

# 19. Safety Functions Table

**Description** Universal Robots safety functions and safety I/O are PLd Category 3 (ISO 13849-1), where each safety function has a PFH<sub>D</sub> value less than 1.8E-07. The PFH<sub>D</sub> values are updated to include greater design flexibility for supply chain resilience. For Safety Function (SF) Descriptions see: [Safety-related Functions and Interfaces](#). For safety I/O the resulting safety function including the external device, or equipment, is determined by the overall architecture and the sum of all PFH<sub>D</sub>s, including the UR robot safety function PFH<sub>D</sub>.



**NOTICE**  
The Safety Functions tables presented in this chapter are simplified. You can find the comprehensive versions of them here: <https://www.universal-robots.com/support>

SF# and  
Safety  
Function

SF1  
Emergency  
Stop  
(according to  
ISO 13850)  
  
See footnotes

Description	What happens?	Tolerance and PFH <sub>D</sub>	Affects
Pressing the Estop PB on the pendant <sup>1</sup> or the External Estop (if using the Estop Safety Input) results in a Stop Cat 1 <sup>3</sup> with power removed from the robot actuators and the tool I/O. Command <sup>1</sup> all joints to stop and upon all joints coming to a monitored standstill state, power is removed. For the integrated functional safety rating with an external safety-related control system or an external emergency stop device that is connected to the Emergency Stop input, add the PFH <sub>D</sub> of this safety-related input to the PFH <sub>D</sub> of this safety function's PFH <sub>D</sub> value (less than 1.8E-07).	Category 1 stop (IEC 60204-1)	Tol: -- PFH <sub>D</sub> : 1.8E-07	Robot including robot tool I/O

**SF2  
Safeguard  
Stop 4  
(Robot Stop  
according to  
ISO 10218-1)**

Description	What happens?	Tolerance and PFH <sub>D</sub>	Affects
This safety function is initiated by an external protective device using safety inputs that initiate a Cat 2 stop <sup>3</sup> . The tool I/O are unaffected by the safeguard stop. Various configurations are provided. If an enabling device is connected, it's possible to configure the safeguard stop to function in automatic mode ONLY. See the Stop Time and Stop Distance Safety Functions <sup>4</sup> . For the functional safety of the complete integrated safety function, add the PFHd of the external protective device to the PFHd of the Safeguard Stop.	Category 2 stop (IEC 60204-1) SS2 stop (as described in IEC 61800-5-2)	Tol: -- PFH <sub>D</sub> : 1.8E-07	Robot

**SF3 Joint  
Position  
Limit (soft  
axis  
limiting)**

Description	What happens?	Tolerance and PFH <sub>D</sub>	Affects
Sets upper and lower limits for the allowed joint positions. Stopping time and distance is not considered as the limit(s) will not be violated. Each joint can have its own limits. Directly limits the set of allowed joint positions that the joints can move within. It is set in the safety part of the User Interface. It is a means of safety-rated soft axis limiting and space limiting, according to ISO 10218-1:2011, 5.12.3.	Will not allow motion to exceed any limit settings. Speed could be reduced so motion will not exceed any limit. A robot stop will be initiated to prevent exceeding any limit.	Tol: 5° PFH <sub>D</sub> : 1.8E-07	Joint (each)

**SF4 Joint  
Speed  
Limit**

Description	What happens?	Tolerance and PFH <sub>D</sub>	Affects
Sets an upper limit for the joint speed. Each joint can have its own limit. This safety function has the most influence on energy transfer upon contact (clamping or transient). Directly limits the set of allowed joint speeds which the joints are allowed to perform. It is set in the safety setup part of the User Interface. Used to limit fast joint movements, e.g. risks related to singularities.	Will not allow motion to exceed any limit settings. Speed could be reduced so motion will not exceed any limit. A robot stop will be initiated to prevent exceeding any limit.	Tol: 1.15 °/s PFH <sub>D</sub> : 1.8E-07	Joint (each)

**Joint  
Torque  
Limit**

Exceeding the internal joint torque limit (each joint) results in a Cat 0<sup>3</sup>. This is not accessible to the user; it is a factory setting. It is NOT shown as an e-Series safety function because there are no user settings and no user configurations.

**SF5 Called various names: Pose Limit, Tool Limit, Orientation Limit, Safety Planes, Safety Boundaries**

Description	What happens?	Tolerance and PFH <sub>D</sub>	Affects
Monitors the TCP Pose (position and orientation) and will prevent exceeding a safety plane or TCP Pose Limit. Multiple pose limits are possible (tool flange, elbow, and up to 2 configurable tool offset points with a radius) Orientation restricted by the deviation from the feature Z direction of the tool flange OR the TCP. This safety function consists of two parts. One is the safety planes for limiting the possible TCP positions. The second is the TCP orientation limit, which is entered as an allowed direction and a tolerance. This provides TCP and wrist inclusion/ exclusion zones due to the safety planes.	Will not allow motion to exceed any limit settings. Speed or torques could be reduced so motion will not exceed any limit. A robot stop will be initiated to prevent exceeding any limit. Will not allow motion to exceed any limit settings.	Tol: 3° 40 mm PFH <sub>D</sub> : 1.8E-07	TCP Tool flange Elbow

**SF6 Speed Limit TCP & Elbow**

Description	What happens?	Tolerance and PFH <sub>D</sub>	Affects
Monitors the TCP and elbow speed to prevent exceeding a speed limit.	Will not allow motion to exceed any limit settings. Speed or torques could be reduced so motion will not exceed any limit. A robot stop will be initiated to prevent exceeding any limit. Will not allow motion to exceed any limit settings.	Tol: 50 mm/s PFH <sub>D</sub> : 1.8E-07	TCP

**SF7 Force Limit (TCP)**

Description	What happens?	Tolerance and PFH <sub>D</sub>	Affects
The Force Limit is the force exerted by the robot at the TCP (tool center point) and "elbow". The safety function continuously calculates the torques allowed for each joint to stay within the defined force limit for both the TCP & the elbow. The joints control their torque output to stay within the allowed torque range. This means that the forces at the TCP or elbow will stay within the defined force limit. When a monitored stop is initiated by the Force Limit SF, the robot will stop, then "back-off" to a position where the force limit was not exceeded. Then it will stop again.	Will not allow motion to exceed any limit settings. Speed or torques could be reduced so motion will not exceed any limit. A robot stop will be initiated to prevent exceeding any limit. Will not allow motion to exceed any limit settings.	Tol: 25N PFH <sub>D</sub> : 1.8E-07	TCP

**SF8  
Momentum  
Limit**

Description	What happens?	Tolerance and PFH <sub>D</sub>	Affects
The momentum limit is very useful for limiting transient impacts. The Momentum Limit affects the entire robot.	Will not allow motion to exceed any limit settings. Speed or torques could be reduced so motion will not exceed any limit. A robot stop will be initiated to prevent exceeding any limit. Will not allow motion to exceed any limit settings.	Tol: 3kg m/s PFH <sub>D</sub> : 1.8E-07	Robot

**SF9  
Power  
Limit**

Description	What happens?	Tolerance and PFH <sub>D</sub>	Affects
This function monitors the mechanical work (sum of joint torques times joint angular speeds) performed by the robot, which also affects the current to the robot arm as well as the robot speed. This safety function dynamically limits the current/ torque but maintains the speed.	Dynamic limiting of the current/torque	Tol: 10W PFH <sub>D</sub> : 1.8E-07	Robot

**SF10 UR  
Robot  
Estop  
Output**

Description	What Happens	PFH <sub>D</sub>	Affects
<p>When configured for a Robot &lt;Estop&gt; output and there is a robot stop, the dual outputs are LOW. If there is no Robot &lt;Estop&gt; Stop initiated, dual outputs are high. Pulses are not used but they are tolerated.</p> <p>These dual outputs change state for any external Estop that is connected to configurable safety inputs where this input is configured as an Emergency Stop input.</p> <p>For the integrated functional safety rating with an external safety-related control system, add the PFHD of this safety-related output to the PFHD of the external safety-related control system.</p> <p>For the Estop Output, validation is performed at the external equipment, as the UR output is an input to this external Estop safety function for external equipment.</p> <p>NOTE: If the IMMI (Injection Moulding Machine Interface) is used, the UR Robot Estop output is NOT connected to the IMMI. There is no Estop output signal sent from the UR robot to the IMMI. This is a feature to prevent an unrecoverable stop condition.</p>	Dual outputs go low in event of an Estop if configurable outputs are set	1.8E-07	External connection to logic and/or equipment

**SF11 UR  
Robot  
Moving:  
Digital  
Output**

Description	What Happens	PFH <sub>D</sub>	Affects
Whenever the robot is moving (motion underway), the dual digital outputs are LOW. Outputs are HIGH when no movement. The functional safety rating is for what is within the UR robot. The integrated functional safety performance requires adding this PFHd to the PFHd of the external logic (if any) and its components.	If configurable outputs are set: <ul style="list-style-type: none"> <li>When the robot is moving (motion underway), the dual digital outputs are LOW.</li> <li>Outputs are HIGH when no movement.</li> </ul>	1.8E-07	External connection to logic and/or equipment

**SF12 UR  
Robot Not  
stopping:  
Digital  
Output**

Description	PFH <sub>D</sub>	Affects
When the robot is STOPPING (in process of stopping or in a stand-still condition) the dual digital outputs are HIGH. When outputs are LOW, robot is NOT in the process of stopping and NOT in a stand-still condition. The functional safety rating is for what is within the UR robot. The integrated functional safety performance requires adding this PFHd to the PFHd of the external logic (if any) and its components.	1.8E-07	External connection to logic and/or equipment

**SF13 UR  
Robot  
Reduced  
Mode:  
Digital  
Output**

Description	PFH <sub>D</sub>	Affects
When the robot is in reduced mode (or reduced mode is initiated), the dual digital outputs are LOW. See below. The functional safety rating is for what is within the UR robot. The integrated functional safety performance requires adding this PFHd to the PFHd of the external logic (if any) and its components.	1.8E-07	External connection to logic and/or equipment

**SF14 UR  
Robot Not  
Reduced  
Mode:  
Digital  
Output**

Description	PFH <sub>D</sub>	Affects
Whenever the robot is NOT in reduced mode (or the reduced mode is not initiated), the dual digital outputs are LOW. The functional safety rating is for what is within the UR robot. The integrated functional safety performance requires adding this PFHd to the PFHd of the external logic (if any) and its components.	1.8E-07	External connection to logic and/or equipment

**SF15**  
**Stopping**  
**Time Limit**

Description	What happens?	Tolerances and PFH <sub>D</sub> :	Affects
<p>Real time monitoring of conditions such that the stopping time limit will not be exceeded. Robot speed is limited to ensure that the stop time limit is not exceeded.</p> <p>The stopping capability of the robot in the given motion(s) is continuously monitored to prevent motions that would exceed the stopping limit. If the time needed to stop the robot is at risk of exceeding the time limit, the speed of motion is reduced to ensure the limit is not exceeded. A robot stop will be initiated to prevent exceeding the limit. The safety function performs the same calculation of the stopping time for the given motion(s) and initiates a cat 0 stop if the stopping time limit will be or is exceeded.</p>	<p>Will not allow the actual stopping time to exceed the limit setting.</p> <p>Causes decrease in speed or a robot stop so as NOT to exceed the limit</p>	<p>TOL: 50 ms PFH<sub>D</sub>: 1.8E-07</p>	Robot

**SF16**  
**Stopping**  
**Distance Limit**

Description	What happens?	Tolerances and PFH <sub>D</sub> :	Affects
<p>Real time monitoring of conditions such that the stopping distance limit will not be exceeded. Robot speed is limited to ensure that the stop distance limit will not be exceeded.</p> <p>The stopping capability of the robot in the given motion(s) is continuously monitored to prevent motions that would exceed the stopping limit. If the time needed to stop the robot is at risk of exceeding the time limit, the speed of motion is reduced to ensure the limit is not exceeded. A robot stop will be initiated to prevent exceeding the limit. The safety function performs the same calculation of the stopping distance for the given motion(s) and initiates a cat 0 stop if stopping time limit will be or is exceeded.</p>	<p>Will not allow the actual stopping time to exceed the limit setting.</p> <p>Causes decrease in speed or a robot stop so as NOT to exceed the limit</p>	<p>TOL: 40 mm PFH<sub>D</sub>: 1.8E-07</p>	Robot

**SF17 Safe Home Position "monitored position"**

Description	What happens?	Tolerances and PFH <sub>D</sub> :	Affects
<p>Safety function which monitors a safety rated output, such that it ensures that the output can only be activated when the robot is in the configured and monitored "safe home position".</p> <p>A stop cat 0 is initiated if the output is activated when the robot is not in the configured position.</p>	<p>The "safe home output" can only be activated when the robot is in the configured "safe home position"</p>	<p>TOL: 1.7 °</p> <p>PFH<sub>D</sub>: 1.8E-07</p>	<p>External connection to logic and/or equipment</p>

**Table 1 footnotes**

<sup>1</sup>Communications between the Teach Pendant, controller and within the robot (between joints) are SIL 2 for safety data, per IEC 61784-3.

<sup>2</sup>Estop validation: the pendant Estop pushbutton is evaluated within the pendant, then communicated<sup>1</sup> to the safety controller by SIL2 communications. To validate the pendant Estop functionality, press the Pendant Estop pushbutton and verify that an Estop results. This validates that the Estop is connected within the pendant, the estop functions as intended, and the pendant is connected to the controller.

<sup>3</sup>Stop Categories according to IEC 60204-1 (NFPA79). For the Estop, only stop category 0 and 1 are allowed according to IEC 60204-1.

- Stop Category 0 and 1 result in the removal of drive power, with stop cat 0 being IMMEDIATE and stop cat 1 being a controlled stop (e.g. decelerate to a stop then removal of drive power). With UR robots, a stop category 1 is a controlled stop where power is removed when a monitored standstill is detected.
- Stop Category 2 is a stop where drive power is NOT removed. Stop category 2 is defined in IEC 60204-1. Descriptions of STO, SS1 and SS2 are in IEC 61800-5-2. With UR robots, a stop category 2 maintains the trajectory, then retains power to the drives after stopping.

<sup>4</sup>It is recommended to use the UR Stop Time and Stop Distance Safety Functions. These limits should be used for your application stop time/ safety distance values.

<sup>5</sup>Robot stop was previously known as "Protective stop" for Universal Robots robots.

## 19.1. Table 1a

**Reduced Mode SF parameter settings change**

Description	PFH <sub>D</sub>	Affects
<p>Reduced Mode can be initiated by a safety plane/ boundary (starts at 2cm of the plane and reduced mode settings are achieved within 2cm of the plane) or by use of an input to initiate (will achieve reduced settings within 500ms). When the external connections are Low, Reduced Mode is initiated. Reduced Mode means that ALL reduced mode limits are ACTIVE.</p> <p>Reduced mode is not a safety function, rather it is a state change affecting the settings of the following safety function limits: joint position, joint speed, TCP pose limit, TCP speed, TCP force, momentum, power, stopping time, and stopping distance.</p> <p>Reduced mode is a means of parametrization of safety functions in accordance with ISO 13849-1. All parameter values need to be verified and validated as to whether they are appropriate for the robot application.</p>	Less than 1.8E-07	Robot

**Safeguard Reset**

Description	PFH <sub>D</sub>	Affects
When configured for Safeguard Reset and the external connections transition from low to high, the safeguard stop RESETS. Safety input to initiate a reset of safeguard stop safety function.	Less than 1.8E-07 Input to SF2	Robot

**3-Position Enabling Device INPUT**

Description	PFH <sub>D</sub>	Affects
<p>When the external Enabling Device connections are Low, a Safeguard Stop (SF2) is initiated. Recommendation: Use with a mode switch as a safety input. If a mode switch is not used and connected to the safety inputs, then the robot mode will be determined by the User Interface. If the User Interface is in:</p> <ul style="list-style-type: none"> <li>“running mode”, the enabling device will not be active.</li> <li>“programming mode”, the enabling device will be active. It is possible to use password protection for changing the mode by the User Interface.</li> </ul>	Less than 1.8E-07 Input to SF2	Robot



**Mode switch INPUT**

Description	PFH <sub>D</sub>	Affects
<p>When the external connections are Low, Operation Mode (running/automatic operation in automatic mode) is in effect. When High, mode is programming/ teach. Recommendation: Use with an enabling device, for example a UR e-Series Teach Pendant with an integrated 3-position enabling device.</p> <p>When in teach/program, initially both TCP speed and elbow speed will be limited to 250mm/s. The speed can manually be increased by using the pendant user interface “speed-slider”, but upon activation of the enabling device, the speed limitation will reset to 250mm/s.</p>	Less than 1.8E-07 Input to SF2	Robot

**Freedrive INPUT**

Description	PFH <sub>D</sub>	Affects
<p>Recommendation: Use with 3PE TP and/or 3 Position Enabling Device INPUT. When Freedrive INPUT is High, the robot will only enter Freedrive if the following conditions are satisfied:</p> <ul style="list-style-type: none"> <li>• 3PE TP button is not pressed</li> <li>• 3 Position Enabling Device INPUT either not configured or not pressed (INPUT Low)</li> </ul>	Less than 1.8E-07 Input to SF2	Robot

## 19.2. Table 2

**Description**

UR e-Series robots comply with ISO 10218-1:2011 and the applicable portions of ISO/TS 15066. It is important to note that most of ISO/TS 15066 is directed towards the integrator and not the robot manufacturer. ISO 10218-1:2011, clause 5.10 collaborative operation details 4 collaborative operation techniques as explained below. It is very important to understand that collaborative operation is of the APPLICATION when in AUTOMATIC mode.

**Collaborative Operation 2011 edition, clause 5.10.2**

Technique	Explanation	UR e-Series
Safety-rated monitored stop	Stop condition where position is held at a standstill and is monitored as a safety function. Category 2 stop is permitted to auto reset. In the case of resetting and restarting operation after a safety -rated monitored stop, see ISO 10218-2 and ISO/TS 15066 as resumption shall not cause hazardous conditions.	UR robots' safeguard stop is a safety-rated monitored stop, See SF2 on page 1. It is likely, in the future, that “safety-rated monitored stop” will not be called a form of collaborative operation.



Collaborative  
Operation 2011  
edition, clause  
5.10.3

Technique	Explanation	UR e-Series
Hand-guiding	<p>This is essentially individual and direct personal control while the robot is in automatic mode. Hand guiding equipment shall be located close to the end-effector and shall have:</p> <ul style="list-style-type: none"><li>• an Emergency Stop pushbutton</li><li>• a 3-position enabling device</li><li>• a safety-rated monitored stop function</li><li>• a settable safety-rated monitored speed function</li></ul>	<p>UR robots do not provide hand-guiding for collaborative operation. Hand-guided teach (free drive) is provided with UR robots but this is for programming in manual mode and not for collaborative operation in automatic mode.</p>

**Collaborative  
Operation 2011  
edition, clause  
5.10.4**

Technique	Explanation	UR e-Series
Speed and separation monitoring (SSM) safety functions	<p>SSM is the robot maintaining a separation distance from any operator (human). This is done by monitoring of the distance between the robot system and intrusions to ensure that the MINIMUM PROTECTIVE DISTANCE is assured. Usually, this is accomplished using Sensitive Protective Equipment (SPE), where typically a safety laser scanner detects intrusion (s) towards the robot system.</p> <p>This SPE causes:</p> <ol style="list-style-type: none"> <li>dynamic changing of the parameters for the limiting safety functions; or</li> <li>a safety-rated monitored stop condition.</li> </ol> <p>Upon detection of the intrusion exiting the protective device's detection zone, the robot is permitted to:</p> <ol style="list-style-type: none"> <li>resume the "higher" normal safety function limits in the case of 1) above</li> <li>resume operation in the case of 2) above</li> </ol> <p>In the case of 2) 2), restarting operation after a safety -rated monitored stop, see ISO 10218-2 and ISO/TS 15066 for requirements.</p>	<p>To facilitate SSM, UR robots have the capability of switching between two sets of parameters for safety functions with configurable limits (normal and reduced). See Reduced Mode on page 4. Normal operation can be when no intrusion is detected. It can also be caused by safety planes/ safety boundaries. Multiple safety zones can be readily used with UR robots. For example, one safety zone can be used for "reduced settings" and another zone boundary is used as a safeguard stop input to the UR robot. Reduced limits can also include a reduced setting for the stop time and stop distance limits - to reduce the work area and floorspace.</p>



Collaborative  
Operation 2011  
edition, clause  
5.10.5

Technique	Explanation	UR e-Series
Power and force limiting (PFL) by inherent design or control	How to accomplish PFL is left to the robot manufacturer. The robot design and/or safety functions will limit the energy transfer from the robot to a person. If any parameter limit is exceeded, a robot stop happens. PFL applications require considering the ROBOT APPLICATION (including the end-effector and workpiece(s), so that any contact will not cause injury. The study performed evaluated pressures to the ONSET of pain, not injury. See Annex A. See ISO/TR 20218-1 End-effectors.	UR robots are power and force limiting robots specifically designed to enable collaborative applications where the robot could contact a person and cause no injury. UR robots have safety functions that can be used to limit motion, speed, momentum, force, power and more of the robot. These safety functions are used in the robot application to thereby lessen pressures and forces caused by the end-effector and workpiece (s).