

10.2. Safety-related Functions and Interfaces

Description

Universal Robots 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 (see Certifications) with Performance Level d (PLd) using a category 3 architecture.

See Software Safety Configuration for configuration of the safety functions, inputs and outputs in the user interface. See Safety I/O for descriptions on how to connect safety devices to I/O.



WARNING

The use of safety configuration parameters different from those determined as necessary for risk reduction, can result in hazards that are not reasonably eliminated, or risks that are not sufficiently reduced.

- Ensure tools and grippers are connected correctly to avoid hazards due to interruption of power.



WARNING: ELECTRICITY

Programmer and/or wiring errors can cause the voltage to change from 12V to 24V leading to fire damage to equipment.

- Verify the use of 12V and proceed with caution.

Additional Information



NOTICE

- The use and configuration of safety functions and interfaces must follow the risk assessment procedures for each robot application. (see chapter **Safety** section **Safety-related Functions and Interfaces**)
- The stopping time should be taken into account as part of the application risk assessment
- If the robot detects 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 exceeded), then a Stop Category 0 is initiated.



NOTICE

The end effector is not protected by the UR safety system. The functioning of the end effector and/or connection cable is not monitored

10.2.1. Configurable Safety Functions

Description 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 robot stop is initiated. ¹
Stopping Distance Limit	Limits maximum distance travelled by the robot after a robot stop is initiated.

Safety Function 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. 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:

¹Robot stop was previously known as "Protective stop".

Safety Function	Accuracy	Performance Level	Category
Emergency Stop	-	d	3
Safeguard Stop	-	d	3
Joint Position Limit	5 °	d	3
Joint Speed Limit	1.15 °/s	d	3
Safety Planes	40 mm	d	3
Tool Orientation	3 °	d	3
Speed Limit	50 mm/s	d	3
Force Limit	25 N	d	3
Momentum Limit	3 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
Safe Home	1.7 °	d	3

Warnings



CAUTION

Failure to configure the maximum speed limit can result in hazardous situations.

- If the robot is used in manual hand-guiding applications with linear movements, the speed limit must be set to maximum 250 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.

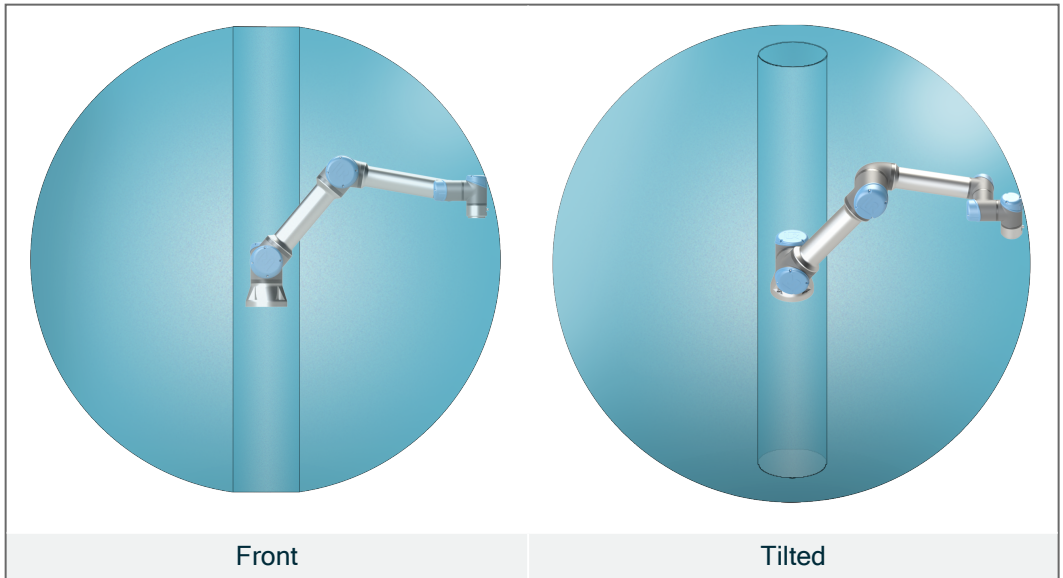


NOTICE

There are two exceptions to the force limiting function that are important when designing an application.

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.

Workspace



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.

Placing the robot in certain areas can create pinching hazards that can lead to injury.

**Safety
inputs**

The robot also has the following safety inputs:

Safety Input	Description
Emergency Stop Button	Performs a Stop Category 1 (IEC 60204-1) informing other machines using the <i>System Emergency Stop</i> output, if that output is defined. A stop is initiated in anything connected to the output.
Robot Emergency Stop	Performs a Stop Category 1 (IEC 60204-1) via Control Box input, informing other machines using the <i>System Emergency Stop</i> output, if that output is defined.
System Emergency Stop	Performs a Stop Category 1 (IEC 60204-1) on robot only, in all modes and takes precedence over all other commands.
Safeguard Stop	Performs a Stop Category 2 (IEC 60204-1) in all modes, except when using a 3-Position Enabling Device and a mode selector - then when in Manual Mode, the Safeguard Stop can be set to only function in Automatic Mode.
Automatic Mode Safeguard Stop	Performs a Stop Category 2 (IEC 60204-1) in Automatic mode ONLY. <i>Automatic Mode Safeguard Stop</i> can only be selected when a Three-Position Enabling Device is configured and installed.
Safeguard Reset	Returns from the <i>Safeguard Stop</i> state, when a rising edge on the Safeguard Reset input occurs.
Reduced Mode	Transitions the safety system to use the <i>Reduced mode</i> limits.
Three-Position Enabling Device	Initiates a Stop Category 2 (IEC 60204-1) when the enabling device is fully pressed or fully released in manual mode only. Three-Position Enabling Device Stop is triggered when an input goes low. It is unaffected by a Safeguard Reset.
Freedrive on robot	Enables freedrive, when the robot is not in Automatic Mode.
Operational Mode	Switches between Operational modes. The robot is in Automatic mode when input is low, Manual mode when input is high.
Automatic Mode Safeguard Reset	Returns from the <i>Automatic Mode Safeguard Stop</i> state, when a rising edge on the Automatic Mode Safeguard Reset input occurs.

Safety outputs

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 <i>Robot Emergency Stop</i> 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/s.
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	Logic low when the safety system is in Reduced Mode.
Not Reduced	Logic low when the system is not in Reduced Mode.
Safe Home	Logic high when robot is in the configured Safe Home Position.

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).

10.2.2. Safety Functions

Description

The safety system acts by monitoring if any of the safety limits are exceeded 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
3PE Stop (if a 3-Position Enabling device is connected)	Stop Category 2
Limit Violation	Stop Category 0
Fault Detection	Stop Category 0



NOTICE

If the safety system detects any fault or violation, all safety outputs re-set to low.

10.2.3. Safety Parameter Set

Description

The safety system has the following set of configurable safety parameters:

- Normal
- Reduced

Normal and Reduced

You can set up the safety limits for each set of safety parameters, creating distinct configurations for normal, or higher settings, and reduced. The reduced configuration is active when the tool/end effector is positioned on the reduced side of a Trigger Reduced Plane, or when the reduced configuration is externally triggered by a safety input.

Using a plane to trigger the Reduced configuration: When the robot arm moves from the side of the trigger plane configured with reduced safety parameters, to the side that is configured with normal safety parameters, there is a 20 mm area around the trigger plane where both normal and reduced limits are allowed. This area around the trigger plane prevents nuisance safety stops when the robot is exactly at the limit.

Using an input to trigger the Reduced configuration: When a safety input starts, or stops, the reduced configuration, up to 500 ms can elapse before the new limit values become active. This can happen in either of the following circumstances:

- Switching from the reduced configuration to normal
- Switching from the normal configuration to reduced

The robot arm adapts to the new safety limits within the 500 ms.

Recovery

When a safety limit is exceeded, the safety system must be restarted. For example, if a joint position limit is outside a safety limit, at start-up, Recovery is activated. You cannot run programs for the robot when recovery is activated, but the robot arm can be manually moved back within limits using Freedrive, or by using the Move tab in PolyScope. The safety limits for Recovery are:

Safety Function	Limit
Joint Speed Limit	30 °/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

Failure to use caution when moving the robot arm in recovery mode can lead to hazardous situations.

- Use caution when moving the robot arm back within the limits, as limits for the joint positions, the safety planes, and the tool/end effector orientation are all disabled in recovery mode.

