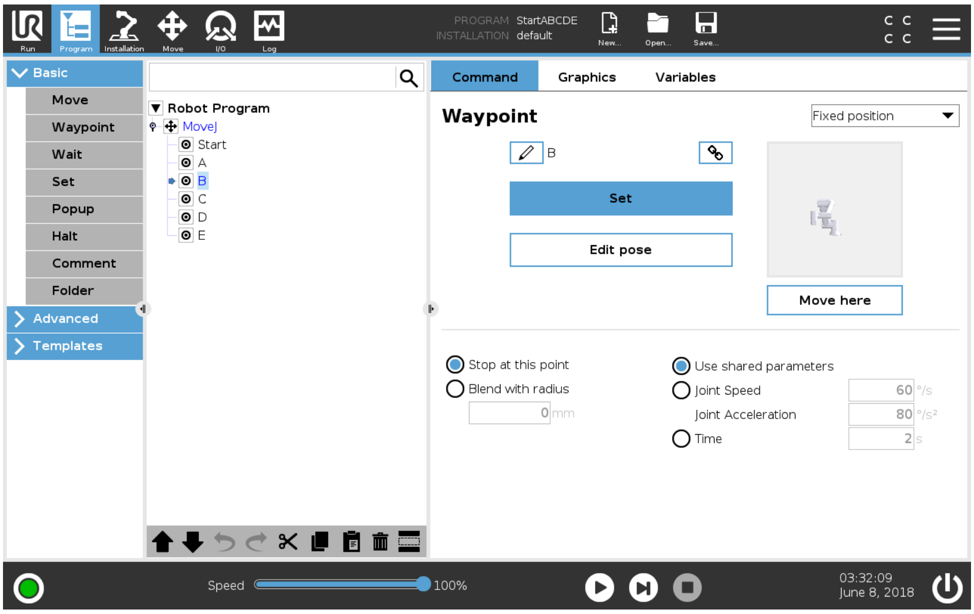
The program tab shows the current program being edited.

16.1 Program Tree

The Program Tree displays the program as a list of commands called Program Nodes. The program name is displayed directly above this list of commands.
To the right of the Program Tree, information relating to the selected command is displayed.
Add commands from the command list under **Basic**, by clicking the desired command type. You can add advanced commands under **Advanced** or you can use **Templates**. Templates provide a Program Tree that is ready to configure.

In the Program Tree, the command that is currently being executed is highlighted as described in `16.1.1`.

16.1.1 Program Execution Indication



The **Program Tree** contains visual cues informing about the command currently being executed by the robot controller. A small indicator icon is displayed to the left of the command icon, and the name of the executing command and any commands of which this command is a sub-command (typically identified by the ▷/▽ command icons) are highlighted with blue. This aids the user in locating the executing command in the tree.

For example, if the robot arm is moving towards a waypoint, the corresponding waypoint sub-command is marked with the icon and its name together with the name of the Move command `(see 16.5.1)` to which it belongs to are shown in blue.

If the program is paused, the program execution indicator icon marks the last command that was in the process of being executed.

Clicking the button with the icon below the Program Tree jumps to the current executing or the last executed command in the tree. If a command is clicked while a program is running, the `Command` tab will keep displaying the information related to the selected command. Pressing the button will make the `Command` tab continuously show information about the currently executing commands again.

16.1.2 Search Button

Tap the 🔍 to perform a text search in the Program Tree. When clicked a search text can be entered and program nodes that match will be highlighted in yellow. Additionally, navigation buttons are made available to navigate through the matches. Press the icon × to exit search mode.

16.1.3 Program Tree Toolbar

Use the toolbar at the base of the Program Tree to modify the Program Tree.

Undo/Redo Buttons

The ⮌ and ⮎ buttons serve to undo and redo changes to commands.

Move Up & Down

The and buttons change the position of a node.

Cut

The button cuts a node and allows it to be used for other actions (e.g., paste it on other place on the Program Tree).

Copy

button allows copies a node and allows it to be used for other actions (e.g., paste it on other place on the Program Tree).

Paste

The button allows you to paste a node that was previously cut or copied.

Delete

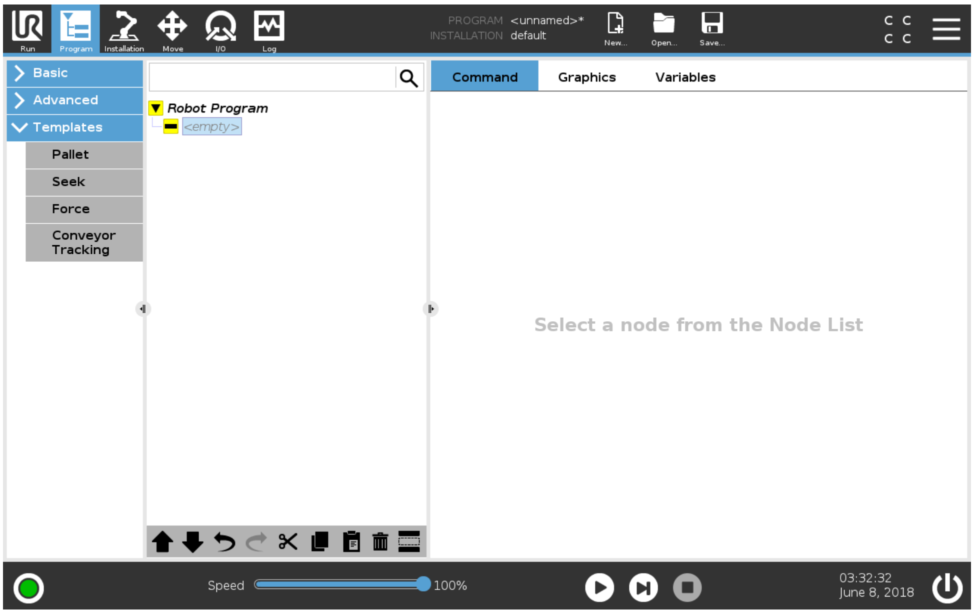
Tap the button to remove a node from the Program Tree.

Suppress

Tap the button to suppress specific nodes on the Program Tree.

Suppressed program lines are simply skipped when the program is run. A suppressed line can be unsuppressed again at a later time. This is a quick way to make changes to a program without destroying the original contents.

16.1.4 Empty Node

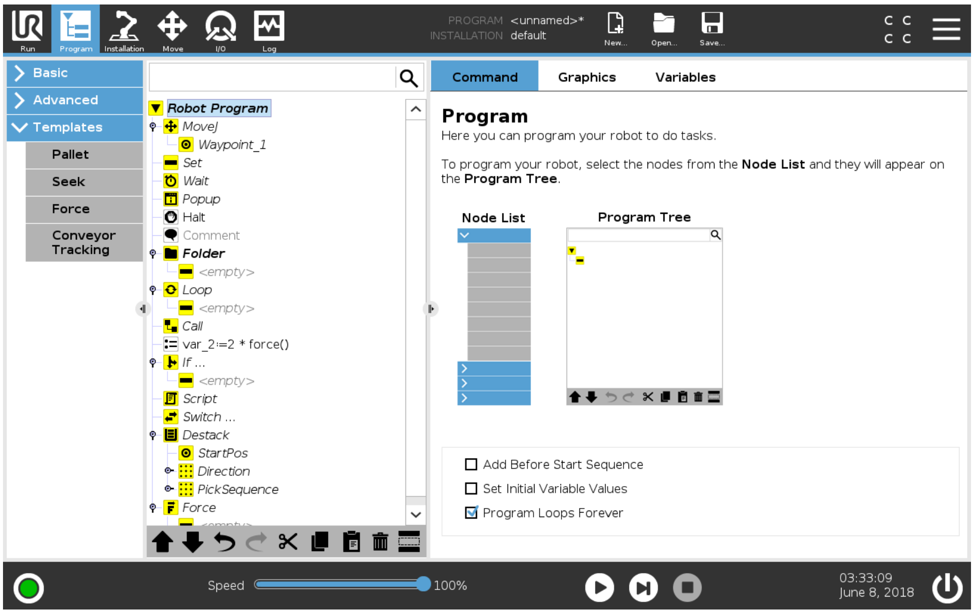


Program Nodes cannot be *empty*. All lines must be specified and defined in the Program Tree for a program to run.

16.2 Command Tab

Use the Command Tab to configure each Program Node on the Program Tree in order to run your Program. The information that is displayed changes depending on the type of node you select.

In the Command Tab field, there are additional check-box options described in the following subsections.



Add Before Start Sequence

Select this check-box to add a set of commands before running your program.

Set Initial Variables Values

Select this check-box to set variable values before the program (and any threads) start to run. The Command Tab field is replaced by an Initial Variable Value field and Init Variables appears at the top of your program tree.

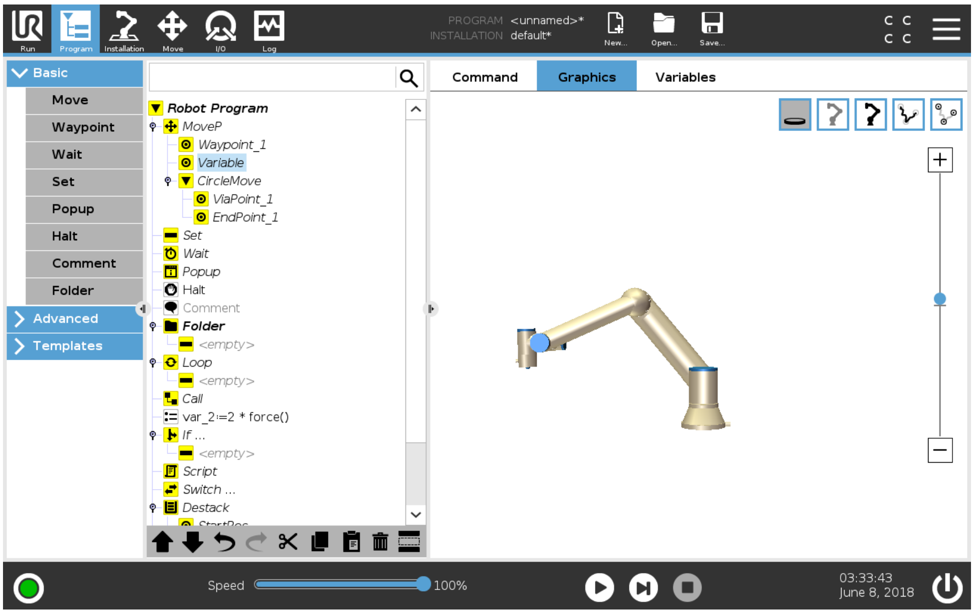
1. Select a variable from the dropdown list, or by use the variable selector box.
2. Enter an expression for that variable. This expression is used to set the variable value at program start.
3. You can select **Keep value from previous run** to initialize the variable to the value found on the **Variables** tab (see 16.4).
   This allows variables to maintain their values between program executions. The variable gets its value from the expression if the program is run for the first time, or if the value tab has been cleared.

A variable can be deleted from the program by setting its name to blank (only spaces).

Program Loops Forever

Select this checkbox to run a program continuously.

16.3 Graphics Tab



Graphical representation of the current robot program. The path of the TCP is shown in 3D view, with motion segments in black, and blend segments (transitions between motion segments) shown in green. The green dots specify the positions of the TCP at each of the waypoints in the program. The 3D drawing of the robot arm shows the current position of the robot arm, and the *shadow* of the robot arm shows how the robot arm intends to reach the waypoint selected in the left hand side of the screen.

If the current position of the robot TCP comes close to a safety or trigger plane, or the orientation of robot tool is near the tool orientation boundary limit (see 13.2.5, a 3D representation of the proximate boundary limit is shown.
Note: when the robot is running a program, the visualization of boundary limits will be disabled.

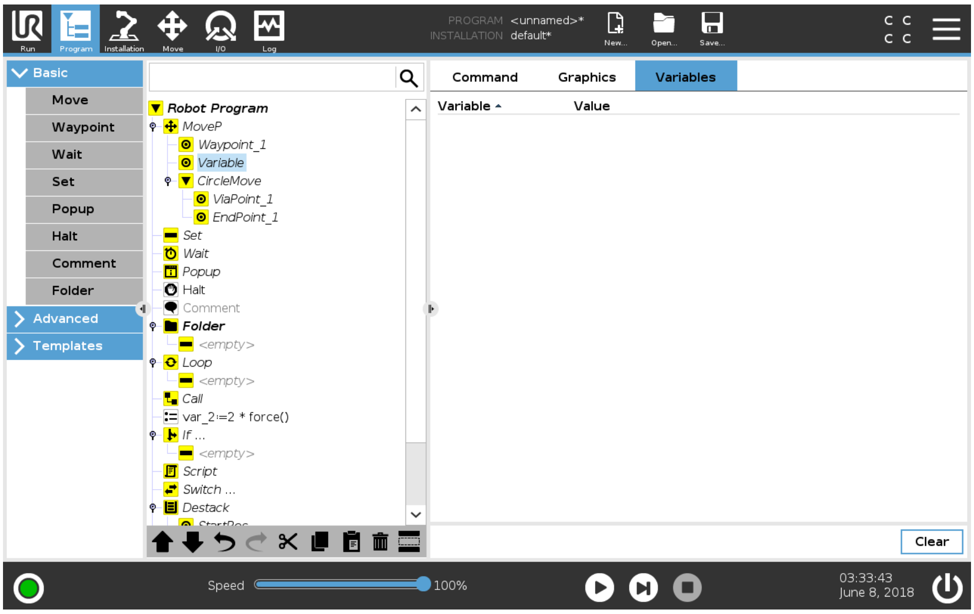
Safety planes are visualized in yellow and black with a small arrow representing the plane normal, which indicates the side of the plane on which the robot TCP is allowed to be positioned. Trigger planes are displayed in blue and green and a small arrow pointing to the side of the plane, where the **Normal** mode limits (see 13.2.2) are active. The tool orientation boundary limit is visualized with a spherical cone together with a vector indicating the current orientation of the robot tool. The inside of the cone represents the allowed area for the tool orientation (vector).

When the target robot TCP no longer is in the proximity of the limit, the 3D representation disappears. If the TCP is in violation or very close to violating a boundary limit, the visualization of the limit turns red.

The 3D view can be zoomed and rotated to get a better view of the robot arm. The buttons in the top-right side of the screen can disable the various graphical components in 3D view. The bottom button switches on/off the visualization of proximate boundary limits.

The motion segments shown depend on the selected program node. If a `Move` node is selected, the displayed path is the motion defined by that move. If a **Waypoint** node is selected, the display shows the following ~ 10 steps of movement.

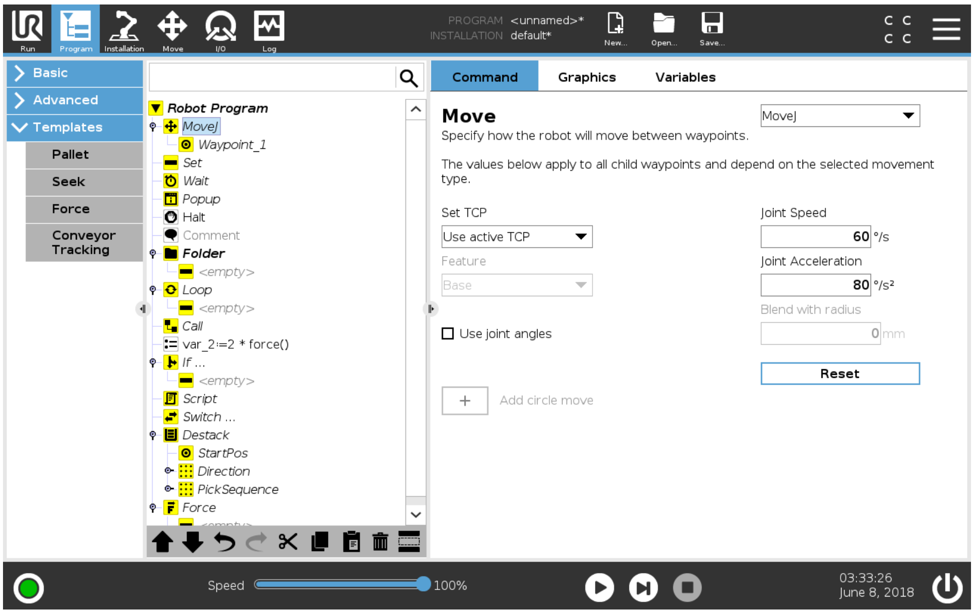
16.4 Variables Tab



The **Variables** tab shows the live values of variables in the running program, and keeps a list of variables and values between program runs. It only appears when it has information to display. The variables are ordered alphabetically by their names. The variable names on this screen are shown with at most 50 characters, and the values of the variables are shown with at most 500 characters.

16.5 Basic program nodes

16.5.1 Move

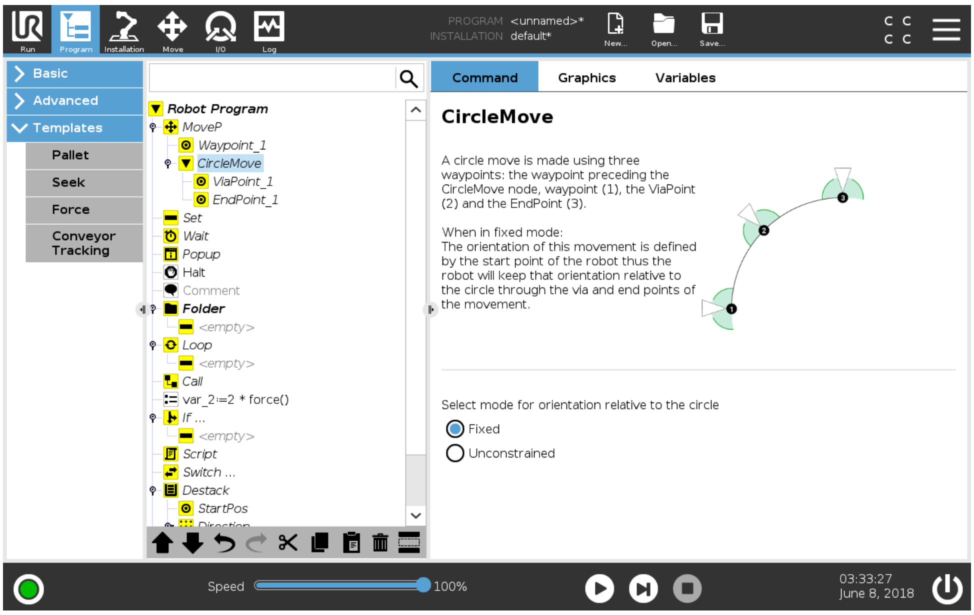


The **Move** command controls the robot motion through the underlying waypoints. Waypoints have to be under a Move command. The Move command defines the acceleration and the speed at which the robot arm will move between those waypoints.

Movement Types

You can select one of three types of movements: **MoveJ**, **MoveL** and **MoveP**. Each movement type is explained below.

- **moveJ** makes movements that are calculated in the robot arm **joint space**. Each joint is controlled to reach the desired end location at the same time. This movement type results in a curved path for the tool. The shared parameters that apply to this movement type are the maximum joint speed and joint acceleration to use for the movement calculations, specified in deg/s and deg/s^2, respectively. If it is desired to have the robot arm move fast between waypoints, disregarding the path of the tool between those waypoints, this movement type is the favorable choice.
- **moveL** moves the Tool Center Point (TCP) linearly between waypoints. This means that each joint performs a more complicated motion to keep the tool on a straight line path. The shared parameters that can be set for this movement type are the desired tool speed and tool acceleration specified in mm/s and mm/s^2, respectively, and also a feature. The selected feature will determine in which feature space the tool positions of the waypoints are represented in.
- **moveP** moves the tool linearly with constant speed with circular blends, and is intended for some process operations, like gluing or dispensing. The size of the blend radius is by default a shared value between all the waypoints. A smaller value will make the path turn sharper whereas a higher value will make the path smoother. While the robot arm is moving through the waypoints with constant speed, the robot control box cannot wait for either an I/O operation or an operator action. Doing so might stop the robot arm's motion, or cause a protective stop.
- **Circle move** can be added to a **moveP** to make a circular movement. The robot starts the movement from its current position or start point, moves through a **ViaPoint** specified on the circular arc, and an **EndPoint** that completes the circular movement.
  A mode is used to calculate tool orientation, through the circular arc. The mode can be:
  - Fixed: only the start point is used to define tool orientation
  - Unconstrained: the start point transforms to the **EndPoint** to define tool orientation



Shared parameters

The shared parameters in the bottom right corner of the Move screen apply to the movement from the previous position of the robot arm to the first waypoint under the command, and from there to each of the following waypoints. The Move command settings do not apply to the path going *from* the last waypoint under that Move command.

TCP selection

The way the robot moves between waypoints is adjusted depending on whether the TCP is set using a user defined TCP or an active TCP. **Use Tool Flange** allows this movement to be adjusted in relation to the Tool Flange.

Setting the TCP in a Move

1. Access the Program Tab screen to set the TCP used for waypoints.
2. Under Command, in the drop down menu on the right select the Move type.
3. Under Move, select an option in the **Set TCP** drop down menu.
4. Select **Use active TCP** or select **a user defined TCP**.
   You can also choose **Use Tool Flange**

Feature selection the feature space the waypoints under the Move command, that should be represented when specifying these waypoints (see section 17.3). This means that when setting a waypoint, the program will remember the tool coordinates in the feature space of the selected feature. There are a few circumstances that need detailed explanation:

Relative waypoints The selected feature has no effect on relative waypoints. The relative movement is always performed with respect to orientation of the **Base**.

Variable waypoints When the robot arm moves to a variable waypoint, the tool target position is calculated as the coordinates of the variable in the space of the selected feature. Therefore, the robot arm movement for a variable waypoint changes if another feature is selected.

Feature variable You can change a feature's position while the program is running by assigning a pose to its corresponding variable.

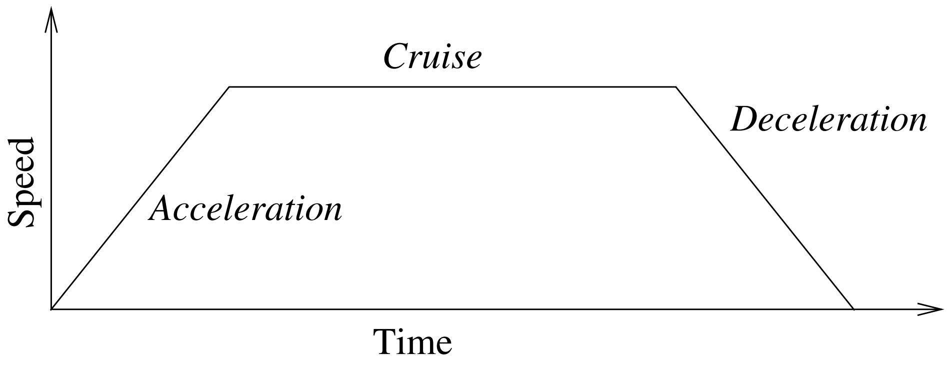
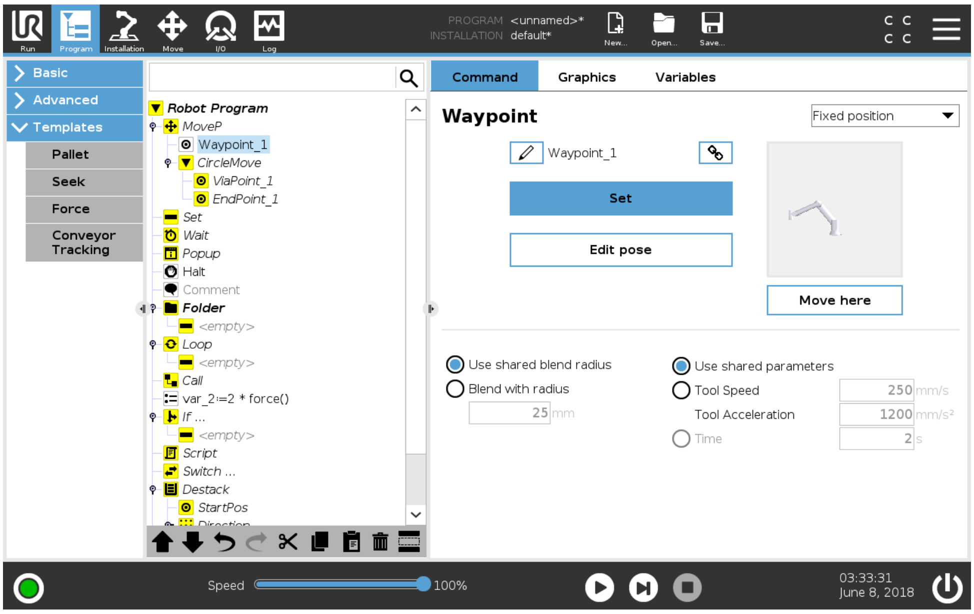


Figure 16.1: Speed profile for a motion. The curve is divided into three segments: *acceleration*, *cruise* and *deceleration*. The level of the *cruise* phase is given by the speed setting of the motion, while the steepness of the *acceleration* and *deceleration* phases is given by the acceleration parameter.

Fixed Waypoint



A point on the robot path. Waypoints are the most central part of a robot program, telling the robot arm where to be. A fixed position waypoint is given by physically moving the robot arm to the position.

Setting the waypoint

Waypoint names

Waypoints automatically get a unique name. The name can be changed by the user. By selecting the link icon, waypoints are linked and share position information. Other waypoint information such as blend radius, tool/joint speed and tool/joint acceleration is configured for individual waypoints even though they may be linked.

Blending

Blending enables the robot to smoothly transition between two trajectories, without stopping at the waypoint between them.

Example Consider a pick and place application as an example (see figure 16.2), where the robot is currently at Waypoint 1 (WP_1), and it needs to pick up an object at Waypoint 3 (WP_3). To avoid collisions with the object and other obstacles (O), the robot must approach WP_3 in the direction coming from Waypoint 2 (WP_2). So three waypoints are introduced to create a path that fulfils the requirements.

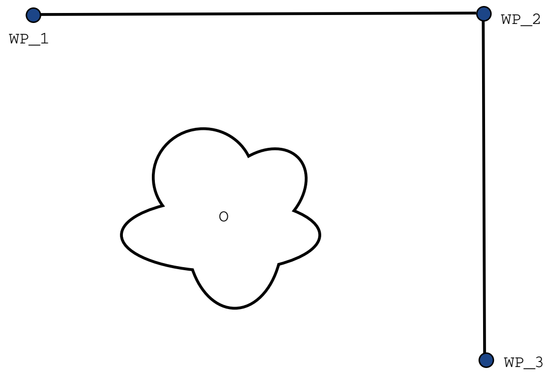


Figure 16.2: WP_1: initial position, WP_2: via point, WP_3: pick up position, O: obstacle.

Without configuring other settings, the robot will make a stop at each waypoint, before continuing the movement. For this task a stop at WP_2 is not optimal since a smooth turn would require less time and energy while still fulfilling the requirements. It is even acceptable that the robot does not reach WP_2 exactly, as long as the transition from the first trajectory to the second happens near this position.

The stop at WP_2 can be avoided by configuring a blend for the waypoint, allowing the robot to calculate a smooth transition into the next trajectory. The primary parameter for the blend is a radius. When the robot is within the blend radius of the waypoint it can start blending and deviate from the original path. This allows for faster and smoother movements, as the robot does not need to decelerate and re-accelerate.

Blend parameters Apart from the waypoints, multiple parameters will influence the blend trajectory (see figure 16.3):

- the blend radius (r)
- the initial and final speed of the robot (at positions p1 and p2, respectively)
- the movement time (e.g. if setting a specific time for a trajectory this will influence the initial/final speed of the robot)
- the trajectory types to blend from and to (MoveL, MoveJ)

If a blend radius is set, the robot arm trajectory blends around the waypoint, allowing the robot arm not to stop at the point.

Blends cannot overlap, so it is not possible to set a blend radius that overlaps with the blend radius of a previous or following waypoint as shown in figure 16.4.

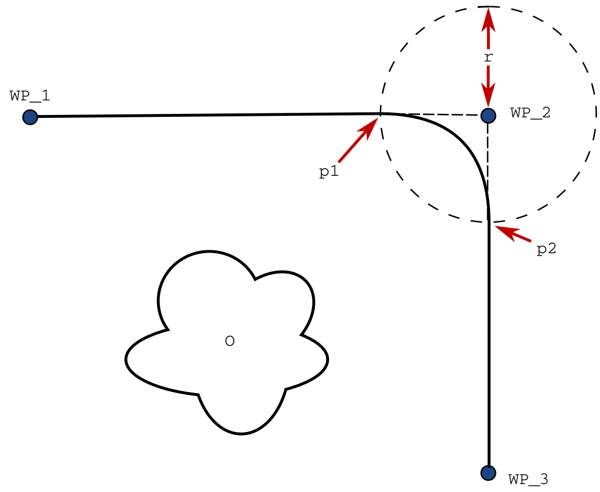


Figure 16.3: Blend over `WP_2` with radius `r`, initial blend position at `p1` and final blend position at `p2`. `O` is an obstacle.

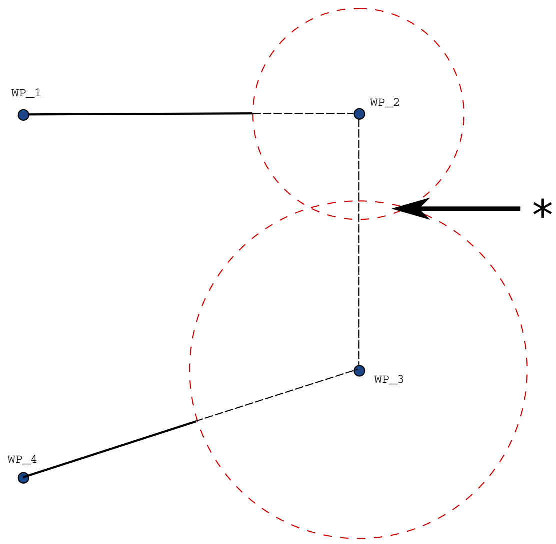


Figure 16.4: Blend radius overlap not allowed (*).

Conditional blend trajectories The blend trajectory is affected both by the waypoint where the blend radius is set and the following one in the program tree. That is, in the program in figure 16.5 the blend around `WP_1` is affected by `WP_2`. The consequence of this becomes more apparent when blending around `WP_2` in this example. There are two possible ending positions and to determine which is the next waypoint to blend to, the robot must evaluate the current reading of the `digital_input[1]` already when entering the blend radius. That means the **if...then** expression (or other necessary statements to determine the following waypoint, e.g. variable waypoints) is evaluated before we actually reach `WP_2` which is somewhat counter-intuitive when looking at the program sequence. If a waypoint is a stop point and followed by conditional expressions to determine the next waypoint (e.g. the I/O command) it is executed when the robot arm has stopped at the waypoint.

```
MoveL
    WP_I
    WP_1 (blend)
    WP_2 (blend)
    if (digital_input[1]) then
        WP_F_1
    else
        WP_F_2
```

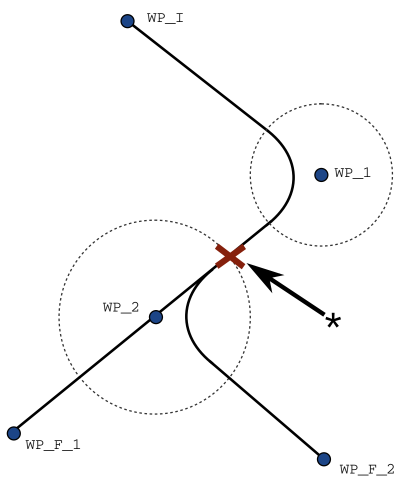


Figure 16.5: `WP_I` is the initial waypoint and there are two potential final waypoints `WP_F_1` and `WP_F_2`, depending on a conditional expression. The conditional `if` expression is evaluated when the robot arm enters the second blend (*).

Trajectory type combinations It is possible to blend between all four combinations of trajectory types of **MoveJ** and **MoveL**, but the specific combination will affect the computed blend trajectory. There are 4 possible combinations:

1. **MoveJ** to **MoveJ** (Pure Joint space blend)
2. **MoveJ** to **MoveL**
3. **MoveL** to **MoveL** (Pure Cartesian space blend)
4. **MoveL** to **MoveJ**

Pure joint space blending (bullet 1) vs. pure Cartesian space blending (bullet 3) is compared in figure 16.6. It shows two potential paths of the tool for identical sets of waypoints.

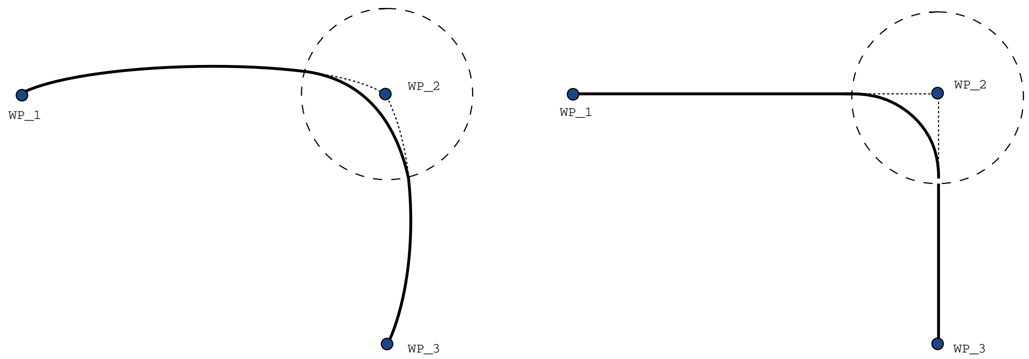


Figure 16.6: Joint space (`MoveJ`) vs. cartesian space (`MoveL`) movement and blend.

Of the different combinations, bullets 2, 3 and 4 will result in trajectories that keep within the boundaries of the original trajectory in Cartesian space. An example of a blend between different trajectory types (bullet 2) can be seen in figure 16.7.

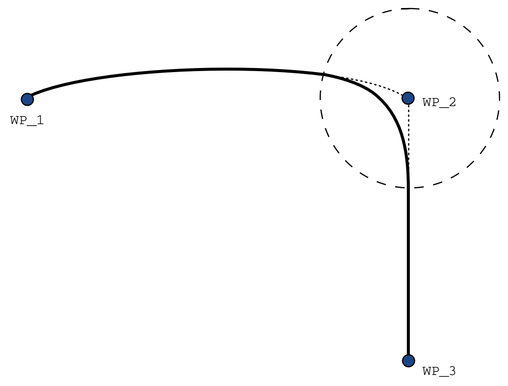


Figure 16.7: Blending from a movement in joint space (`MoveJ`) to linear tool movement (`MoveL`).

Pure joint space blends (bullet 1), however, may behave in a way that is less intuitive, since the robot will try to achieve the smoothest possible trajectory in Joint space taking velocities and time requirements into account. Due to this, they may deviate from the course specified by the waypoints. This is especially the case if there are significant differences in a joint's velocity between the two trajectories. *Caution:* if the velocities are very different (e.g. by specifying advanced settings - either velocity or time - for a specific waypoint) this can result in large deviations from the original trajectory as shown in figure `16.8`. If you need to blend between different velocities and cannot accept this deviation consider a blend in Cartesian space using **MoveL** instead.

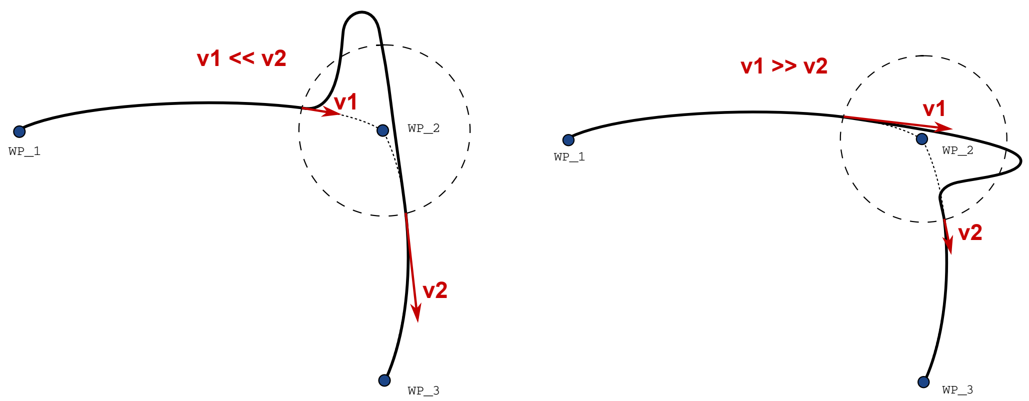
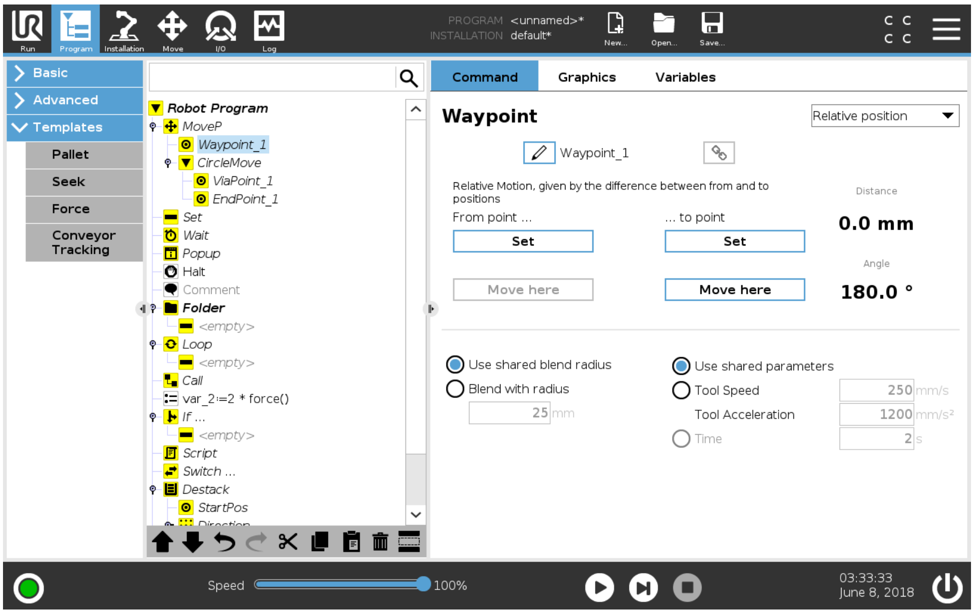


Figure 16.8: Joint space blending when initial velocity `v1` is significantly smaller than final velocity `v2` or the opposite.

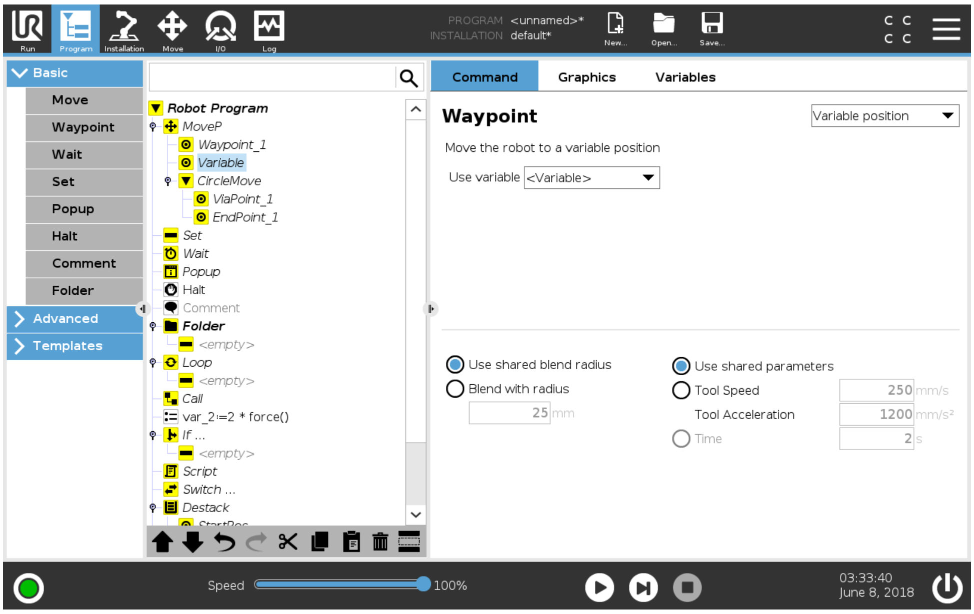
Relative Waypoint



A waypoint with the position given relative to the robot arm's previous position, such as "two centimeters to the left". The relative position is defined as the difference between the two given positions (left to right).
Note: repeated relative positions can move the robot arm out of its workspace.

The distance here is the Cartesian distance between the TCP in the two positions. The angle states how much the TCP orientation changes between the two positions. More precisely, the length of the rotation vector describing the change in orientation.

Variable Waypoint

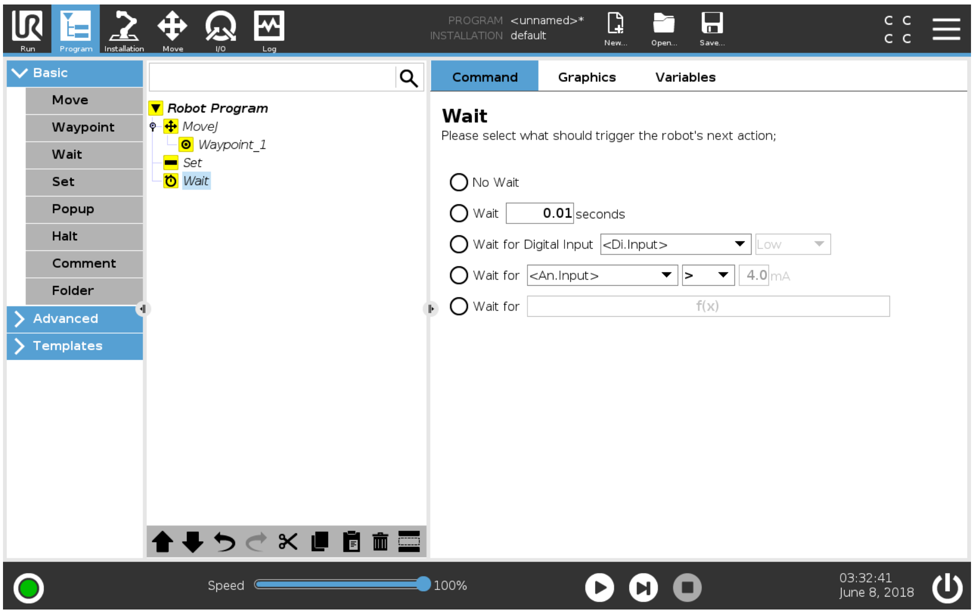


A waypoint with the position given by a variable, in this case `calculated_pos`. The variable has to be a *pose* such as var=p[0.5,0.0,0.0,3.14,0.0,0.0]. The first three are *x,y,z* and the last three are the orientation given as a *rotation vector* given by the vector *rx,ry,rz*. The length of the axis is the angle to be rotated in radians, and the vector itself gives the axis about which to rotate. The position is always given in relation to a reference frame or coordinate system, defined by the selected feature. If a blend radius is set on a fixed waypoint and the waypoints preceding and succeeding it are variable or if the blend radius is set on a variable waypoint, then the blend radius will not be checked for overlap (see 16.5.1). If, when running the program, the blend radius overlaps a point, the robot will ignore it and move to the next one.

For example, to move the robot 20 mm along the z-axis of the tool:

```
var_1=p[0,0,0.02,0,0,0]
Movel
  Waypoint_1 (variable position):
    Use variable=var_1, Feature=Tool
```

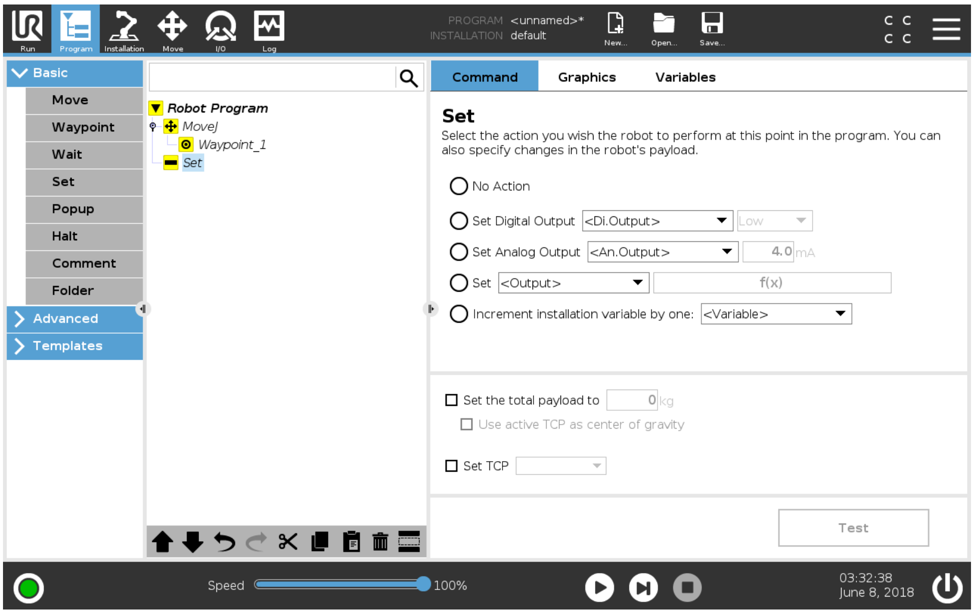
16.5.2 Wait



Wait pauses I/O signal, or expression, for a given amount of time. If **No Wait** is selected, nothing is done.

Note: Once **Tool Communication Interface TCI** is enabled, the tool analog input is unavailable for **Wait For** selection and expressions (see 17.1.10).

16.5.3 Set

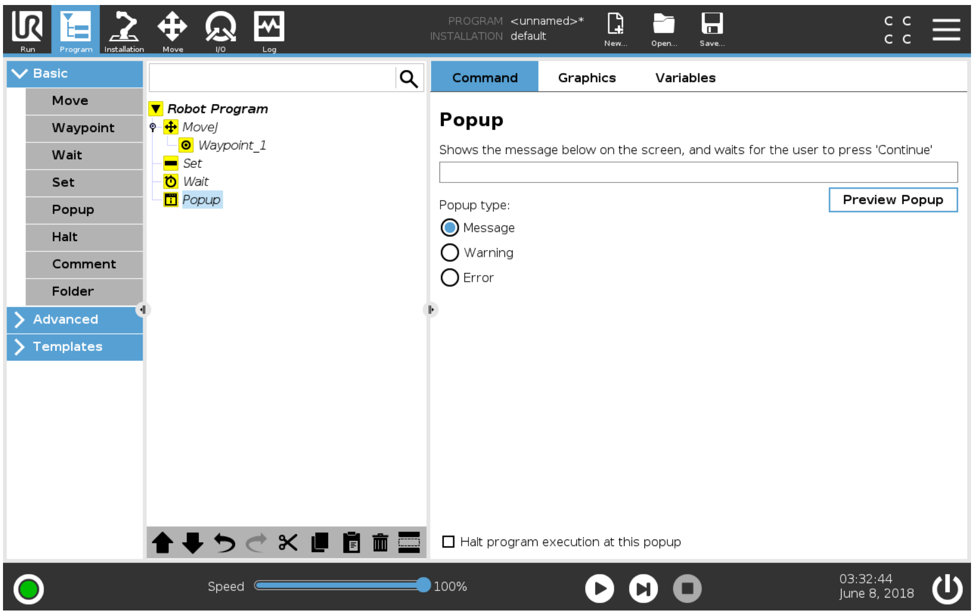


Sets either digital or analog outputs to a given value.

The command can also be used to set the payload of the robot arm. Adjusting the payload weight can be necessary to prevent the robot from triggering a protective stop, when the weight at the tool differs from the expected payload. As default the active TCP is also used as the center of gravity. If the active TCP should not be used as the center of gravity the checkbox can be unchecked.

The active TCP can also be modified using a **Set** command. Simply tick the check box and select one of the TCP offsets from the menu. If the active TCP for a particular motion is known at the time of writing of the program, consider using the TCP selection on the **Move** card instead (see 16.5.1). For further information about configuring named TCPs (see 17.1.1).

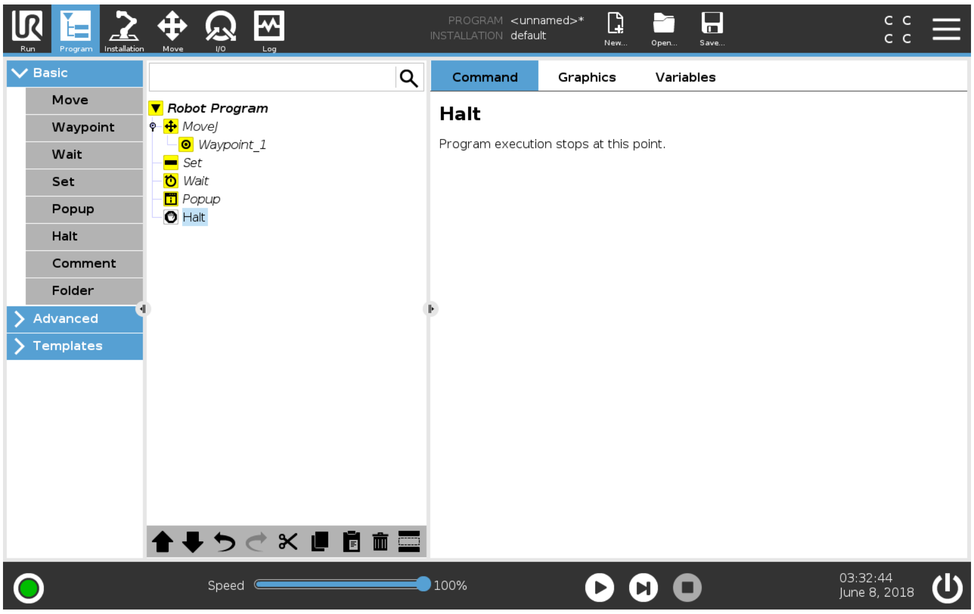
16.5.4 Popup



The popup is a message that appears on the screen when the program reaches this command. The style of the message can be selected, and the text itself can be given using the on-screen keyboard. The robot waits for the user/operator to press the “OK” button under the popup before continuing the program. If the “Halt program execution” item is selected, the robot program halts at this popup.

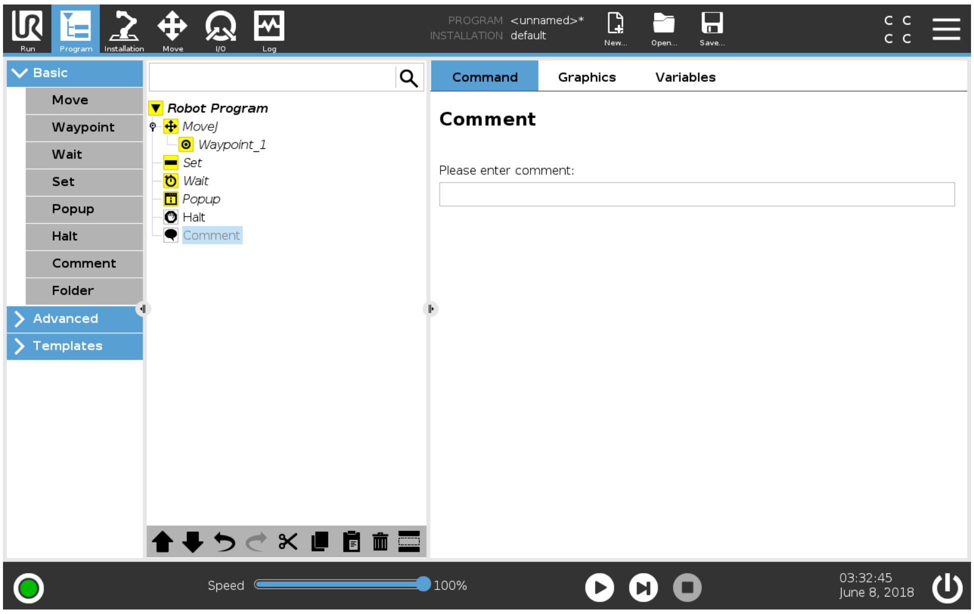
Note: Messages are limited to a maximum of 255 characters.

16.5.5 Halt



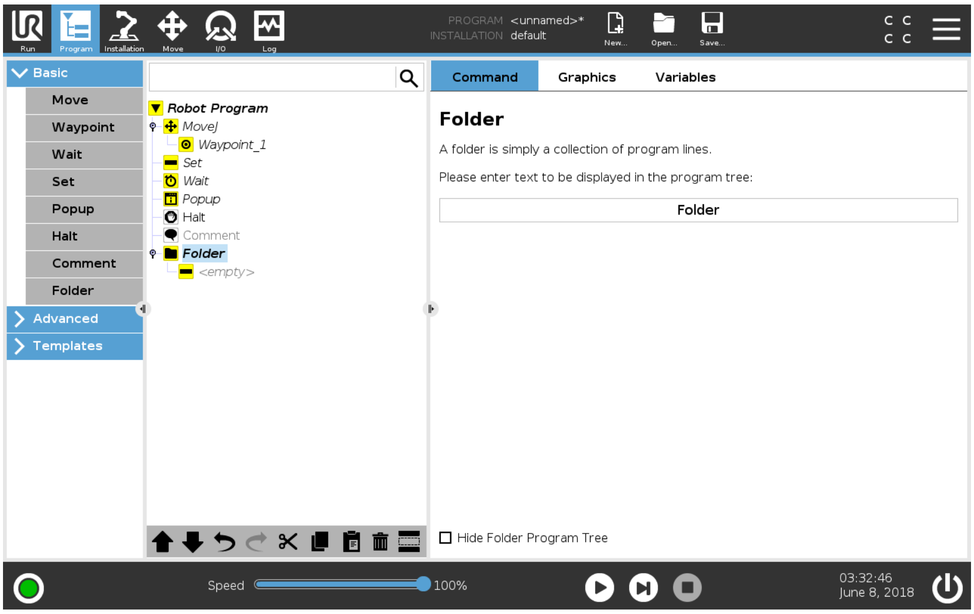
The program execution stops at this point.

16.5.6 Comment



Gives the programmer an option to add a line of text to the program. This line of text does not do anything during program execution.

16.5.7 Folder

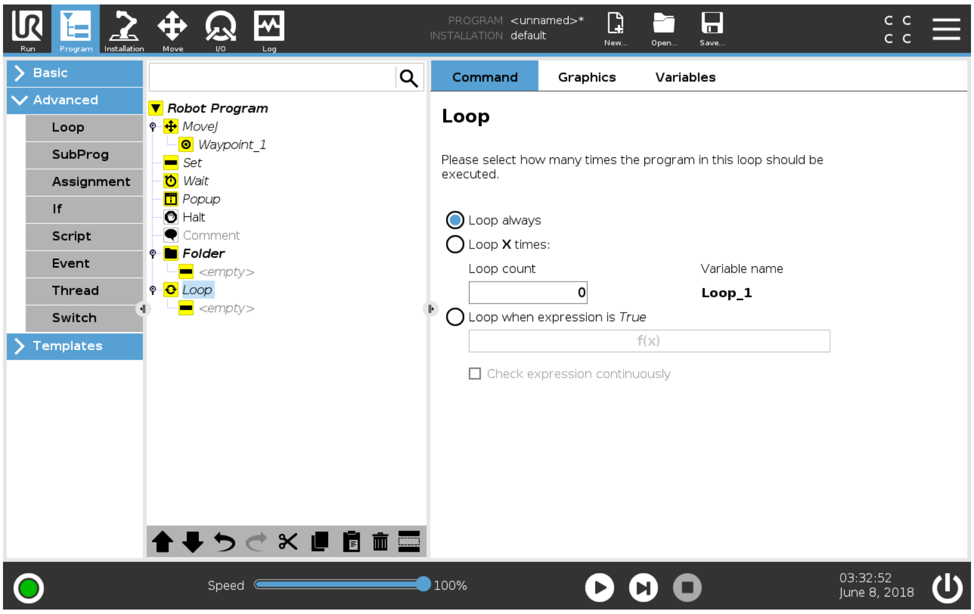


A **Folder** is used to organize and label specific parts of a program, to clean up the program tree, and to make the program easier to read and navigate.

Folders have no impact on the program and its execution.

16.6 Advanced program nodes

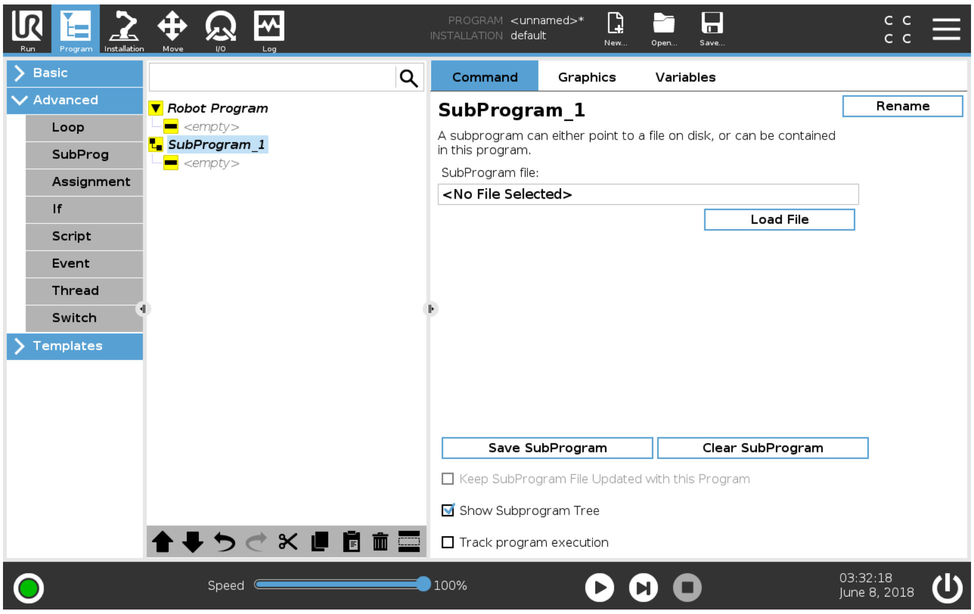
16.6.1 Loop



Loops the underlying program commands. Depending on the selection, the underlying program commands are either looped infinitely, a certain number of times or as long as the given condition is true. When looping a certain number of times, a dedicated loop variable (called `loop_1` in the screen shot above) is created, which can be used in expressions within the loop. The loop variable counts from 0 to $N-1$.

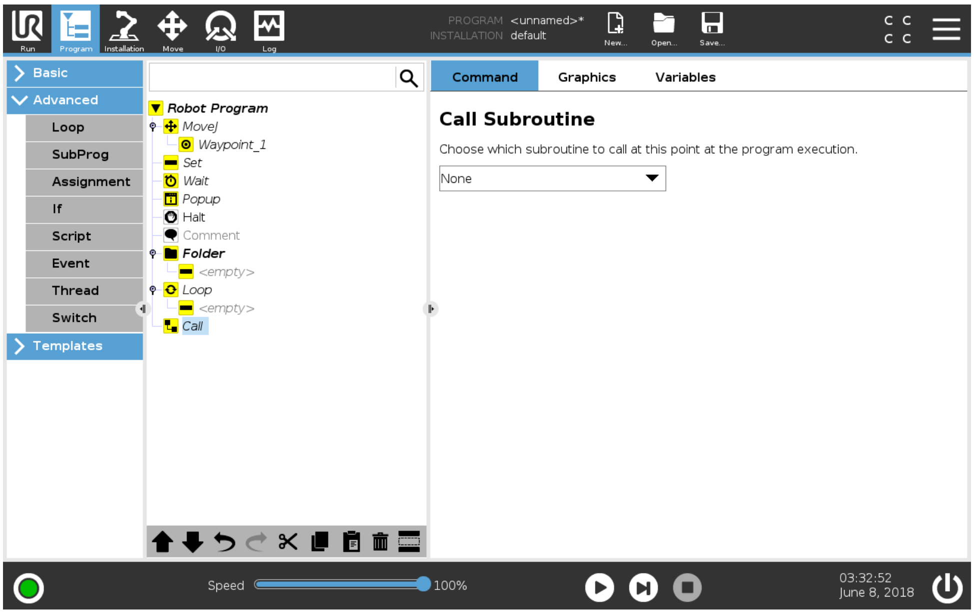
When looping using an expression as end condition, PolyScope provides an option for continuously evaluating that expression, so that the “loop” can be interrupted anytime during its execution, rather than just after each iteration.

16.6.2 SubProgram



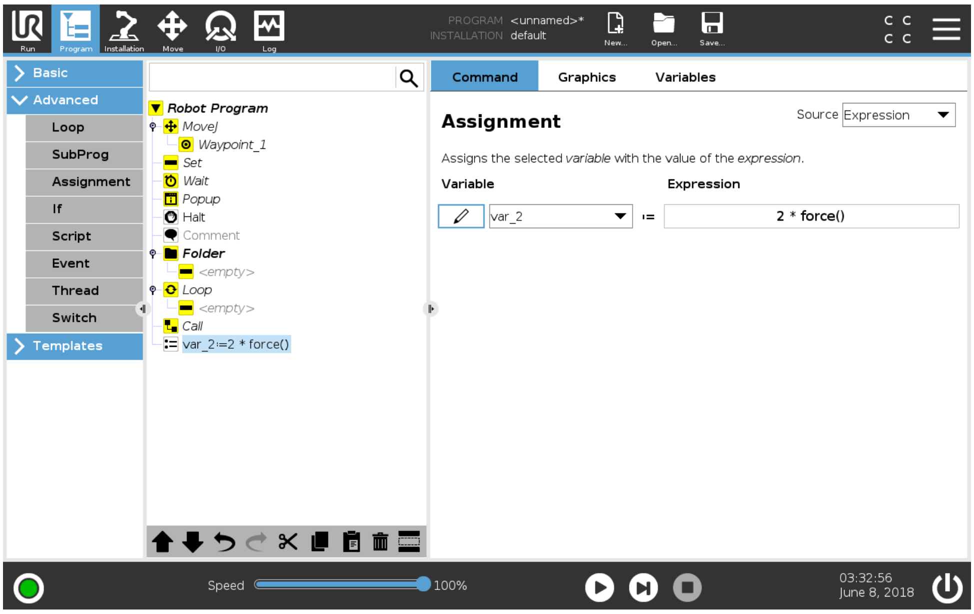
A Sub Program can hold program parts that are needed several places. A Sub Program can be a separate file on the disk, and can also be hidden to protect against accidental changes to the SubProgram.

Call SubProgram



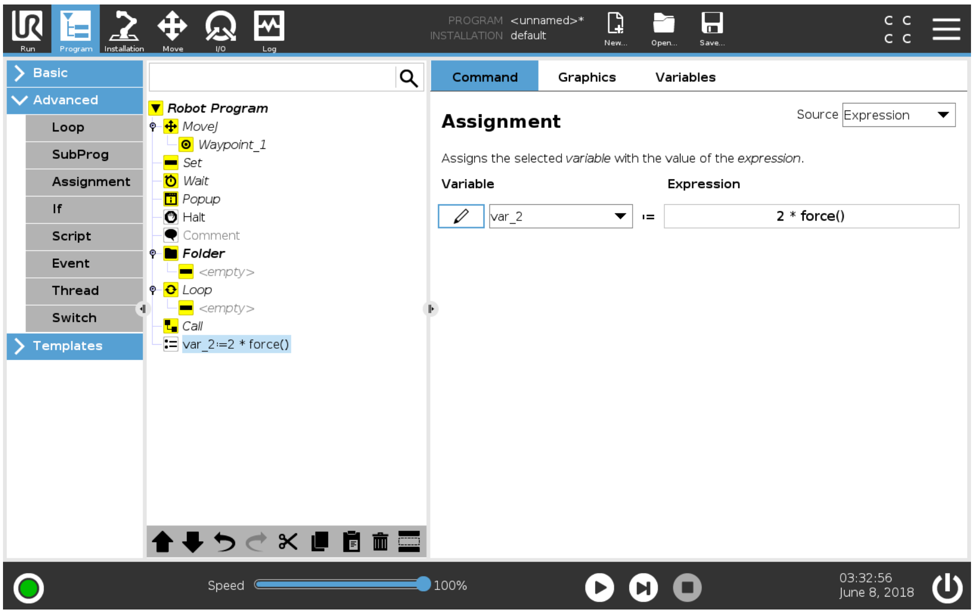
A call to a sub program will run the program lines in the sub program, and then return to the following line.

16.6.3 Assignment



Assigns values to variables. An assignment puts the computed value of the right hand side into the variable on the left hand side. This can be useful in complex programs.

16.6.4 If

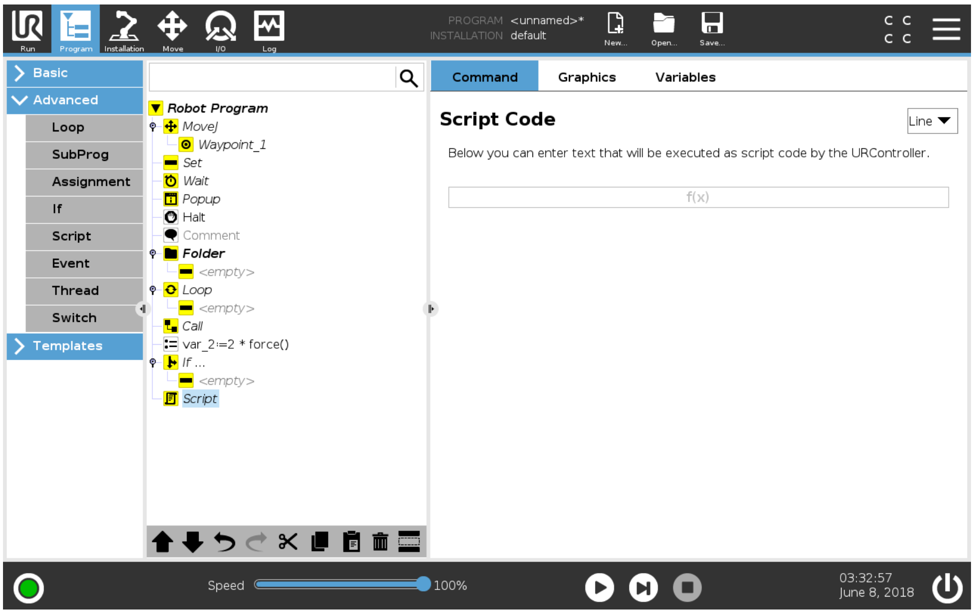


An **If...Else** command construction changes the robot's behavior based on sensor inputs or variable values. Use the Expression Editor to describe the condition under which the robot follows the statements of this **If** command. If the condition is evaluated as True, the statements within this **If** command are executed.

An **If** command can have several ElseIf statements that can be added and removed using the **Add ElseIf** and the **Remove ElseIf** buttons. However, an **If** command can have only one **Else** statement.

Note: You can select the **Check expression continuously** checkbox to allow the conditions of the **If** command and **ElseIf** statements to be evaluated while the contained lines are executed. If an expression within the **If** command is evaluated as False, the **ElseIf** or **Else** statements are followed.

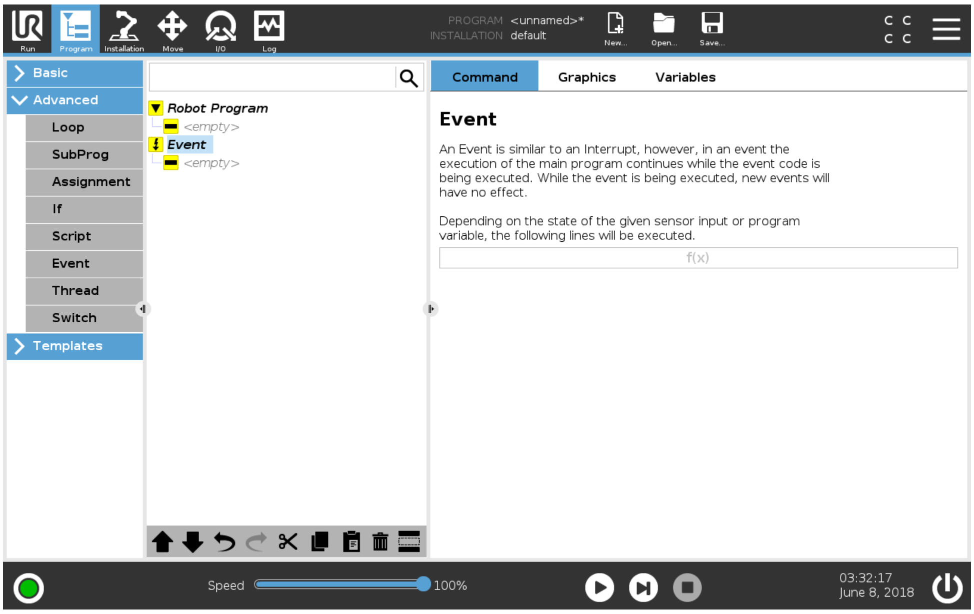
16.6.5 Script



This command gives access to the underlying real time script language that is executed by the robot controller. It is intended for advanced users only and instructions on how to use it can be found in the Script Manual on the support website (`http://www.universal-robots.com/support`).

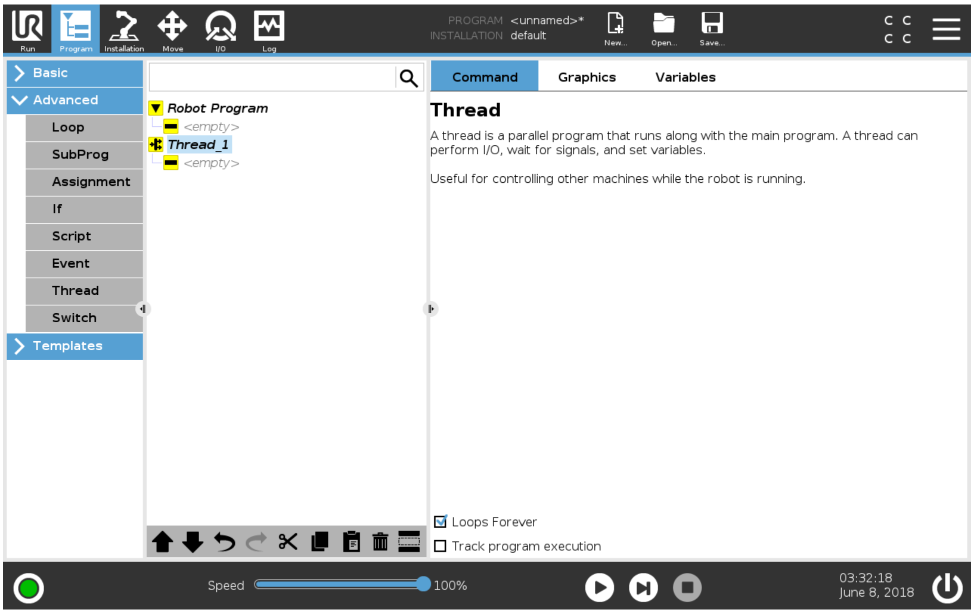
If the “File” option in the top left corner is chosen, it is possible to create and edit script programs files. This way, long and complex script programs can be used together with the operator-friendly programming of PolyScope.

16.6.6 Event



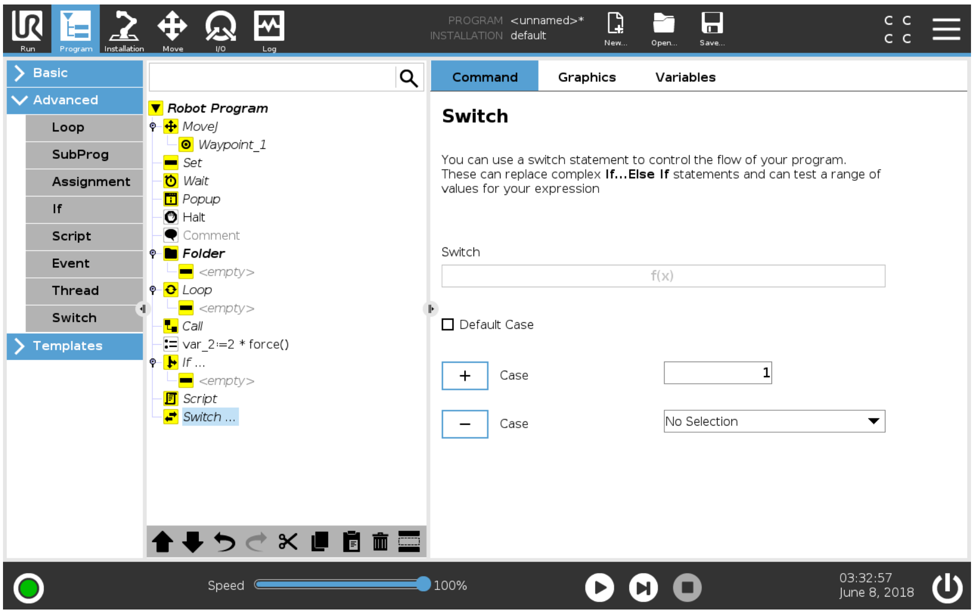
An event can be used to monitor an input signal, and perform some action or set a variable when that input signal goes high. For example, in the event that an output signal goes high, the event program can wait for 200ms and then set it back to low again. This can make the main program code a lot simpler in the case on an external machine triggering on a rising flank rather than a high input level. Events are checked once every control cycle (8ms).

16.6.7 Thread



A thread is a parallel process to the robot program. A thread can be used to control an external machine independently of the robot arm. A thread can communicate with the robot program with variables and output signals.

16.6.8 Switch

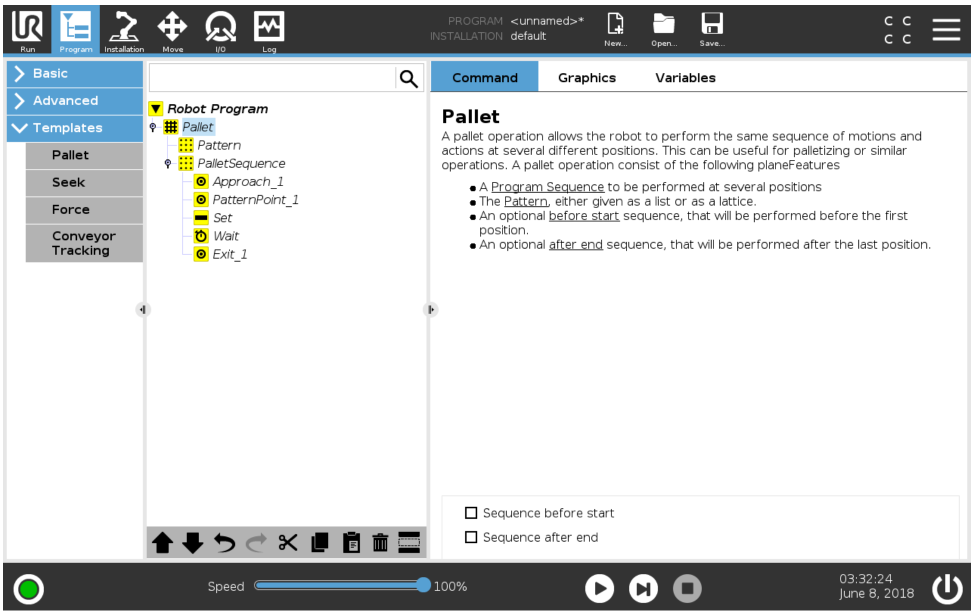


A **Switch Case** construction can make the robot change behavior based on sensor inputs or variable values. Use the **Expression Editor** to describe the base condition and define the cases under which the robot should proceed to the sub-commands of this `Switch`. If the condition is evaluated to match one of the cases, the lines inside the `Case` are executed. If a `Default Case` has been specified, then the lines will be executed only if no other matching cases were found.

Each `Switch` can have several `Cases` and one `Default Case`. `Switches` can only have one instance of any `Case` values defined. `Cases` can be added using the buttons on the screen. A `Case` command can be removed from the screen for that switch.

16.7 Wizards

16.7.1 Pallet



A pallet operation can perform a sequence of motions in a set of places given as a pattern (`see 16.7.1.1`). At each of the positions in the pattern, the sequence of motions will be run relative to the pattern position.

Programming a Pallet Operation

The steps to go through are as follows;

1. Define the pattern.
2. Make a **PalletSequence** for picking up/placing at each single point. The sequence describes what should be done at each pattern position.
3. Use the selector on the sequence command screen to define which of the waypoints in the sequence should correspond to the pattern positions.

Pallet Sequence/Anchorable Sequence

In a **Pallet Sequence** node, the motions of the robot arm are relative to the pallet position. The behavior of a sequence is such that the robot arm will be at the position specified by the pattern at the **Anchor Position/Pattern Point**. The remaining positions will all be moved to make this fit.

Do not use the **Move** command inside a sequence, as it will not be relative to the anchor position.

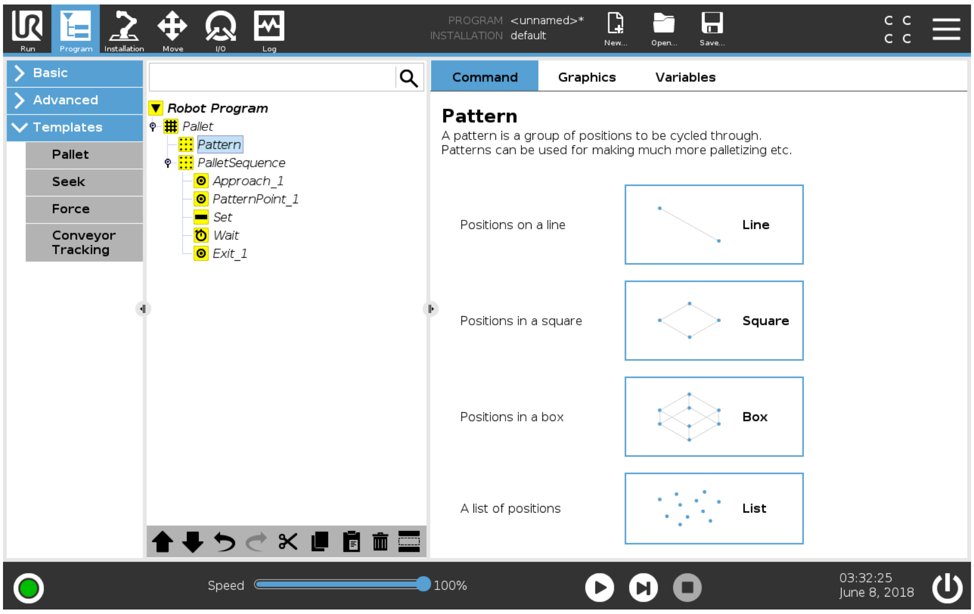
“BeforeStart”

The optional **BeforeStart** sequence is run just before the operation starts. This can be used to wait for ready signals.

“AfterEnd”

The optional **AfterEnd** sequence is run when the operation is finished. This can be used to signal conveyor motion to start, preparing for the next pallet.

16.7.1.1 Pattern



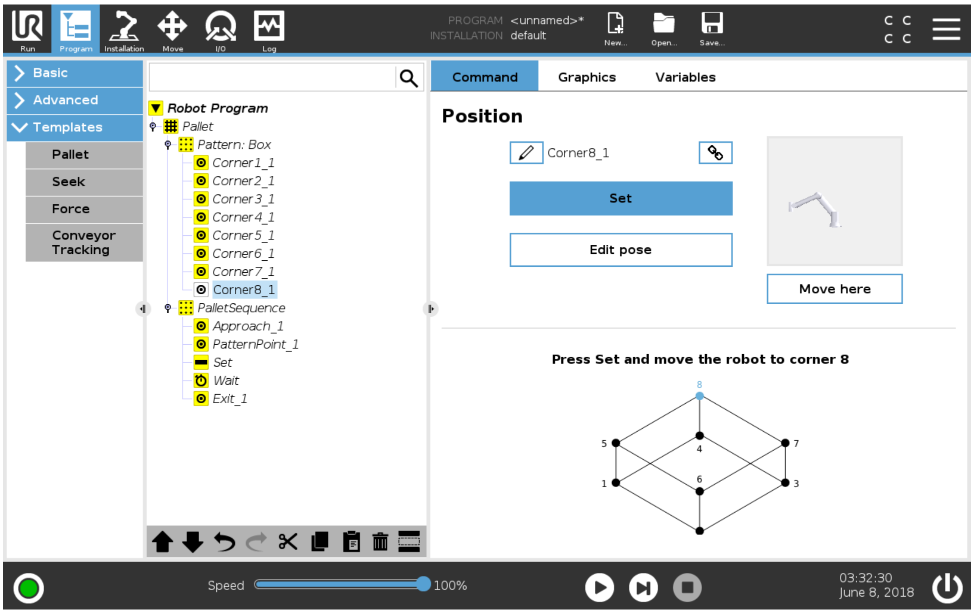
The **Pattern** command can be used to cycle through positions in the robot program. The **Pattern** command corresponds to one position at each execution.

A pattern can be given as one of four types. The first three, **Line**, **Square** or **Box** can be used for positions in a regular pattern. The regular patterns are defined by a number of characteristic points, where the points define the edges of the pattern. For **Line** this is the two end points, for **Square** this is three of the four corner points, where as for **Box** this is four of the eight corner points. The programmer enters the number of positions along each of the edges of the pattern. The robot controller then calculates the individual pattern positions by proportionally adding the edge vectors together.

If the positions to be traversed do not fall in a regular pattern, the **List** option can be chosen, where a list of all the positions is provided by the programmer. This way any kind of arrangement of the positions can be realized.

Defining the Pattern

When the **Box** pattern is selected, the screen changes to what is shown below.



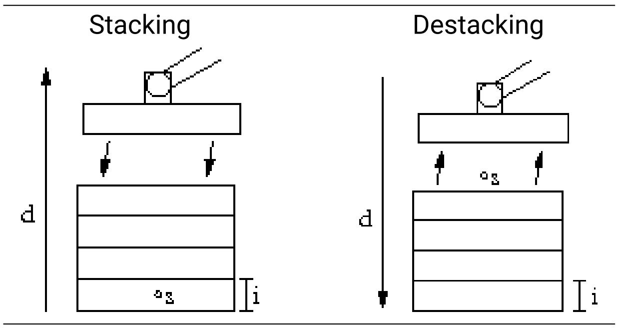
A **Box** pattern uses three vectors to define the side of the box. These three vectors are given as four points, where the first vector goes from point one to point two, the second vector goes from point two to point three, and the third vector goes from point three to point four. Each vector is divided by the interval count numbers. A specific position in the pattern is calculated by simply adding the interval vectors proportionally.

The **Line** and **Square** patterns work similarly.

A counter variable is used while traversing the positions of the pattern. The name of the variable can be seen on the **Pattern** command screen. The variable cycles through the numbers from 0 to $X * Y * Z - 1$, the number of points in the pattern. This variable can be manipulated using assignments, and can be used in expressions.

16.7.2 Seek

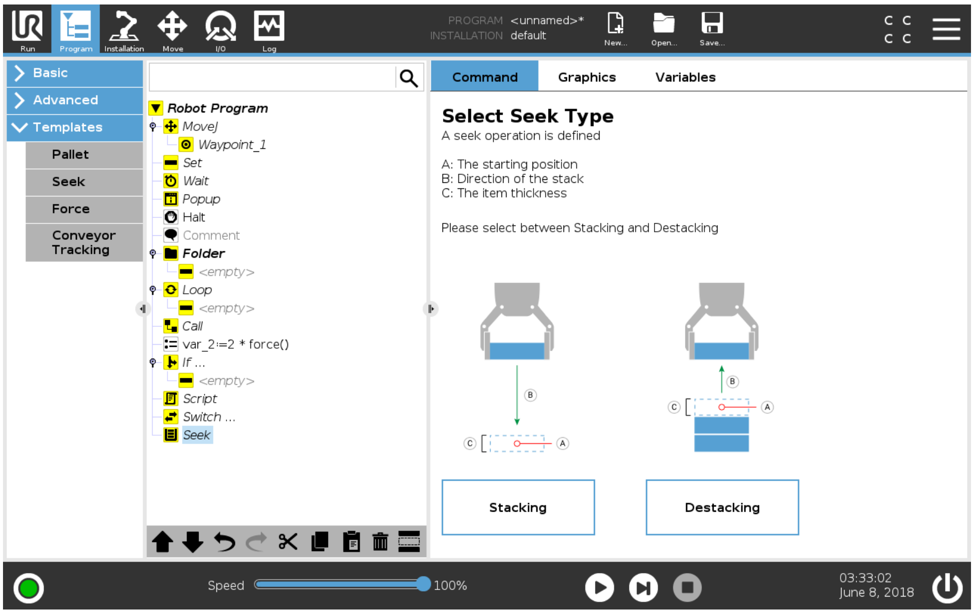
A seek function uses a sensor to determine when the correct position is reached to grab or drop an item. The sensor can be a push button switch, a pressure sensor or a capacitive sensor. This function is made for working on stacks of items with varying item thickness, or where the exact positions of the items are not known or too hard to program.



When programming a seek operation for working on a stack, one must define s the starting point, d the stack direction and i the thickness of the items in the stack.

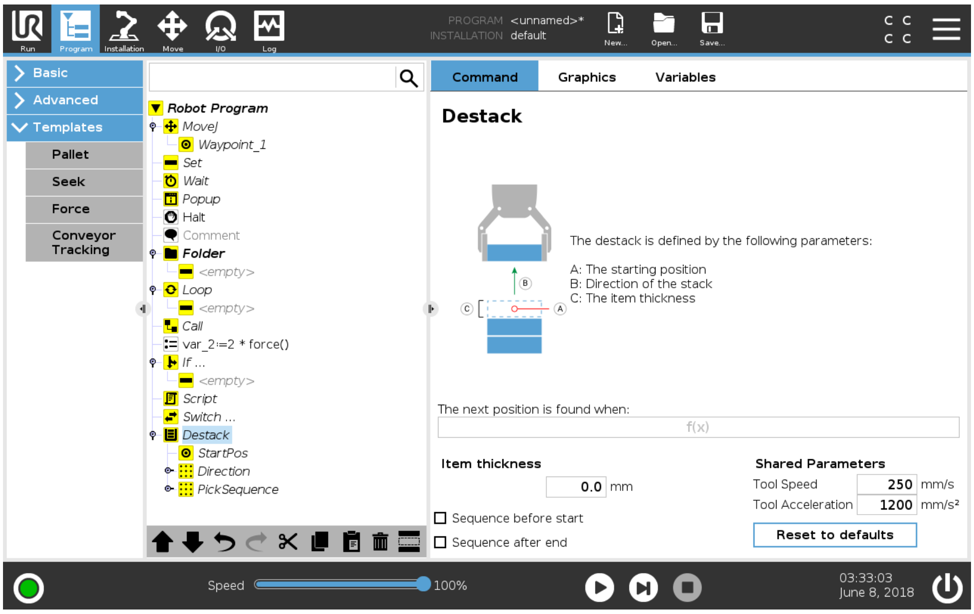
On top of this, one must define the condition for when the next stack position is reached, and a special program sequence that will be performed at each of the stack positions. Also speed and accelerations need to be given for the movement involved in the stack operation.

Stacking



When stacking, the robot arm moves to the starting position, and then moves *opposite* the direction to search for the next stack position. When found, the robot remembers the position and performs the special sequence. The next time round, the robot starts the search from the remembered position incremented by the item thickness along the direction. The stacking is finished when the stack height is more than some defined number, or when a sensor gives a signal.

Destacking

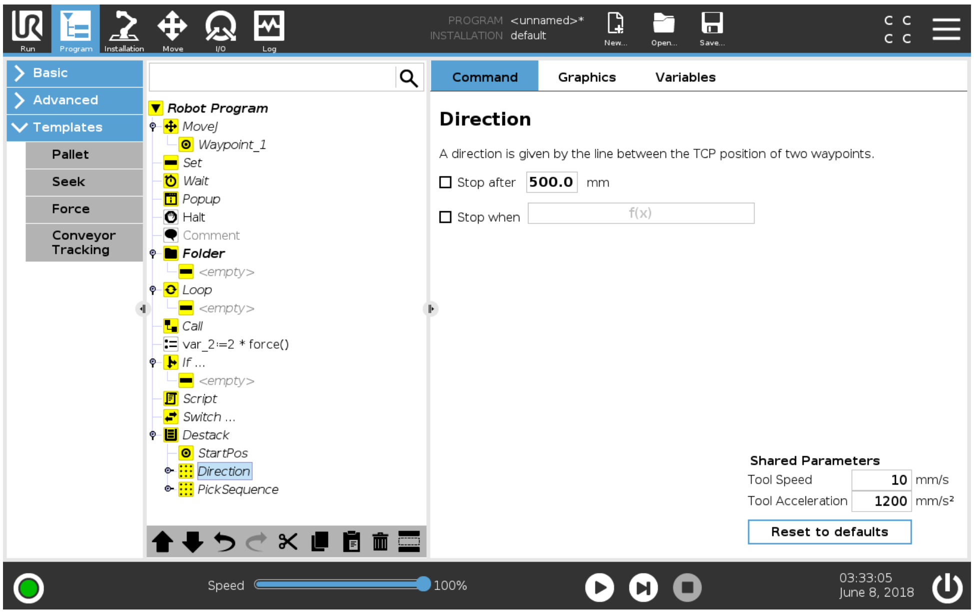


When destacking, the robot arm moves from the starting position in the given direction to search for the next item. The condition on the screen determines when the next item is reached. When the condition becomes satisfied, the robot remembers the position and performs the special sequence. The next time round, the robot starts the search from the remembered position, incremented by the item thickness along the direction.

Starting position

The starting position is where the stack operation starts. If the starting position is omitted, the stack starts at the robot arm's current position.

Direction



The direction is given by two positions, and is calculated as the position difference from the first positions TCP to the second positions TCP.

Note: A direction does not consider the orientations of the points.

Next Stacking Position Expression

The robot arm moves along the direction vector while continuously evaluating whether the next stack position has been reached. When the expression is evaluated to `True` the special sequence is executed.

"BeforeStart"

The optional `BeforeStart` sequence is run just before the operation starts. This can be used to wait for ready signals.

"AfterEnd"

The optional `AfterEnd` sequence is run when the operation is finished. This can be used to signal conveyor motion to start, preparing for the next stack.

Pick/Place Sequence

Like for the Pallet operation (16.7.1), a special program sequence is performed at each stack position.

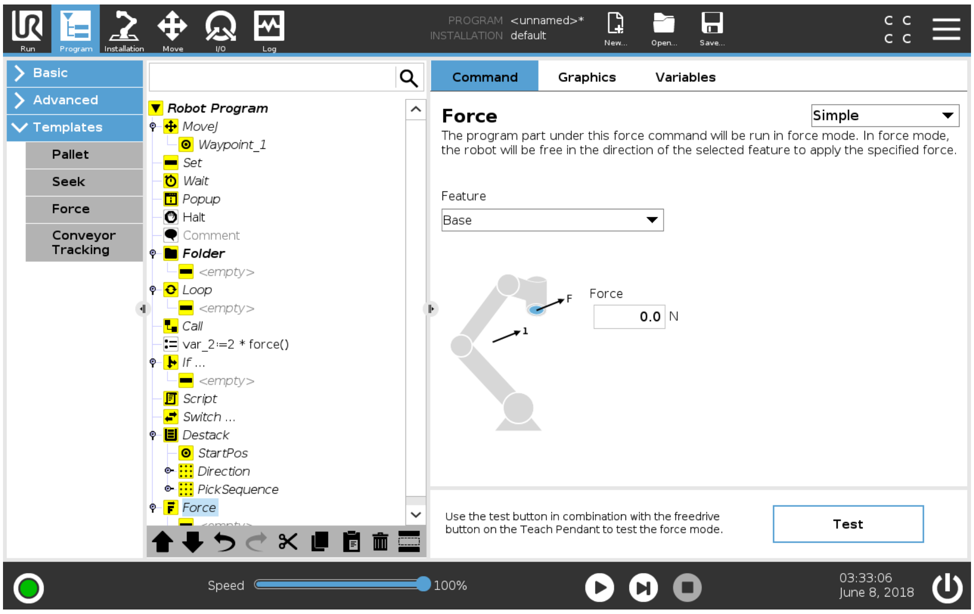
16.7.3 Force

In the robot workspace **Force mode** allows for compliance and force in selectable axes. All robot arm movements under a **Force** command are in **Force mode**. When the robot arm is moving in **Force mode**, it is possible to select one or more axes there the robot arm is compliant. The robot arm complies with the environment along a compliant axes. This means the robot arm automatically adjusts its position in order to achieve the desired force. It is also possible to make the robot arm itself apply a force to its environment, e.g. a workpiece.

Force mode is suited to applications where the actual TCP position along a predefined axis is not important, but instead a desired force along that axis is required. For example if the robot TCP rolls against a curved surface, pushes or pulls a workpiece. **Force mode** also supports applying certain torques around predefined axes.
Note: if no obstacles are met in an axis where a non-zero force is set, the robot arm attempts to accelerate along that axis.
Although an axis is selected to be compliant, the robot program still tries to move the robot along that axis. However, force control assures that the robot arm still approaches the specified force.

WARNING:

1. Avoid high deceleration just before entering force mode.
2. Avoid high acceleration in force mode, since it decreases force control accuracy.
3. Avoid movements parallel to compliant axes before entering force mode.



Feature selection

The **Feature menu** is used to select the coordinate system (axes) the robot will use while it is operating in force mode. The features in the menu are those which have been defined in the installation (see 17.3).

Force mode type

The are four different types of force mode each determining the way in which the selected feature will be interpreted.

- **Simple**: Only one axis will be compliant in force mode. The force along this axis is adjustable. The desired force will always be applied along the z-axis of the selected feature. However, for Line features, it is along their y-axis.
- **Frame**: The Frame type allows for more advanced usage. Here, compliance and forces in all six degrees of freedom can be independently selected.
- **Point**: When Point is selected, the task frame has the y-axis pointing from the robot TCP towards the origin of the selected feature. The distance between the robot TCP and the origin of the selected feature is required to be at least 10 mm. Note that the task frame will change at runtime as the position of the robot TCP changes. The x- and z-axis of the task frame are dependent on the original orientation of the selected feature.
- **Motion**: Motion means that the task frame will change with the direction of the TCP motion. The x-axis of the task frame will be the projection of the TCP movement direction onto the plane spanned by the x- and y-axis of the selected feature. The y-axis will be perpendicular to the robot arm's motion, and in the x-y plane of the selected feature. This can be useful when de-burring along a complex path, where a force is needed perpendicular to the TCP motion.
  Note: when the robot arm is not moving: If force mode is entered with the robot arm standing still, there will be no compliant axes until the TCP speed is above zero. If later, while still in force mode, the robot arm is again standing still, the task frame has the same orientation as the last time the TCP speed was larger than zero.

For the last three types, the actual task frame can be viewed at runtime on the graphics tab (see 16.3), when the robot is operating in force mode.

Force value selection

- Force or torque value can be set for compliant axes, and robot arm adjusts its position to achieve the selected force.
- For non-compliant axes robot arm will follow the trajectory set by the program.

For translational parameters, the force is specified in Newtons [N] and for rotational the torque is specified in Newton meters [Nm].

NOTE:
You must do the following:

- Use `get_tcp_force()` script function in separate thread, to read actual force and torque.
- Correct wrench vector, if actual force and/or torque is lower than requested.

Limits selection

For all axes a limit can be set, but these have different meaning corresponding to the axes being compliant or non-compliant.

Test force settings

The on/off button, labelled **Test**, toggles the behavior of the **Freedrive** button on the back of the Teach Pendant from normal Freedrive mode to testing the force command.

When the **Test button** is on and the **Freedrive** button on the back of the Teach Pendant is pressed, the robot will perform as if the program had reached this force command, and this way the settings can be verified before actually running the complete program. Especially, this possibility is useful for verifying that compliant axes and forces have been selected correctly. Simply hold the robot TCP using one hand and press the **Freedrive** button with the other, and notice in which directions the robot arm can/cannot be moved. Upon leaving this screen, the Test button automatically switches off, which means the **Freedrive** button on the back of the Teach Pendant is again used for regular **Freedrive** mode.
Note: The **Freedrive** button will only be effectual when a valid feature has been selected for the Force command.

16.8 URCaps

16.8.1 Conveyor Tracking

The robot can be configured to track conveyor movement. Conveyor Tracking is defined in the Installation Tab. Once onfigured correctly, the robot adjusts its movements to follow the conveyor. The Conveyor Tracking setup (see section 17.1.7) provides options for configuring the robot to work with absolute and incremental encoders, as well as, linear and circular conveyors. The Conveyor Tracking program node is available in the Program Tab under Templates. All movements under this node are allowed while tracking the conveyor, but they are relative to the motion of the conveyor belt.

16.9 The First Program

A program is a list of commands telling the robot what to do. PolyScope 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.

Tool motion is the part of a robot program that teaches the Robot Arm how to move. In PolyScope, tool motions are set using a series of **waypoints**. The combined waypoints form a path that the Robot Arm follows. A waypoint is set by using the Move Tab, manually moving (teaching) the robot to a certain position, or it can be calculated by software. Use the Move tab `(see 18)` to move the Robot Arm to a desired position, or teach the position by pulling the Robot Arm into place while holding the Freedrive button at the top of the Teach Pendant.

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.

The following is a simple program that allows a Robot arm that has been started up, to move between two waypoints.

1. In the PolyScope Header **File Path**, tap **New...** and select **Program**.
2. Under Basic, tap **Waypoint** to add a waypoint to the program tree. A default MoveJ is also added to the program tree.
3. Select the new waypoint and in the Command tab, tap **Waypoint**.
4. On the Move Tool screen, move the Robot arm by pressing the move arrows.
   You can also move the Robot arm by holding down the Freedrive button and pulling the Robot arm into desired positions.
5. Once the Robot arm is in position, press **OK** and the new waypoint displays as Waypoint_1.
6. Follow steps 2 to 5 to create Waypoint_2.
7. Select Waypoint_2 and press the Move Up arrow until it is above Waypoint_1 to change the order of the movements.
8. Stand clear, hold on to the emergency stop button and in the PolyScope Footer, press **Play** button for the Robot arm to move between Waypoint_1 and Waypoint_2.
   Congratulations! You have now produced your first robot program that moves the Robot arm between the two given waypoints.

WARNING:

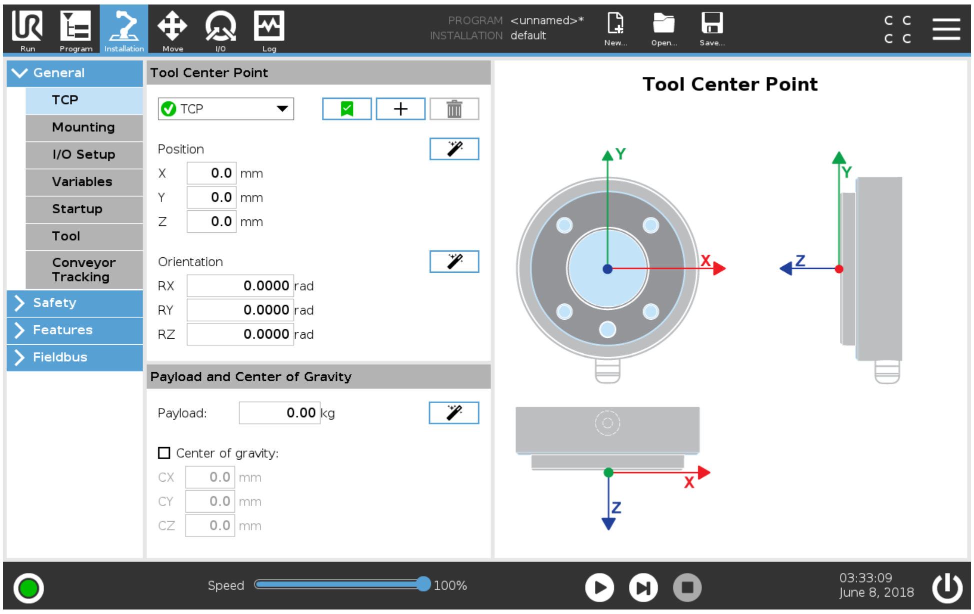
1. Do not drive the robot into itself or anything else as this may cause damage to the robot.
2. Keep your head and torso outside the reach (workspace) of the robot. Do not place fingers where they can be caught.
3. This is only a quick start guide to show how easy it is to use a UR robot. It assumes a harmless environment and a very careful user. Do not increase the speed or acceleration above the default values. Always conduct a risk assessment before placing the robot into operation.

17 Installation Tab

17.1 General

The Installation Tab allows you to configure the settings which affect the overall performance of the robot and PolyScope.

17.1.1 TCP Configuration



A **Tool Center Point** (TCP) is a point on the robot's tool. The TCP is defined and named in the Installation Tab **Setup for the Tool Center Point** screen (shown above). Each TCP contains a translation and a rotation relative to the center of the tool output flange.

When programmed to return to a previously stored waypoint, a robot moves the TCP to the position and orientation saved within the waypoint. When programmed for linear motion, the TCP moves linearly.

The `X`, `Y` and `Z` coordinates specify the TCP position, while the`RX`, `RY` and `RZ` coordinates specify its orientation. When all values are zero, the TCP coincides with the center point of the tool output flange and adopts the coordinate system depicted on the screen.

Adding, modifying and removing TCPs

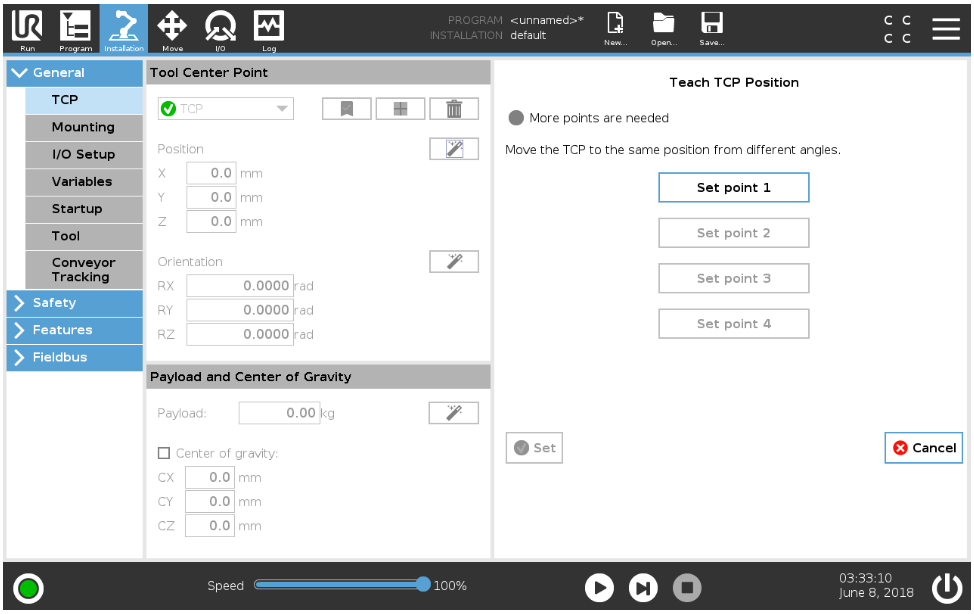
To define a new TCP, tap the **New** button. The created TCP automatically receives a unique name and becomes selectable in the drop-down menu. The translation and rotation of the selected TCP can be modified by tapping the respective white text fields and entering new values. To remove the selected TCP, simply tap the **Remove** button. The last remaining TCP cannot be deleted.

The default and the active TCP

There is one default configured TCP, marked by a green checkmark icon to the laft of its name in the **Available TCPs drop-down** menu. To set a TCP as the default, select the desired TCP and tap **Set as default**.

A TCP offset is designated as *active* to determine all linear motions in Cartesian coordinate system space. The motion of the active TCP is visualized on the Graphics Tab (see 16.3). Before a program runs, the default TCP is set as the active TCP. Within a program, any of the specified TCPs can be set as *active* for a particular movement of the robot (see 16.5.1 and 16.5.3).

Teaching TCP position

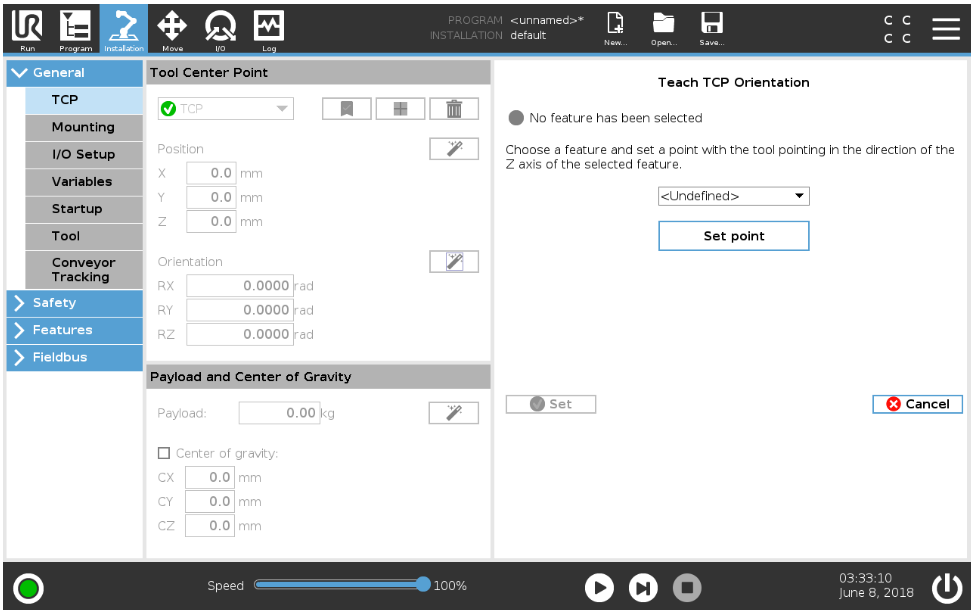


TCP position coordinates can be calculated automatically as follows:

1. Tap **Position**.
2. Choose a fixed point in the workspace of the robot.
3. Use the position arrows on the right side of the screen to move the TCP from at least three different angles and to save the corresponding positions of the tool output flange.
4. Use the **Set** button to apply the verified coordinates to the appropriate TCP. The positions must be sufficiently diverse for the calculation to work correctly. If they are not sufficiently diverse, the status LED above the buttons turns red.

Though three positions are sufficient to determine the TCP, a fourth position can be used to further verify the calculation is correct. The quality of each saved point, with respect to the calculated TCP, is indicated using a green, yellow, or red LED on the corresponding button.

Teaching TCP orientation



1. Tap **Orientation**.
2. Select a feature from the drop-down list. (See 17.3) for additional information on defining new features
3. Tap **Select point** and use **Move tool arrows** to a position where the tool's orientation and the corresponding TCP coincide with the selected features's coordinate system.
4. Verify the calculated TCP orientation and apply it to the selected TCP by tapping **Set**.

Payload

The weight of the robot's tool is specified in the lower part of the screen.To change this setting, simply tap the white text field and enter a new weight. The setting applies to all defined TCPs. For details about the maximum allowed payload, see the Hardware Installation Manual.

Payload Estimation

This feature allows the robot to help set the correct payload and Center of Gravity.

Using Payload Estimation Wizard

1. In the Installation Tab, under General, select **TCP**
2. On the TCP screen, under Payload and Center of Gravity, tap the **Icon**.
3. In the Payload Estimation Wizard tap **Next**
4. Follow the steps to set the four positions.
   Setting the four positions requires moving the robot arm into four different positions. Each position is measured. Individual measurements can be modified by tapping the center of gravity fields and entering values.
5. Once all measurements are complete, tap **Finish**

NOTE:
Follow the these guidelines for best Payload Estimation results:

- Ensure the four TCP positions are as different as possible from each other
- Perform the measurements within a short timespan

WARNING:

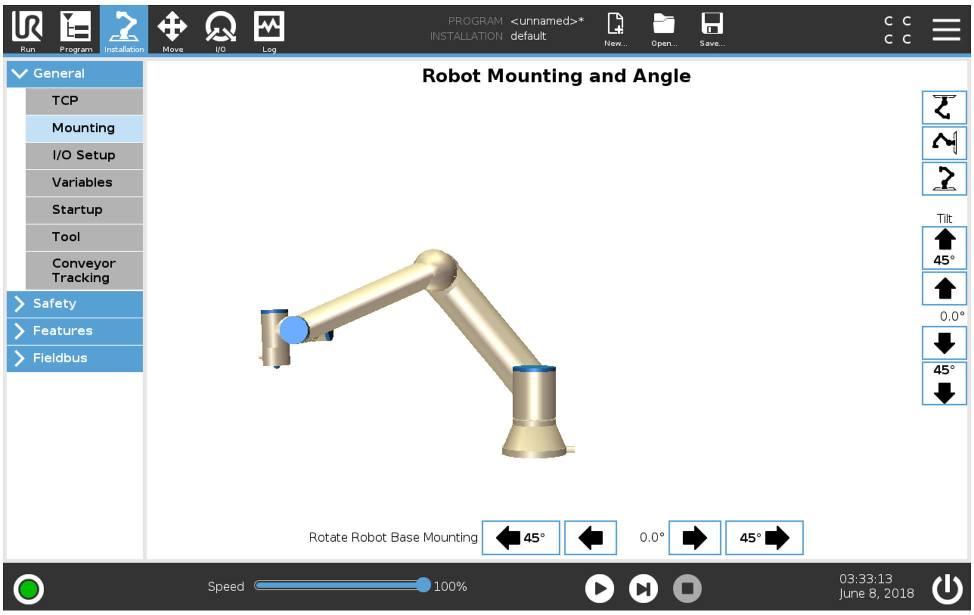
- Avoid pulling on the tool and/or attached payload before and during estimation
- Robot mounting and angle must be correctly defined in the installation

Center of gravity

The tool's center of gravity is specified using the fields `CX`, `CY` and `CZ`. If not specified, the TCP is assumed to be the tool's center of gravity. The settings apply to all defined TCPs.

WARNING:
Use the correct installation settings. Save and load the installation files with the program.

17.1.2 Mounting



Specifying the mounting of the Robot arm serves two purposes:

1. Making the Robot arm appear correctly on screen.

2. Telling the controller about the direction of gravity.

An advanced dynamics model gives the Robot arm smooth and precise motions, as well as allows the Robot arm to hold itself in **Freedrive Mode**. For this reason, it is important to mount the Robot arm correctly.

WARNING:
Failure to mount the Robot's arm correctly may result in frequent Protective Stops, and/or the Robot arm will move when pressing the **Freedrive** button.

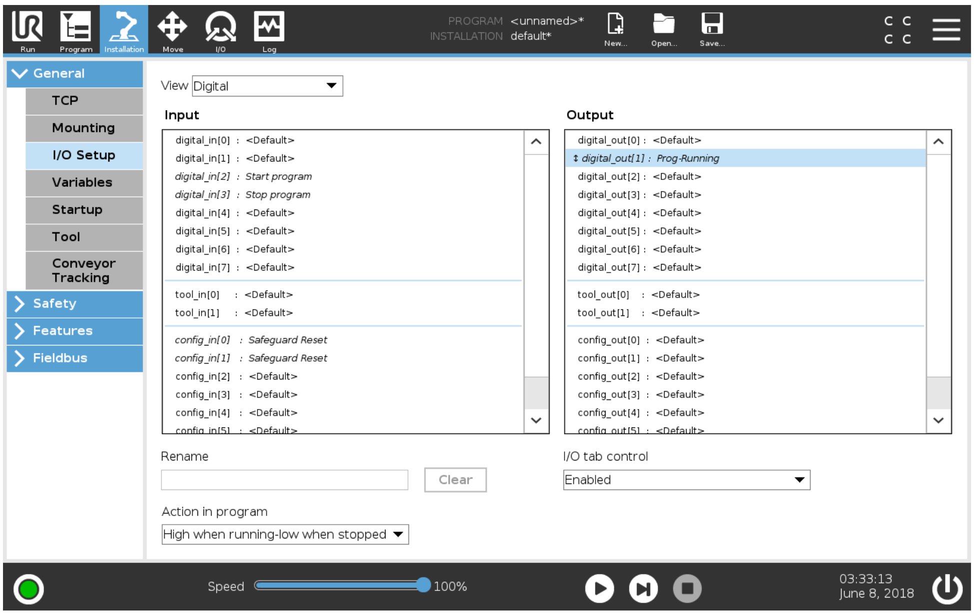
If the Robot arm is mounted on a flat table or floor, no change is needed on this screen. However, if the Robot arm is **ceiling mounted**, **wall mounted**, or **mounted at an angle**, this needs to be adjusted using the buttons.

The buttons on the right side of the screen are for setting the angle of the Robot arm's mounting. The top three right side buttons set the angle to **ceiling** $(180°)$, **wall** $(90°)$, **floor** $(0°)$. The **Tilt** buttons set an arbitrary angle.

The buttons on the lower part of the screen are used to rotate the mounting of the Robot arm to match the actual mounting.

WARNING:
Use the correct installation settings. Save and load the installation files with the program.

17.1.3 I/O Setup



On the I/O Setup screen, users can define I/O signals and configure actions with the I/O tab control.

Note: When the **Tool Communication Interface TCI** is enabled (see 17.1.10), the tool analog input becomes unavailable.

The **Input** and **Output** sections list types of I/O signals such as:

- Digital standard general purpose, configurable and tool
- Analog standard general purpose and tool
- MODBUS
- General purpose registers (boolean, integer and float) The general purpose registers can be accessed by a fieldbus (e.g., Profinet and EtherNet/IP).

17.1.4 I/O Signal Type

To limit the number of signals listed in the **Input** and **Output** sections, use the **View** drop-down menu at the top of the screen to change the displayed content based on signal type.

17.1.5 Assigning User-defined Names

To easily remember what the signals do while working with the robot, users can associate names to Input and Output signals.

1. Select the desired signal
2. Tap the text field in the lower part of the screen to set the name.
3. To reset the name to default, tap **Clear**.

A general purpose register must be given a user-defined name to make it available in the program (i.e., for a **Wait** command or the conditional expression of an **If** command) The **Wait** and **If** commands are described in (16.5.2) and (16.6.4), respectively. Named general purpose registers can be found in the **Input** or **Output** selector on the **Expression Editor** screen.

17.1.6 I/O Actions and I/O Tab Control

Input Actions The eight standard general purpose Digital Inputs and the two Digital Tool inputs as well as the general purpose input registers of type *boolean* may trigger an action. Available actions include the ability execute the following actions on a rising edge:

- Start the current program
- Stop the current program
- Pause the current program

Furthermore, an action can be configured to enter or leave Freedrive Mode when the Input is high/low. (similar to pressing or releasing the **Freedrive** button on the back of the Teach Pendant).

Output Actions and I/O Tab Control Outputs, by default, preserve their values after a program stops running. It is also possible to configure an Output with a default value that is applied whenever no program is running.

The eight standard general purpose Digital Outputs and the two Digital Tool Outputs can furthermore be configured to reflect if a program is running, so the Output is high when a program is running and low when it is stopped or paused. Otherwise, the output is low when a program is running and high when it is stopped or paused. These values can be set while the program is running. General purpose output registers of type *boolean* and digital MODBUS output signals also support this.

Finally, it is also possible to specify whether an output can be controlled on the I/O tab (by either programmers, or both operators and programmers) or if it is only robot programs that may alter the output value.

17.1.7 Conveyor Tracking

When using a conveyor, the robot can be configured to track its movement. The Conveyor Tracking Setup provides options for configuring the robot to work with absolute and incremental encoders, as well as linear and circular conveyors.

Conveyor Parameters

Incremental encoders can be connected to Digital Inputs 0 to 3. Decoding of digital signals runs at 40kHz. Using a **Quadrature** encoder (requiring two inputs), the robot can determine the speed and direction of the conveyor. If the direction of the conveyor is constant, a single input can be used to detect either `Rising`, `Falling`, or `Rise and Fall` edges which determine conveyor speed.

Absolute encoders can be connected through a MODBUS signal. This requires a Digital MODBUS Input register is preconfigured in `(section 17.4.1)`.

Linear conveyors

When a linear conveyor is selected, a line feature must be configured in the **Features** part of the installation to determine the direction of the conveyor. The line feature should be parallel to the direction of the conveyor, and there should be a large distance between the two points defining the line feature. Configure the line feature by placing the tool firmly against the side of the conveyor when teaching the two points. If the line feature's direction is opposite to the conveyor's movement, use the **Reverse direction** button.

The field **Ticks per meter** field displays the number of ticks the encoder generates when the conveyor moves one meter.

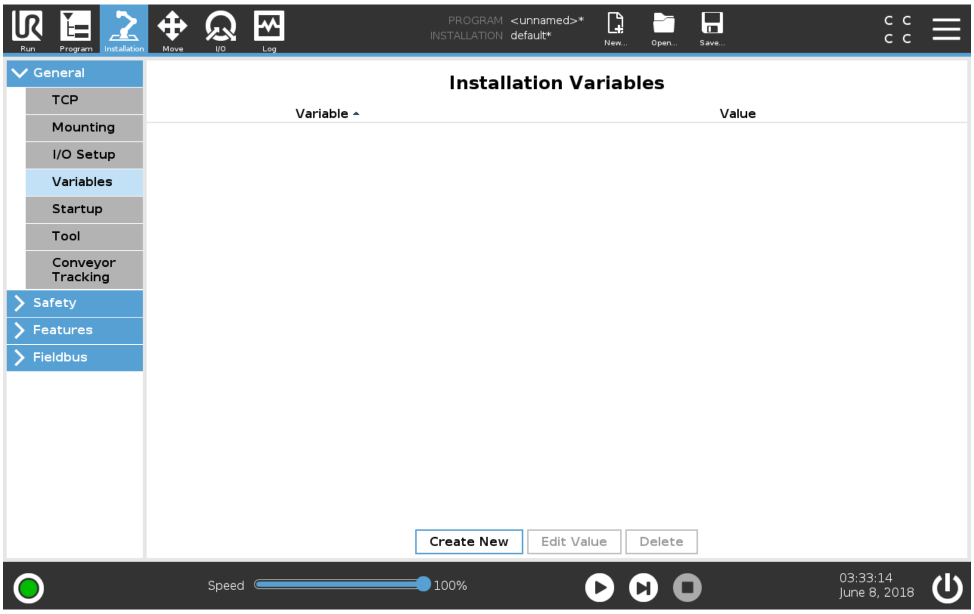
$$\text{Ticks per meter} = \frac{\text{ticks per revolution of encoder}}{2\pi \cdot \text{radius of encoder disc[m]}} \tag{17.1}$$

Circular conveyors

When tracking a circular conveyor, the conveyor center point must be defined.

1. Define the center point in the **Features** part of the installation. The value of **Ticks per revolution** must be the number of ticks the encoder generates when the conveyor rotates one full revolution.
2. Select the **Rotate tool with conveyor** checkbox if the tool's orientation should be with respect to the conveyor (e.g. if the tool is perpendicular to the conveyor, it will stay perpendicular during the movement).
3. Deselect the **Rotate tool with conveyor** checkbox if the orientation should be controlled by the trajectory.

17.1.8 Variables



Variables created on the Variables screen are called Installation Variables and are used like normal program variables. Installation Variables are distinct because they keep their value even if a program stops and then starts again, and when the Robot arm and/or Control Box is powered down and powered up again. Their names and values are stored with the installation, therefore it is possible to use the same variable in multiple programs.

Pressing **Create New** brings up a panel with a suggested name for the new variable. The name may be changed and its value may be entered by touching either text field. The **OK**-button can only tapped if the new name is unused in this installation.

It is possible to change the value of an installation variable by highlighting the variable in the list and then clicking on **Edit Value**.

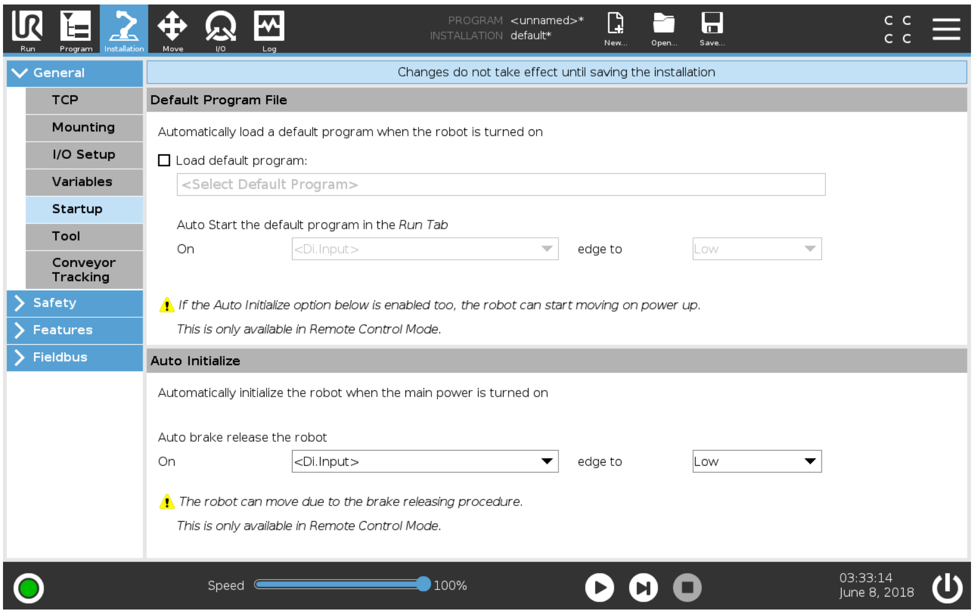
To delete a variable, select it and tap **Delete**.

After configuring the installation variables, the installation itself must be saved to keep the configuration, (see 15.4).

The installation variables and their values are saved automatically every 10 minutes.

If a program or an installation is loaded and one or more of the program variables have the same name as the installation variables, the user is presented with options to either resolve the issue using the installation variables of the same name instead of the program variable or rsolve the issue by having the conflicting variables renamed automatically.

17.1.9 Startup



The Startup screen contains settings for automatically loading and starting a default program, and for auto-initializing the Robot arm during power up.

WARNING:

1. When autoload, auto start and auto initialize are enabled, the robot runs the program as soon as the Control Box is powered up as long as the input signal matches the selected signal level. For example, the edge transition to the selected signal level will not be required in this case.
2. Use caution when the signal level is set to LOW. Input signals are low by default, leading the program to automatically run without being triggered by an external signal.
3. You must be in **Remote Control** Mode before running a program where auto start and auto initialize are enabled.

Loading a Startup Program

A default program is loaded after the Control Box is powered up. Furthermore, the default program is auto loaded when the **Run Program** screen (see 14) is entered and no program is loaded.

Starting a Startup Program

The default program is auto started in the **Run Program** screen. When the default program is loaded and the specified external input signal edge transition is detected, the program is started automatically.

On Startup, the current input signal level is undefined. Choosing a transition that matches the signal level on startup starts the program immediately. Furthermore, leaving the **Run Program** screen or tapping the Stop button in the Dashboard disables the auto start feature until the Run button is pressed again.

Auto Initialization

The Robot arm is automatically initialized. On the specified external input signal edge transition, the Robot arm is completely initialized, regardless of the visible screen.
Brake Release is the final initialization stage. During Brake Release, the Robot arm makes a minor movement and a clicking noise. Furthermore, the brakes cannot be automatically released if the configured mounting does not match the mounting detected (based on sensor data). In this case, the robot must be initialized manually on the initialization screen (see 15).
On Startup, the current input signal level is undefined. Choosing a transition that matches the signal level on startup initializes the Robot arm immediately.

17.1.10 Tool

The **Tool Communication Interface (TCI)** enables the robot to communicate with an attached tool via the robot tool analog input. This removes the need for external cabling.
Once the **Tool Communication Interface** is enabled, all tool analog inputs are unavailable.

Enabling the Tool Communication Interface

1. In Polyscope, tap the **Enable button** to edit baud rate, parity and stop bits.
2. On the relevant drop down menus, select the appropriate values. You can edit the **Transmit and receive idle in characters**, by tapping on the text field and entering a new value
3. Tap the **Disable button** to disable TCI.
   Note: Any changes in values are immediately sent to the tool. If any installation values differ from what the tool is using, a warning appears.

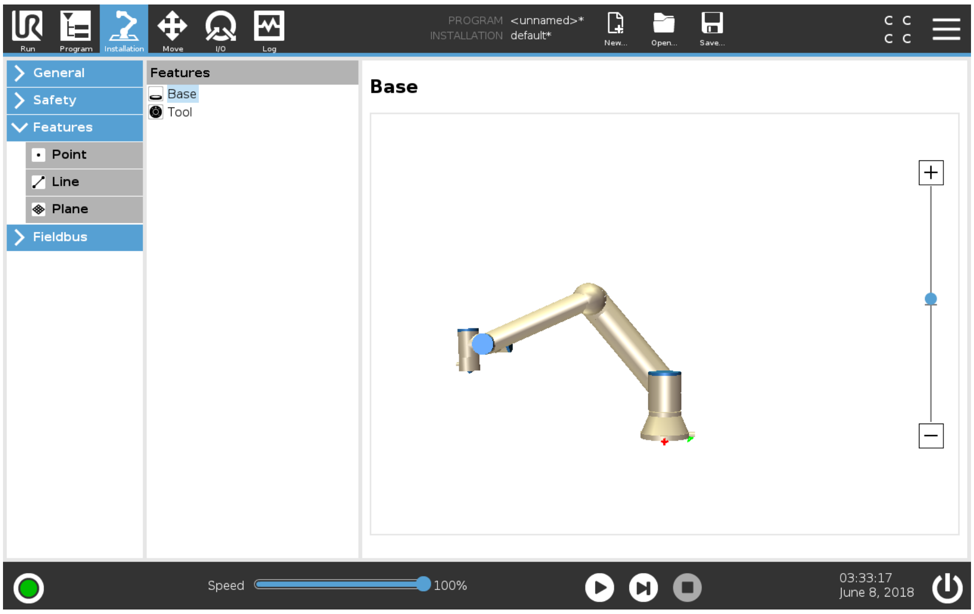
Disabled Analog Input

Once the **TCI** is enabled, the tool analog input is unavailable for the **I/O Setup** of the Installation and does not appear in the input list. Tool analog input is also unavailable for programs as **Wait For** options and expressions.
In the **Tool Input** section of **I/O**, the parameters received from the tool are displayed instead of analog values.

17.2 Safety

See chapter 13.

17.3 Features



The **Feature**, is a representation of an object that is defined with a name for future reference and a six dimensional pose (position and orientation) relative to the robot base.
Some subparts of a robot program consist of movements executed relative to specific objects other than the base of the Robot arm. These objects could be tables, other machines, work-pieces, conveyors, pallets, vision systems, blanks, or boundaries which exist in the surroundings of the Robot arm. Two predefined features always exist for the robot. Each feature has its pose defined by the configuration of the Robot arm itself:

- The Base feature is located with origin in the centre of the robot base (`see figure 17.1`)
- The Tool feature is located with origin in the centre of the current TCP (`see figure 17.2`)

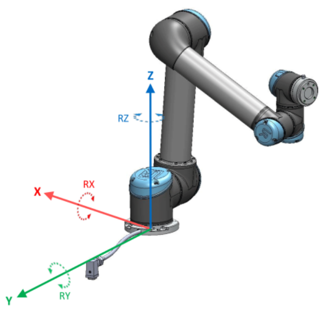


Figure 17.1: Base feature

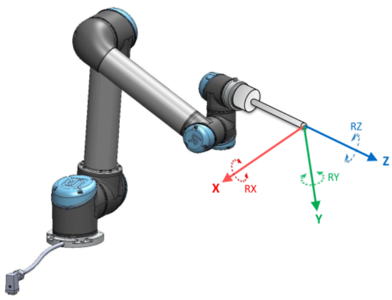


Figure 17.2: Tool (TCP) feature

User-defined features are positioned through a method that uses the current pose of the TCP in the work area. This means the users can teach feature locations using Freedrive Mode or ”jogging” to move the robot to the desired pose.

Three different strategies exist (**Point**, **Line** and **Plane**) for defining a feature pose. The best strategy for a given application depends on the type of object being used and the precision requirements. In general a feature based on more input points (**Line** and **Plane**) is be preferred if

applicable to the specific object.
To accurately define the direction of a linear conveyor, define two points of a Line feature with as much physical separation as possible. The Point feature can also be used to define a linear conveyor, however, the user must point the TCP in the direction of the conveyor movement.
Using more points to define the pose of a table means that the orientation is based on the positions rather than the orientation of a single TCP. A single TCP orientation is harder to configure with high precision.
To learn about the different methods to define a feature see `(sections: 17.3.2)`, `(17.3.3)` and `(17.3.4)`.

17.3.1 Using a feature

When a feature is defined in the installation, you can refer to it from the robot program to relate robot movements (e.g. **MoveL** and **MoveP** commands) to the feature `(see section 16.5.1)`. This allows for easy adaptation of a robot program (e.g., when there are multiple robot stations, when an object is moved during program runtime, or when an object is permanently moved in the scene). By adjusting the feature of an object, all program movements relative to the object is moved accordingly. For further examples, see `(sections 17.3.5)` and `(17.3.6)`.

Features configured as joggable are also useful tools when manually moving the robot in the Move Tab `(section 18)` or the **Pose Editor** screen `(see 18.3.1)`. When a feature is chosen as a reference, the Move Tool buttons for translation and rotation operate in the selected feature space `(see 18.3)` and `(18.1)`, reading of the TCP coordinates. For example, if a table is defined as a feature and is chosen as a reference in the Move Tab, the translation arrows (i.e., up/down, left/right, forward/backward) move the robot in these directions relative to the table. Additionally, the TCP coordinates will be in the frame of the table.

- In the Features tree you can rename a Point, Line or Plane by tapping the pencil button.
- In the Features tree you can delete a Point, Line or Plane by tapping the Delete button.

Joggable

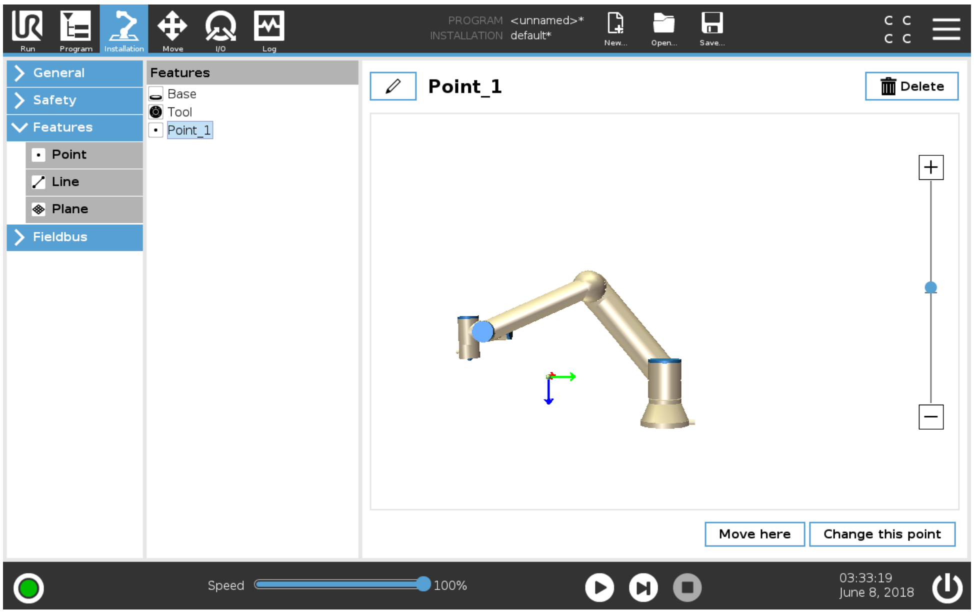
Choose whether the selected feature should be joggable. This determines whether the feature will appear in the feature menu on the Move screen.

Using Move robot here

Push the **Move robot here** button to move the Robot arm towards the selected feature. At the end of this movement, the coordinate systems of the feature and the TCP will coincide.

17.3.2 Adding a Point

Push the **Point**button to add a point feature to the installation. The point feature defines a safety boundary or a global home configuration of the Robot arm. The point feature pose is defined as the position and orientation of the TCP.



17.3.3 Addine a Line

Push the **Line** button to add a line feature to the installation. The line feature defines lines that the robot needs to follow. (e.g., when using conveyor tracking). A line *l* is defined as an axis between two point features *p1* and *p2* as shown in figure 17.3.

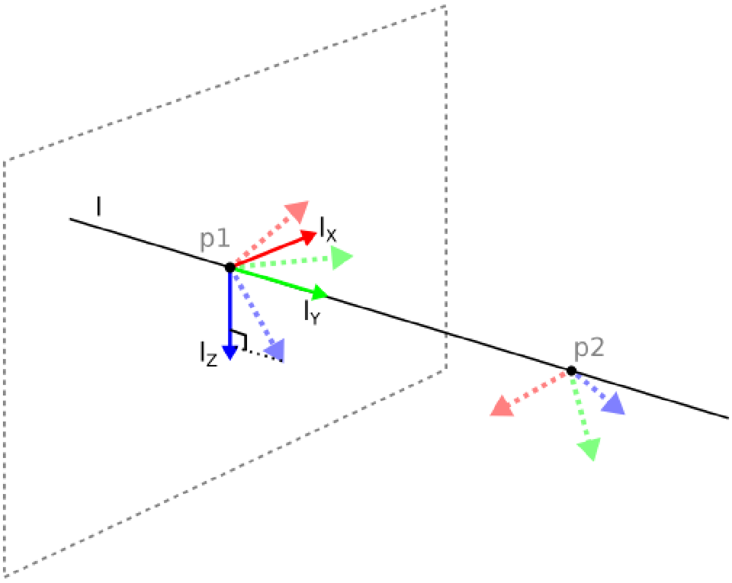
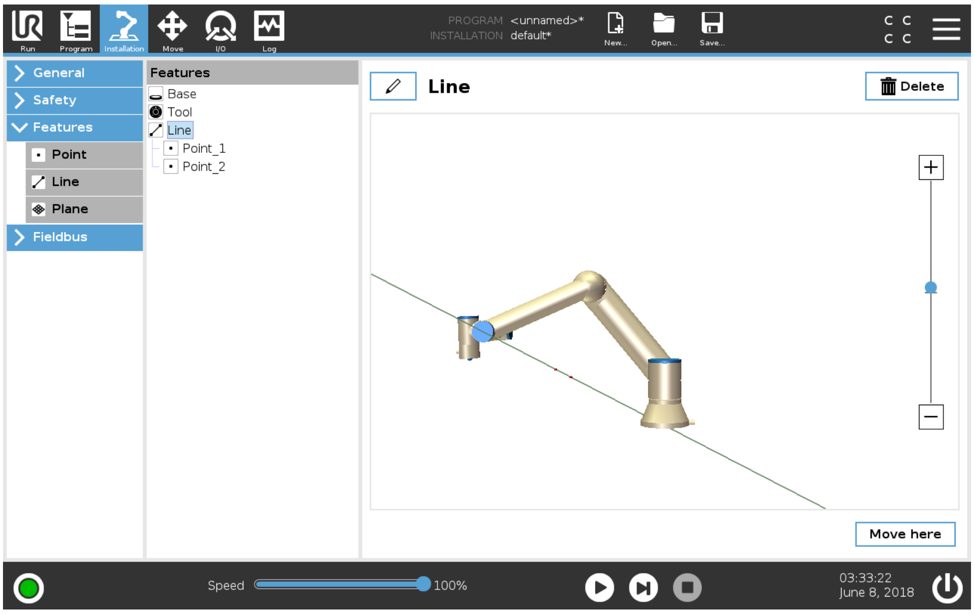


Figure 17.3: Definition of the line feature

In figure 17.3 the axis directed from the first point towards the second point, constitutes the y-axis of the line coordinate system. The z-axis is defined by the projection of the z-axis of *p1* onto the plane perpendicular to the line. The position of the line coordinate system is the same as the position of *p1*.



17.3.4 Plane Feature

Select the plane feature when you need a frame with high precision: e.g., when working with a vision system or doing movements relative to a table.

Adding a plane

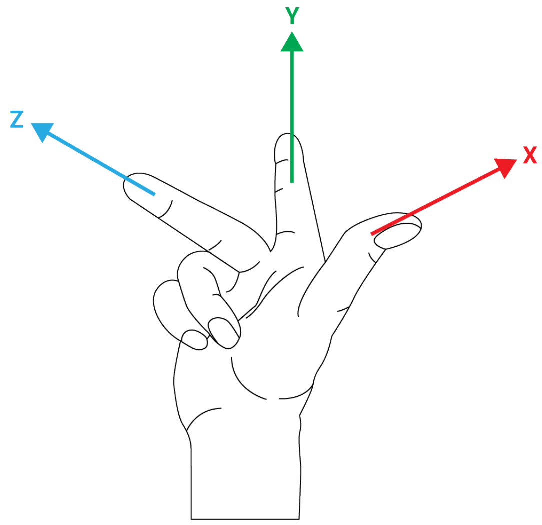
1. In Installation, select **Features**.
2. Under Features select **Plane**.

Teaching a plane

When you press the plane button to create a new plane, the on-screen guide assists you creating a plane.

1. Select Origo
2. Move robot to define the direction of the positive x-axis of the plane
3. Move robot to define the direction of the positive y-axis of the plane

The plane is defined using the right hand rule so the z- axis is the cross product of the x-axis and the y-axis, as illustrated below.



NOTE:
You can re-teach the plane in the opposite direction of the x-axis, if you want that plane to be normal in the opposite direction.

Modify an existing plane by selecting Plane and pressing Modify Plane. You will then use the same guide as for teaching a new plane.

17.3.5 Example: Manually Updating a Feature to Adjust a Program

Consider an application where multiple parts of a robot program is relative to a table. Figure 17.4 illustrates the movement from waypoints `wp1` through `wp4`.

```
Robot Program
    MoveJ
        S1
    MoveL # Feature: P1_var
        wp1
        wp2
        wp3
        wp4
```

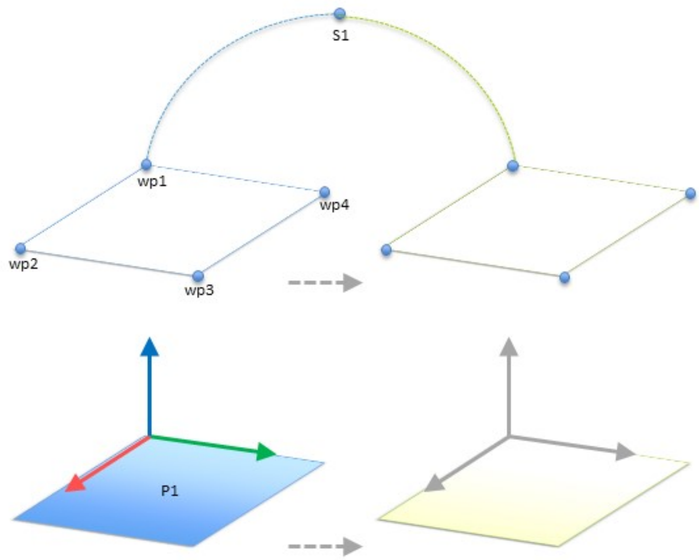


Figure 17.4: Simple program with four waypoints relative to a feature plane manually updated by changing the feature

The application requires the program to be reused for multiple robot installations where the position of the table varies slightly. The movement relative to the table is identical. By defining the table position as a feature *P1* in the installation, the program with a *MoveL* command configured relative to the plane can be easily applied on additional robots by just updating the installation with the actual position of the table.

The concept applies to a number of Features in an application to achieve a flexible program can solve the same task on many robots even though if other places in the work space varies between installations.

17.3.6 Example: Dynamically Updating a Feature Pose

Consider a similar application where the robot must move in a specific pattern on top of a table to solve a particular task (see 17.5).

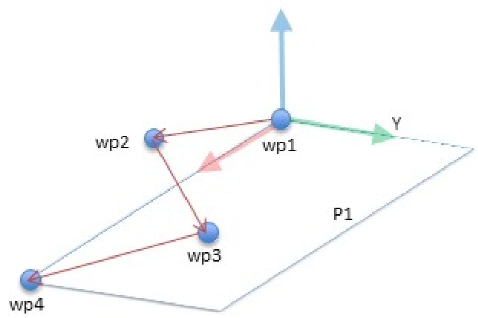


Figure 17.5: A *MoveL* command with four waypoints relative to a plane feature

The movement relative to *P1* is repeated a number of times, each time by an offset *o*. In this example the offset is set to 10 cm in the Y-direction (see figure 17.6, offsets *O1* and *O2*). This is achieved using *pose_add()* or *pose_trans()* script functions to manipulate the variable.

```
Robot Program
    MoveJ
        wp1
    y = 0.01
    o = p[0,y,0,0,0,0]
    P1_var = pose_trans(P1_var, o)
    MoveL # Feature: P1_var
        wp1
        wp2
        wp3
        wp4
```

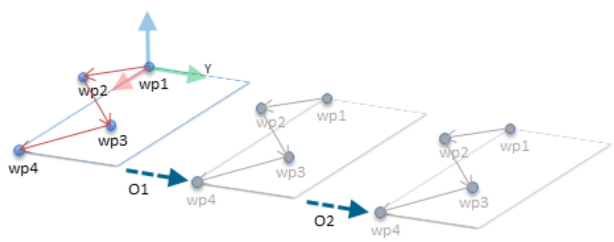


Figure 17.6: Applying an offset to the plane feature

It is possible to switch to a different feature while the program is running instead of adding an offset. This is shown in the example below (see figure 17.7) where the reference feature for the *MoveL* command *P1_var* can switch between two planes *P1* and *P2*.

17.4 Fieldbus

Here you can set the family of industrial computer network protocols used for real-time distributed control accepted by PolyScope: MODBUS and Ethernet/IP

```
Robot Program
    MoveJ
        S1
    if (digital_input[0]) then
        P1_var = P1
    else
        P1_var = P2
    MoveL # Feature: P1_var
        wp1
        wp2
        wp3
        wp4
```

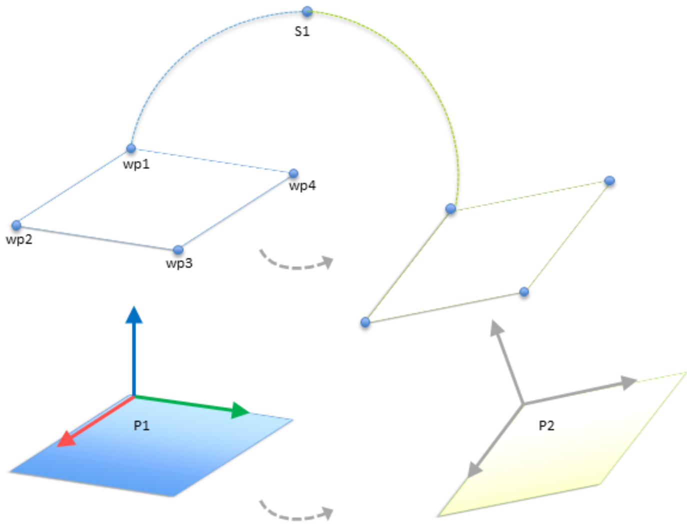
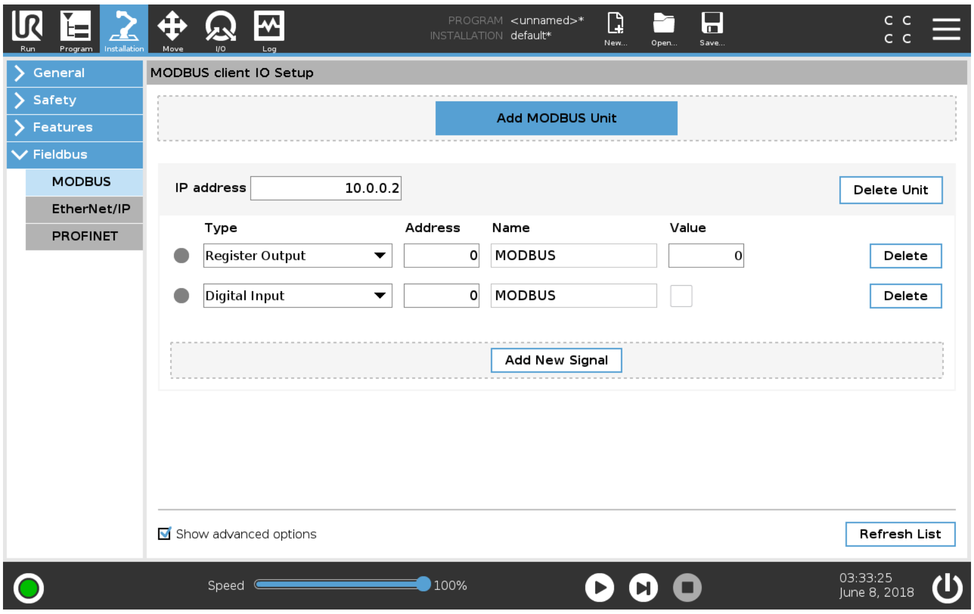


Figure 17.7: Switching from one plane feature to another

17.4.1 MODBUS client I/O Setup



Here, the MODBUS client (master) signals can be set up. Connections to MODBUS servers (or slaves) on specified IP addresses can be created with input/output signals (registers or digital). Each signal has a unique name so it can be used in programs.

Refresh

Push this button to refresh all MODBUS connections. Refreshing disconnects all modbus units, and connects them back again. All statistics are cleared.

Add unit

Push this button to add a new MODBUS unit.

Delete unit

Push this button to delete the MODBUS unit and all signals on that unit.

Set unit IP

Here the IP address of the MODBUS unit is shown. Press the button to change it.

Sequential mode

Available only when Show Advanced Options (see 17.4.1) is selected. Selecting this checkbox forces the modbus client to wait for a response before sending the next request. This mode is required by some fieldbus units. Turning this option on may help when there are multiple signals, and increasing request frequency results in signal disconnects. Note that the actual signal frequency may be lower than requested when multiple signals are defined in sequential mode. Actual signal frequency can be observed in signal statistics (see section 17.4.1). The signal indicator will turn yellow if the actual signal frequency is less than half of the value selected from the ”Frequency” drop-down list.

Add signal

Push this button to add a signal to the corresponding MODBUS unit.

Delete signal

Push this button to delete a MODBUS signal from the corresponding MODBUS unit.

Set signal type

Use this drop down menu to choose the signal type. Available types are:

Digital input A digital input (coil) is a one-bit quantity which is read from the MODBUS unit on the coil specified in the address field of the signal. Function code 0x02 (Read Discrete Inputs) is used.

Digital output A digital output (coil) is a one-bit quantity which can be set to either high or low. Before the value of this output has been set by the user, the value is read from the remote MODBUS unit. This means that function code 0x01 (Read Coils) is used. When the output has been set by a robot program or by pressing the **set signal value** button, the function code 0x05 (Write Single Coil) is used onwards.

Register input A register input is a 16-bit quantity read from the address specified in the address field. The function code 0x04 (Read Input Registers) is used.

Register output A register output is a 16-bit quantity which can be set by the user. Before the value of the register has been set, the value of it is read from the remote MODBUS unit. This means that function code 0x03 (Read Holding Registers) is used. When the output has been set by a robot program or by specifying a signal value in the **set signal value** field, function code 0x06 (Write Single Register) is used to set the value on the remote MODBUS unit.

Set signal address

This field shows the address on the remote MODBUS server. Use the on-screen keypad to choose a different address. Valid addresses depends on the manufacturer and configuration of the remote MODBUS unit.

Set signal name

Using the on-screen keyboard, the user can give the signal a name. This name is used when the signal is used in programs.

Signal value

Here, the current value of the signal is shown. For register signals, the value is expressed as an unsigned integer. For output signals, the desired signal value can be set using the button. Again, for a register output, the value to write to the unit must be supplied as an unsigned integer.

Signal connectivity status

This icon shows whether the signal can be properly read/written (green), or if the unit responds unexpected or is not reachable (gray). If a MODBUS exception response is received, the response code is displayed. The MODBUS-TCP Exception responses are:

E1 ILLEGAL FUNCTION (0x01) The function code received in the query is not an allowable action for the server (or slave).

E2 ILLEGAL DATA ADDRESS (0x02) The function code received in the query is not an allowable action for the server (or slave), check that the entered signal address corresponds to the setup of the remote MODBUS server.

E3 ILLEGAL DATA VALUE (0x03) A value contained in the query data field is not an allowable value for server (or slave), check that the enterd signal value is valid for the specified address on the remote MODBUS server.

E4 SLAVE DEVICE FAILURE (0x04) An unrecoverable error occurred while the server (or slave) was attempting to perform the requested action.

E5 ACKNOWLEDGE (0x05) Specialized use in conjunction with programming commands sent to the remote MODBUS unit.

E6 SLAVE DEVICE BUSY (0x06) Specialized use in conjunction with programming commands sent to the remote MODBUS unit, the slave (server) is not able to respond now.

Show Advanced Options

This check box shows/hides the advanced options for each signal.

Advanced Options

Update Frequency This menu can be used to change the update frequency of the signal. This means the frequency with which requests are sent to the remote MODBUS unit for either reading or writing the signal value. When the frequency is set to 0, then modbus requests are initiated on demand using a *modbus_get_signal_status*, *modbus_set_output_register*, and *modbus_set_output_signal* script functions.

Slave Address This text field can be used to set a specific slave address for the requests corresponding to a specific signal. The value must be in the range 0-255 both included, and the default is 255. If you change this value, it is recommended to consult the manual of the remote MODBUS device to verify its functionality when changing slave address.

Reconnect count Number of times TCP connection was closed, and connected again.

Connection status TCP connection status.

Response time [ms] Time between modbus request sent, and response received - this is updated only when communication is active.

Modbus packet errors Number of received packets that contained errors (i.e. invalid lenght, missing data, TCP socket error).

Timeouts Number of modbus requests that didn't get response.

Requests failed Number of packets that could not be sent due to invalid socket status.

Actual freq. The average frequency of client (master) signal status updates. This value is recalculated each time the signal receives a response from the server (or slave).

All counters count up to 65535, and then wrap back to 0.

17.4.2 Ethernet/IP

EtherNet/IP is where you can enable or disable the connection of the robot to a EtherNet/IP. If Enable, you can select which action should occur to a program when there is a loss of EtherNet/IP scanner connection. Those actions are:

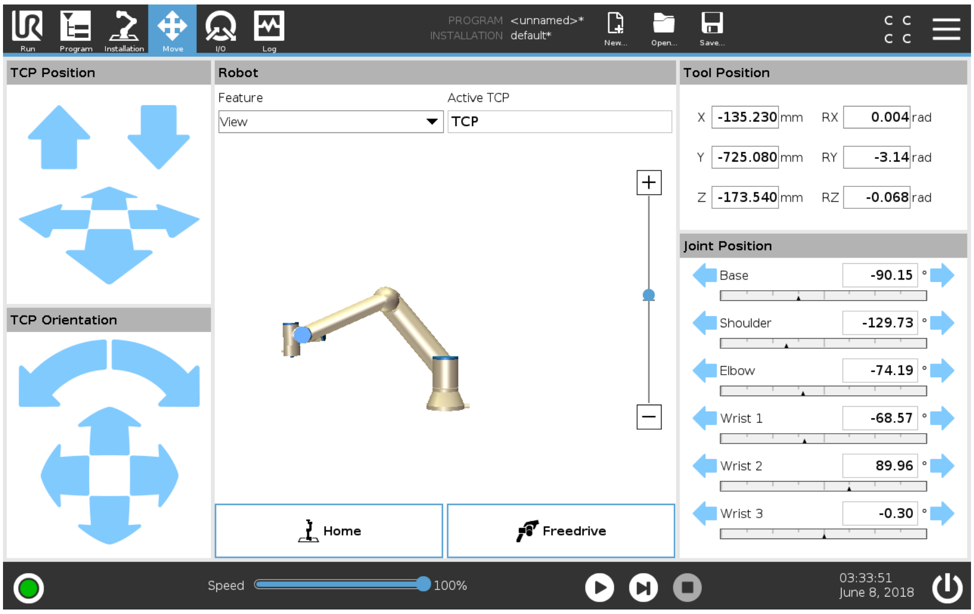
None: PolyScope will ignore the loss of EtherNet/IP connection and continue normally with the program.

Pause: PolyScope will pause the current program. Program will resume where it stopped.

Stop: PolyScope will stop the current program.

18 Move Tab

On this screen, you can move (jog) the robot arm directly, either by translating/rotating the robot tool, or by moving robot joints individually.



18.1 Move Tool

Hold down any of the **Move Tool** arrows to move the robot arm in a particular direction.

- The **Translate arrows** (upper) move the robot tool-tip in the direction indicated.
- The **Rotate arrows** (lower) change the orientation of the robot tool in the indicated direction. The rotation point is the Tool Center Point (TCP), i.e. the point at the end of the robot arm that gives a characteristic point on the robot's tool. The TCP is shown as a small blue ball.

18.2 Robot

If the current position of the robot TCP comes close to a safety or trigger plane, or the orientation of robot tool is near the tool orientation boundary limit (see 13.2.5), a 3D representation of the proximate boundary limit is shown.
Note: when the robot is running a program, the visualization of boundary limits is disabled.

Safety planes are visualized in yellow and black with a small arrow representing the plane normal, which indicates the side of the plane on which the robot TCP is allowed to be positioned. Trigger planes are displayed in blue and green and a small arrow pointing to the side of the plane, where the **Normal** mode limits (see 13.2.2) are active. The tool orientation boundary limit is visualized with a spherical cone together with a vector indicating the current orientation of the robot tool. The inside of the cone represents the allowed area for the tool orientation (vector).

When the robot TCP is no longer in proximity of the limit, the 3D representation disappears. If the TCP is in violation or very close to violating a boundary limit, the visualization of the limit turns red.

Feature

In the top left corner of the **Robot** field, under **Feature**, you can define how to control the robot arm relative to **View**, **Base** or **Tool** features.

Note: For the best feel for controlling the robot arm you can select the **View** feature, then use **Rotate arrows** to change the viewing angle of the 3D image to match your view of the real robot arm.

Active TCP

In the to right corner of the **Robot** field, under **Active TCP**, the name of the current active Tool Center Point (TCP) is displayed.

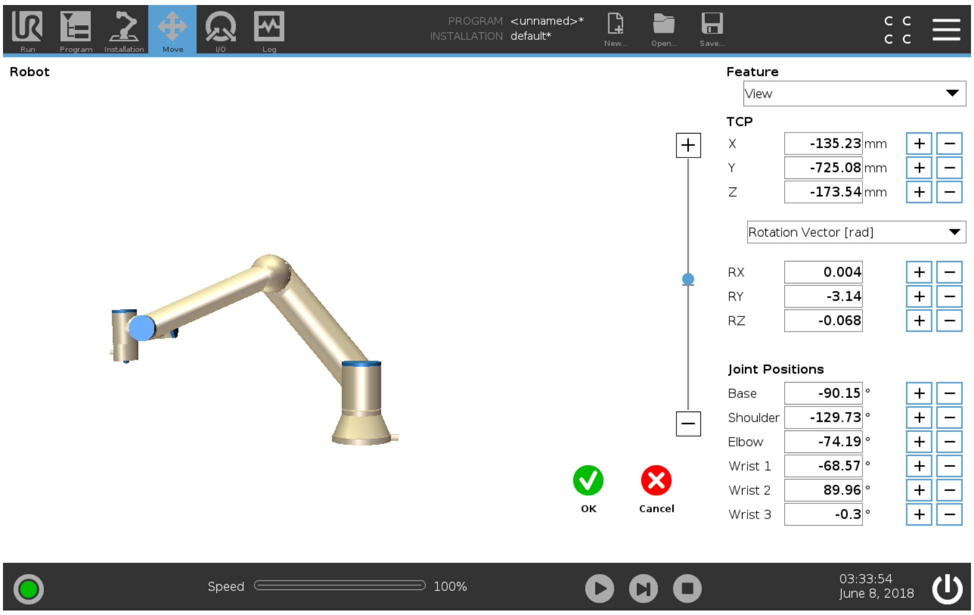
18.3 Tool Position

The text boxes display the full coordinate values of the TCP relative to the selected feature.

Note: You can configure several named TCPs (see 17.1.1). You can also tap **Edit pose** to access the **Pose Editor** screen.

18.3.1 Pose Editor Screen

On this screen you can specify target joint positions, or a target pose (position and orientation) of the robot tool. This screen is “offline” and does not control the robot arm directly.



18.3.1.1 Robot

The current position of the robot arm and the specified new target position are shown in 3D graphics. The 3D drawing of the robot arm shows the current position of the robot arm, and the "shadow" of the robot arm shows the target position of the robot arm controlled by the specified values on the right hand side of the screen. Push the magnifying glass icons to zoom in/out or drag a finger across to change the view.

If the specified target position of the robot TCP is close to a safety or trigger plane, or the orientation of robot tool is near the tool orientation boundary limit (see 13.2.5), a 3D representation of the proximate boundary limit is shown.

Safety planes are visualized in yellow and black with a small arrow representing the plane normal, which indicates the side of the plane on which the robot TCP is allowed to be positioned. Trigger planes are displayed in blue and green and a small arrow pointing to the side of the plane, where the *Normal* mode limits (see 13.2.2) are active. The tool orientation boundary limit is visualized with a spherical cone together with a vector indicating the current orientation of the robot tool. The inside of the cone represents the allowed area for the tool orientation (vector).

When the target robot TCP no longer is in the proximity of the limit, the 3D representation disappears. If the target TCP is in violation or very close to violating a boundary limit, the visualization of the limit turns red.

18.3.1.2 Feature and tool position

In the top right corner of the screen, the feature selector can be found. The feature selector defines which feature to control the robot arm relative to

Below the feature selector, the name of the currently active Tool Center Point (TCP) is displayed. For further information about configuring several named TCPs, see 17.1.1. The text boxes show the full coordinate values of that TCP relative to the selected feature. `X`, `Y` and `Z` control the position of the tool, while `RX`, `RY` and `RZ` control the orientation of the tool.

Use the drop down menu above the `RX`, `RY` and `RZ` boxes to choose the orientation representation. Available types are:

- **Rotation Vector [rad]** The orientation is given as a *rotation vector*. The length of the axis is the angle to be rotated in radians, and the vector itself gives the axis about which to rotate. This is the default setting.
- **Rotation Vector [°]** The orientation is given as a *rotation vector*, where the length of the vector is the angle to be rotated in degrees.
- **RPY [rad]** *Roll*, *pitch* and *yaw* (*RPY*) angles, where the angles are in radians. The RPY-rotation matrix (X, Y', Z" rotation) is given by:

$$R_{rpy}(\gamma, \beta, \alpha) = R_Z(\alpha) \cdot R_Y(\beta) \cdot R_X(\gamma)$$

- **RPY [°]** *Roll*, *pitch* and *yaw* (*RPY*) angles, where angles are in degrees.

Values can be edited by clicking on the coordinate. Clicking on the + or – buttons just to the right of a box allows you to add or subtract an amount to/from the current value. Pressing and holding down a button will directly increase/decrease the value. The longer the button is down, the larger the increase/decrease will be.

18.3.1.3 Joint positions

Allows the individual joint positions to be specified directly. Each joint position can have a value in the range from $-360°$ to $+360°$, which are the *joint limits*. Values can be edited by clicking on the joint position. Clicking on the + or – buttons just to the right of a box allows you to add or subtract an amount to/from the current value. Pressing and holding down a button will directly increase/decrease the value. The longer the button is down, the larger the increase/decrease will be.

18.3.1.4 OK button

If this screen was activated from the `Move` tab (see 18), clicking the `OK` button will return to the `Move` tab, where the robot arm will move to the specified target. If the last specified value was a tool coordinate, the robot arm will move to the target position using the *MoveL* movement type, while the robot arm will move to the target position using the *MoveJ* movement type, if a joint position was specified last. The different movement types are described in 16.5.1.

18.3.1.5 Cancel button

Clicking the `Cancel` button leaves the screen discarding all changes.

18.4 Joint Position

The **Joint Position** field allows you to directly control individual joints. Each joint moves along a default joint limit range from $-360°$ to $+360°$, defined by a horizontal bar. Once the limit is reached you cannot move a joint any further.
Note: You can configure joints with a position range different from the default `(see 13.2.4)`, this new range is indicated with red zone inside the horizontal bar.

18.5 Home

Press the **Home** tab to access the **Move Robot into Position** screen, where you can hold down the **Auto** tab to return robot arm to its start position `(see 14.4)`.

18.6 Freedrive

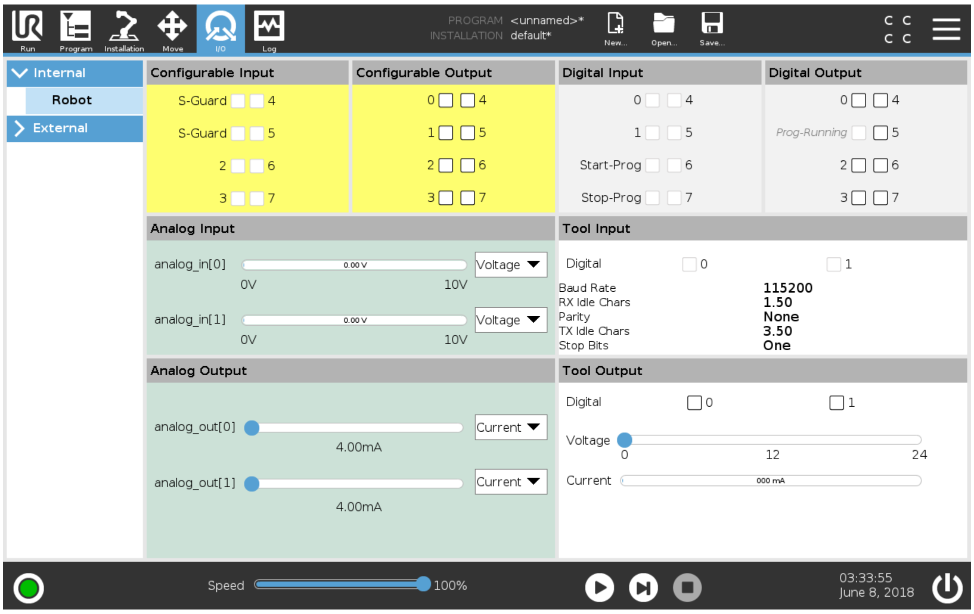
Hold down the **Freedrive** tab to physically grab the robot arm and pull it to your desired position/pose.

WARNING:

1. In the **Setup** tab, if the gravity setting `(see 17.1.2)` is wrong, or the robot arm carries a heavy load, the robot arm can start moving (falling) when you press the **Freedrive** tab. In that case, release **Freedrive**again.
2. Make sure to use the correct installation settings (e.g. Robot mounting angle, weight in TCP, TCP offset). Save and load the installation files along with the program.
3. Make sure that the TCP settings and the robot mounting settings are set correctly before operating **Freedrive** tab. If these settings are not correct, the robot arm will move when you activate **Freedrive**.
4. The **Freedrive** function (Impedance/Backdrive) must only be used in installations where the risk assessment allows it. Tools and obstacles must not have sharp edges or pinch points. Make sure that all personnel remain outside the reach of the robot arm.

19 I/O Tab

19.1 Robot



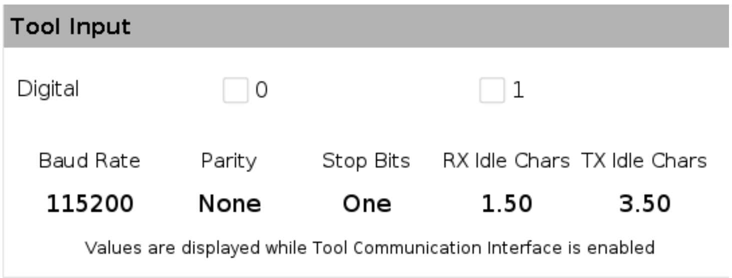
On this screen you can always monitor and set the live I/O signals from/to the robot control box. The screen displays the current state of the I/O, including during program execution. If anything is changed during program execution, the program will stop. At program stop, all output signals will retain their states. The screen is updated at only 10Hz, so a very fast signal might not display properly.

Configurable I/O's can be reserved for special safety settings defined in the safety I/O configuration section of the installation (see 13.2.8); those which are reserved will have the name of the safety function in place of the default or user defined name. Configurable outputs that are reserved for safety settings are not togglable and will be displayed as LED's only.

The electrical details of the signals are described in chapter 5.4.

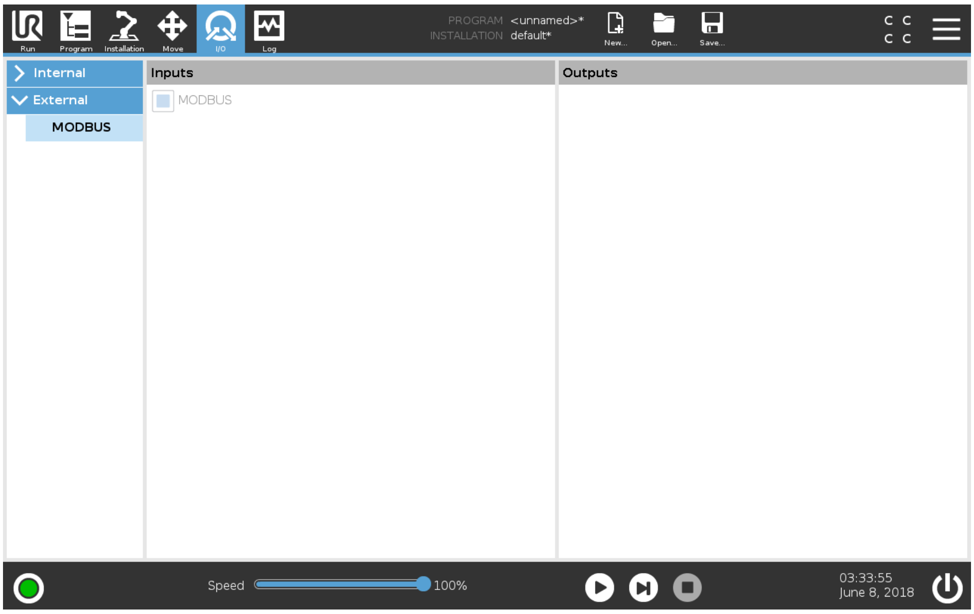
Analog Domain Settings The analog I/O's can be set to either current [4-20mA] or voltage [0-10V] output. The settings will be remembered for eventual later restarts of the robot controller when a program is saved.

Tool Communication Interface When the **Tool Communication Interface TCI** is enabled (see 17.1.10), tool analog input becomes unavailable.
Note: On the **I/O** screen, the **Tool Input** field changes as illustrated below.



19.2 MODBUS

Here, the digital MODBUS client I/O signals as set up in the installation are shown. If the signal connection is lost, the corresponding entry on this screen is disabled.



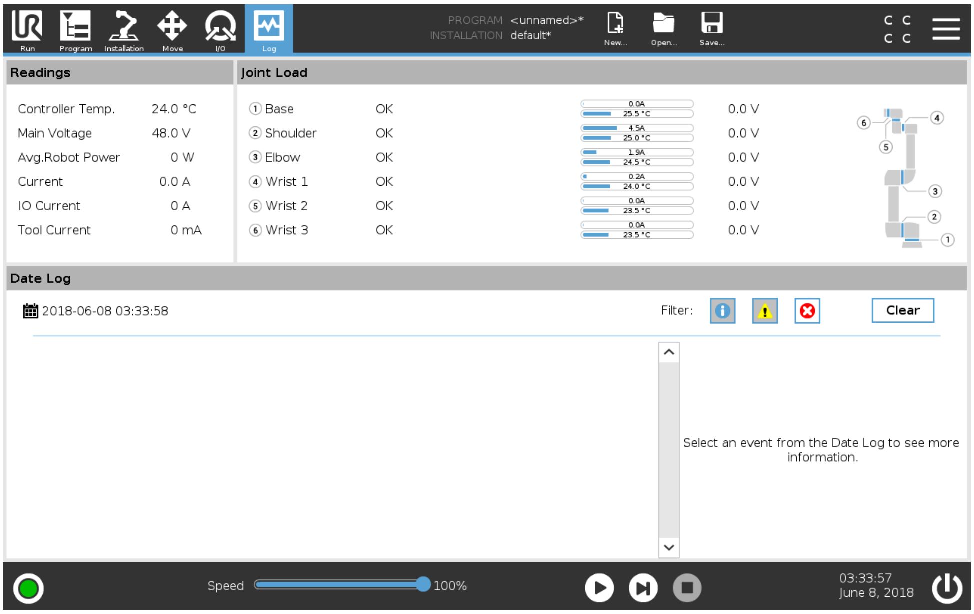
19.2.1 Inputs

View the state of digital MODBUS client inputs.

19.2.2 Outputs

View and toggle the state of digital MODBUS client outputs. A signal can only be toggled if the choice for I/O tab control (see 17.1.3) allows it.

20 Log Tab



20.1 Readings

The top half of the screen displays the "health" of the Robot Arm and Control Box.

20.2 Joint Load

The left side of the screen shows information related to the Control Box, while the right side of the screen displays robot joint information. Each joint dsiplays the temperature of the motor and electronics, the load of the joint, and the voltage.

20.3 Date Log

Messages are displayed on the bottom half of the screen. The first column categorizes the severity of the log entry. The second column shows the messages' time of arrival. The next column shows the sender of the message. The last column shows the message itself. Messages can be filtered by selecting the toggle buttons which correspond to the severity of the log entry. The figure above shows errors will be displayed while information and warning messages will be filtered. Some log messages are designed to provide more information that is accessible by selecting the log entry.

20.4 Saving Error Reports

When an error occurs in PolyScope, a log of the error is generated. In the Log Tab, you can track and/or export generated reports to a USB drive `(see 20)`. The following list of errors can be tracked and exported:

- Fault
- Internal PolyScope exceptions
- Protective Stop
- Unhandled exception in URCap
- Violation

The exported report contains: a user program, a history log, an installation and a list of running services.

Error Report

A detailed status report is available when a paper clip icon appears on the log line.

- Select a log line and tap the Save Report button to save the report to a USB drive.
- The report can be saved while a program is running.

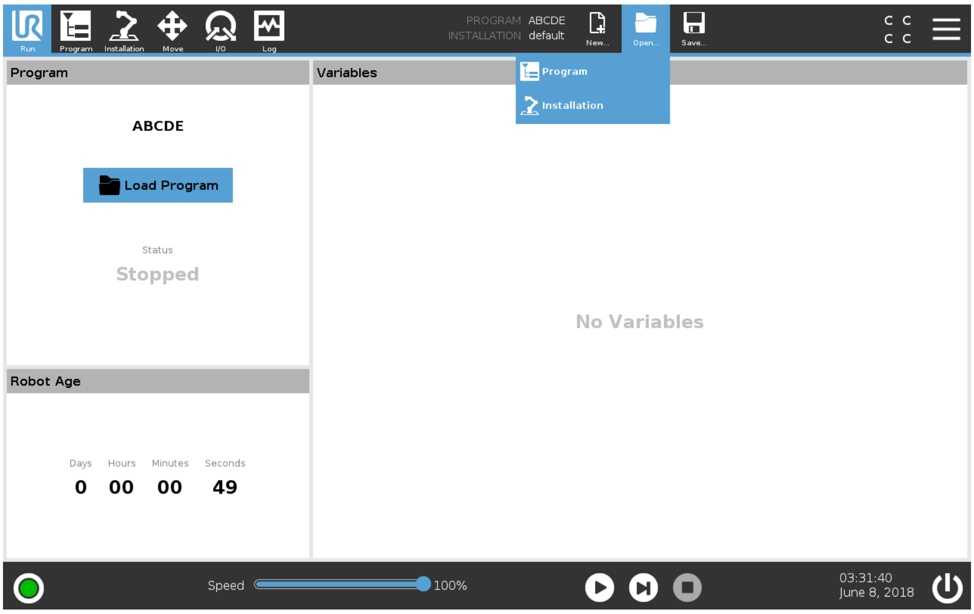
NOTE:
The oldest report is deleted when a new one is generated. Only the five most recent reports are stored.

21 File manager

The File Manager refers to three icons that allow you to create, load and configure Programs and Installations: **New...**, **Open...** and **Save...**. The File Path displays your current loaded Program name and the type of Installation. File Path changes when you create or load a new Program or Installation. You can have several installation files for a robot. Programs created load and use the active installation automatically.

21.1 Open...

Allows you to load a Program and/or Installation.



Opening a Program

1. In File Manager, tap **Open...** and select Program.
2. On the Load Program screen, select an existing program and tap Open.
3. In File Path, verify that the desired program name is displayed.

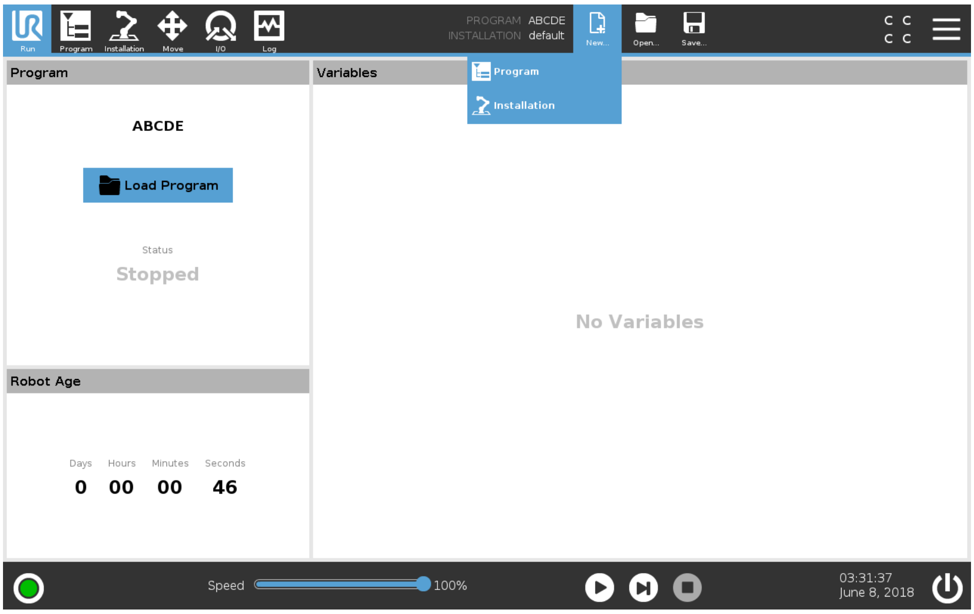
Opening an Installation.

1. In File Manager, tap **Open...** and select Installation.
2. On the Load Robot Installation screen, select an existing installation and tap Open.

3. In the Safety Configuration box, select Apply and restart to prompt robot reboot.
4. Select Set Installation to set installation for the current Program.
5. In File Path, verify that the desired installation name is displayed.

21.2 New...

Allows you to create a new Program and/or Installation.



Creating a new Program

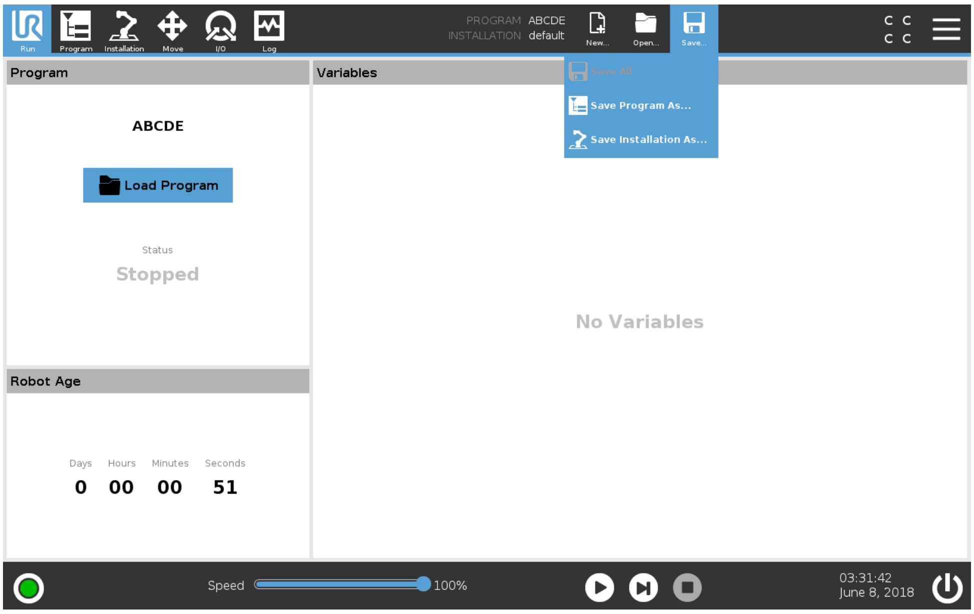
1. In File Manager, tap **New...** and select Program.
2. On the Program screen, configure your new program as desired.
3. In File Manager, tap **Save...** and select Save All or Save Program As...
4. On the Save Program As screen, assign a file name and tap Save.
5. In File Path, verify that the new program name is displayed.

Creating a new Installation
Note: You must save an installation for use after robot power down.

1. In File Manager, tap **New...** and select Installation.
2. Tap Confirm Safety Configuration.
3. On the Installation screen, configure your new installation as desired.
4. In File Manager, tap **Save...** and select Save Installation As...
5. On the Save Robot Installation screen, assign a file name and tap Save.
6. Select Set Installation to set installation for the current Program.
7. In File Path, verify that the new installation name is displayed.

UNIVERSAL ROBOTS

21.3 Save...



Save... proposes three options. Depending on the program/installation you load-create, you can:

Save All to save the current Program and Installation immediately, without the system prompting to save to a different location or different name. Note: If no changes are made to the Program or Installation, the Save All... button appears deactivated.

Save Program As... to change the new Program name and location. Note: the current Installation is also saved, with the existing name and location.

Save Installation As... to change the new Installation name and location. Note: the current Program is saved, with the existing name and location.

22 Hamburger menu

22.1 Help

You can find definitions for all elements that make up PolyScope capabilities.

1. In the right corner of the **Header**, tap the **Hamburger** menu and select **Help**.
2. Tap one of the red question marks that appears, to define desired element.
3. In the top right corner of element definition screen, tap the red X to exit Help.

22.2 About

You can display Version and Legal data.

1. Tap the **Hamburger** menu and select **About**.
2. Tap either **Version** or **Legal** to display data.
3. Tap Close to return to your screen.

22.3 Settings

Personalizing PolyScope Settings

1. In the Header, tap the Hamburger menu and select **Settings**.
2. On the left, in the Settings screen action menu, select an item to personalize. Note: If an operational mode password was set, in the action menu, **System** is only available to the programmer.
3. On the bottom right, tap **Apply and Restart** to implement your changes.
4. On the bottom left, tap **Exit** to close Settings screen without changes.

Hiding Speed Slider

Located at the base of the Run tab screen, the Speed Slider allows the operator to change the speed of a running Program.

1. In the Header, tap the Hamburger menu icon and select **Settings**.
2. Under Preferences, tap **Run Screen**.
3. Select check box to show or hide **Speed Slider**.

22.3.1 Preferences

Language

You can change PolyScope language and measurement unit (Metric or Imperial).

Time

You can adjust the current time displayed on PolyScope (format: 12 or 24 hour).

22.3.2 Password

Mode

The operational mode password prevents unauthorized modification of robot setup, by creating two different user roles on PolyScope: Automatic and Maual. When you set operational mode password, programs or installations can only be created and loaded in manual mode. Any time you enter manual mode, PolyScope prompts for the password that was previously set on this screen.

Safety

The Safety password prevents unauthorized modification of the Safety settings.

22.3.3 System

Update

You can search for updates to verify that the robot software is up-to-date.

1. On the left, in the Settings screen action menu, select **System**
2. In the **Update robot software** field, tap **Search**.
3. In the **Description** field, observe as updates are listed.
4. Select desired update/s and press **Update** to install.

Network

You can configure robot connection to a network by selecting one of three available network methods:

- DHCP
- Static Address
- Disabled network (if you don't wish to connect your robot to a network)

Depending on the network method you select, configure your network settings:

- IP Address
- Subnet Mask
- Default Gateway
- Preferred DNS Server
- Alternative DNS Server

Note: Press **Apply** to apply changes.

URCaps

You can manage your existing **URCaps** or install a new one in your robot.

1. In the Header, press the Hamburger menu and select **Settings**.
2. Under System, select **URCaps**.
3. Press the **+** tab, select the **.urcap** file and press **Open** Note: Check more details about the new URCap by selecting it in **Active URCaps** field. More information appears below in **URCap Information** field below.

4. If you wish to proceed with the installation of that URCap, press **Restart**. After that step, the URCap is installed and ready to be used.
5. To eliminate an installed URCap, select it from Active URCaps, press the **-** button and press **Restart** so changes can take effect.

Remote Control

A robot can either be in Local Control (controlled from the Teach Pendant) or Remote Control (controlled externally).

Local Control does not allow	**Remote Control does not allow**
Power on and brake release sent to the robot over network	Moving the robot from Move Tab
Receiving and executing robot programs and installation sent to the robot over network	Start in programs from Teach Pendant
Autostart of programs at boot, controlled from digital inputs	Load programs and installations from the Teach Pendant
Auto brake release at boot, controlled from digital inputs	Freedrive
Start of programs, controlled from digital inputs	

Control of the robot via network or digital input is, by default, restricted. Enabling and selecting the Remote Control feature removes this restriction. Enable Remote Control by switching to the Local Control profile (PolyScope control) of the robot, allowing all control of running programs and executing scripts to be performed remotely.
Note: Enable the Remote Control feature in Settings to access Remote mode and Local mode in the profile.

1. In the Header, press the Hamburger menu and select **Settings**.
2. Under System, select **Remote Control**.
3. Press **Enable** to make the Remote Control feature available. PolyScope remains active. Note: Enabling Remote Control does not immediately start the feature. It allows you to switch from Local Control to Remote Control.
4. In the profile menu, select **Remote Control** to alter PolyScope. Note: You can return to Local Control by switching back in the profile menu, or selecting Operator or Programmer if a password is specified.

NOTE:

- Although Remote Control limits your actions in PolyScope, you can still monitor robot state.
- When a robot system is powered off in Remote Control, it starts up in Remote Control.

Glossary

Stop Category 0 Robot motion is stopped by immediate removal of power to the robot. It is an uncontrolled stop, where the robot can deviate from the programmed path as each joint brake as fast as possible. This protective stop is used if a safety-related limit is exceeded or in case of a fault in the safety-related parts of the control system. For more information, `see ISO 13850` or `IEC 60204-1`.

Stop Category 1 Robot motion is stopped with power available to the robot to achieve the stop and then removal of power when the stop is achieved. It is a controlled stop, where the robot will continue along the programmed path. Power is removed as soon as the robot stands still. For more information, `see ISO 13850` or `IEC 60204-1`.

Stop Category 2 A controlled stop with power left available to the robot. The safety-related control system monitors that the robot stays at the stop position. For more information, `see IEC 60204-1`.

Category 3 The term *Category* should not be confused with the term *Stop Category*. *Category* refers to the type of architecture used as basis for a certain *Performance Level*. A significant property of a *Category 3* architecture is that a single fault cannot lead to loss of the safety function. For more information, `see ISO 13849-1`.

Performance Level A Performance Level (PL) is a discrete level used to specify the ability of safety-related parts of control systems to perform a safety functions under foreseeable conditions. PLd is the second highest reliability classification, meaning that the safety function is extremely reliable. For more information, `see ISO 13849-1`.

Diagnostic coverage (DC) is a measure of the effectiveness of the diagnostics implemented to achieve the rated performance level. For more information, `see ISO 13849-1`.

MTTFd The Mean time to dangerous failure (MTTFd) is a value based on calculations and tests used to achieve the rated performance level. For more information, `see ISO 13849-1`.

Integrator The integrator is the entity that designs the final robot installation. The integrator is responsible for making the final risk assessment and must ensure that the final installation complies with local laws and regulations.

Risk assessment A risk assessment is the overall process of identifying all risks and reducing them to an appropriate level. A risk assessment should be documented. Consult `ISO 12100` for further information.

Collaborative robot application The term *collaborative* refers to collaboration between operator and robot in a robot application. See precise definitions and descriptions in ISO 10218-1 and ISO 10218-2.

Safety configuration Safety-related functions and interfaces are configurable through safety configuration parameters. These are defined through the software interface, `see part II`.

Index

T

U

V

W