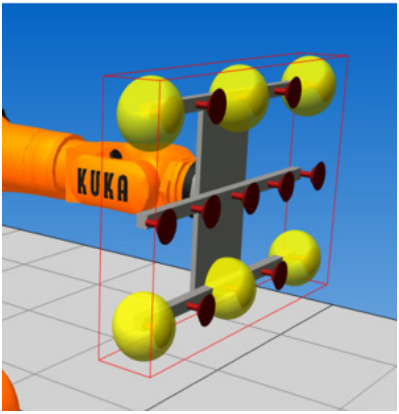
Quickguide

SafeOperation 3.x



KUKA Roboter
KSS Relase 8.x

KUKA Roboter GmbH
Zugspitzstraße 140
D-86165 Augsburg

Contents – SafeOperation

Software for the KUKA.SafeOperation option

Software requirements

- KSS V8.x or higher
- SafeOperation 3.x

User groups

- Safety maintenance
  This user group is protected by means of a password. Only safety maintenance personnel can modify the safety parameters.

- Safety recovery
  This user group is protected by means of a password. Safety recovery personnel can activate an existing safety configuration of the robot using an activation code.

These passwords must be changed after start-up and must not be disclosed to any operator.

Hardware

Hardware requirements

- KR C4 control cabinet
- PROFIsafe/SIB/extended SIB
- Reference switch, reference cable and actuating plate

Opening the configurator

The configuration menu can only be edited in the “Safety Maintenance” user group.

Mastering test/mastering monitoring

Description

The mastering test must be carried out in the following cases:

- Every time the controller is booted
- After mastering

The mastering test can be called in the following ways:

- External request via a signal and automatic call of the program MasRef_Main.src
- Internal request caused by remastering or booting and automatic call of the program MasRef_Main.src
- Manual selection of the program MasRef_Main.src

Programs for the mastering test

The following programs are used for the mastering test:

MasRef_Main.src

- is located in the **R1\System** folder
- checks whether a mastering test is required
- must be executed no later than 2 hours after the internal request
- calls the program MasRef_User.src that is used to address the reference position

```
1 DEF MasRefMain ( )
2 Start conditions for mastering reference
3
4 RunTest Group (1)
5
6 ;RunTest_Group (2)
7
8 ;RunTest_Group (3)
9
10 Finalize mastering reference
11 END
```

MasRef_USER.src

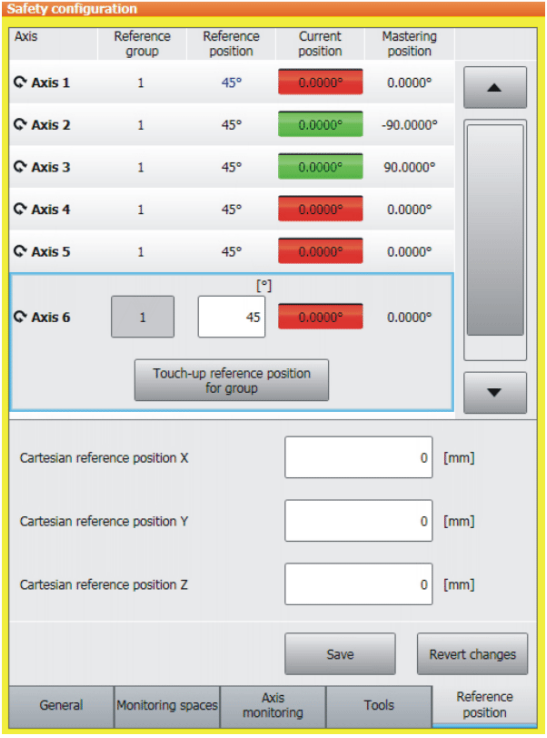
- is located in the **R1\Program** folder
- contains 6 subprograms
- 3 for moving to reference positions 1 to 3
- 3 for moving away from reference positions 1 to 3
- The program cannot be executed as it does not contain an INI line.
- The program must be tested by calling the main program MasRefMain().

```
1 DEF MasRef_USER ( )
2 END
3
4 GLOBAL DEF MASREFSTARTG1 ( )
5 Teach path and position for reference group 1
6
7 END
8
9 GLOBAL DEF MASREFBACKG1 ( )
10 Teach path back for reference group 1
11
12 END
13
14 GLOBAL DEF MASREFSTARTG2 ( )
15 Teach path and position for reference group 2
16
17 END
18
19 GLOBAL DEF MASREFBACKG2 ()
20 Teach path back for reference group 2
21
22 END
23
24 GLOBAL DEF MASREFSTARTG3 ( )
25 Teach path and position for reference group 3
26
27 END
28
29 GLOBAL DEF MASREFBACKG3 ( )
30 Teach path back for reference group 3
31
32 END
```

Reference position

The reference position must meet the following criteria:

- Min. +/- 5° away from the mastering position
- Axes must not be in a relative position of singularity
- It must not impede program execution
- Both proximity switch surfaces must be actuated (max. distance 2 mm)



Brake test

Description

The brake test must be carried out in the following cases:

- External request
- Brake test cycle time has elapsed (max. 46 h)
- After booting the controller
- Function test of the brake test
- Reconfiguration of the I/O drivers

The brake test can be called in the following ways:

- Automatically by calling the program BrakeTestReq as a subprogram
- Manually by calling the program BrakeTestReq

The brake test must be carried out at process velocity (T2, Aut, Ext) and at operating temperature.

Programs for the brake test

The following programs are used for the brake test:

BrakeTestReq.src

- is located in the **R1\TP\BrakeTest** folder
- checks whether a brake test is required
- must be executed no later than 2 hours after the internal request

```
1 DEF BrakeTestReq ( )
2 perform brake test
```

BrakeTestStart.src

- The program contains the position of the robot for the brake test and the path to this position
- If nothing is entered here, the robot performs the brake test at the current position

```
1 DEF BrakeTestStart ( )
2 INI
3 ;Teach here the motion to the start position of the brake
test
4 PTP Home vel=100% default
5 PTP Start1 cont vel=100% PDAT1 Tool[0] Base[0]
6 PTP Start2 cont vel=100% PDAT2 Tool[0] Base[0]
7 PTP BrakeTest_pos vel=100% PDAT3 Tool[0] Base[0]
8 END
```

BrakeTestBack.src

- The program contains the end position of the robot
- The robot moves to this position after the brake test
- If nothing is entered here, the robot remains at the current position after the brake test

```
1 DEF BrakeTestBack ( )
2 INI
3 ;Teach here the motion to the position after the brake test
4 PTP Start2 cont vel=100% PDAT2 TOOL[0] Base[0]
5 PTP Start1 cont vel=100% PDAT1 Tool[0] Base[0]
6 PTP Home vel=100% default
7 END
```

BrakeTestPark.src

- The program contains the parking position of the robot
- If a brake is identified as being defective, the robot can be moved to this position
- The parking position must be selected in a position where the robot can sag safely

```
1 DEF BrakeTestPark ( )
2 INI
3 ;Teach here the motion to the parking position. The parking
position is needed when the robot has failed the brake test.
4 PTP Start1 cont vel=100% PDAT1 Tool[0] Base[0]
5 PTP Park_pos vel=100% PDAT4 Tool[0] und Base[0]
6 END
```

Defining a brake test

The properties of the brake test can be adapted in the following files in the directory

C\KRC\ROBOTER\Config\User\Common\Mada\MotionDrivers :

mdrBrakeTest.ini

Variable	Description
BitfieldAxesActivated	Activation of the axes for the brake test Default: all axes activated
TravAngleAx	Range of motion for the robot axes Default: 10°
TravAngleEx	Range of motion for the external axes Default: 0° or 15 mm for linear axes
BrakeTestCycTime	Cycle time for the brake test Default: 46.0 h

Motiondrv.ini

The driver for the brake test BRAKE_TEST,mdrBRAKETest.o is activated by default. The brake test can be deactivated either by commenting out the driver or by setting the variable BitfieldAxesActivated to 0.
Caution: Any alteration requires consultation with KUKA Roboter GmbH

Brake self-test

The brake self-test provides a means of checking whether a defective brake is correctly detected by the brake test.

➔ Axis 3 must be detected as an error

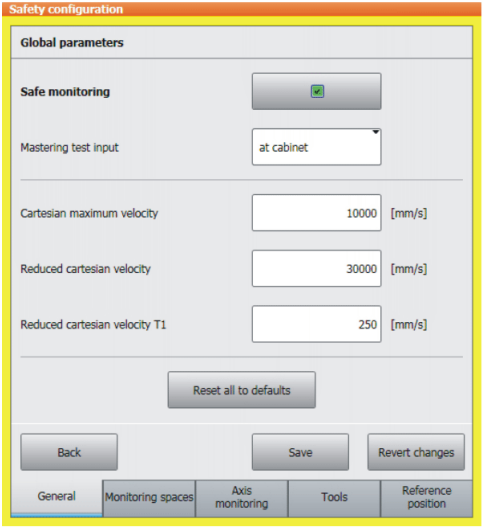
Procedure:

- Select and execute the program BrakeTestSelfTest.src in the directory C:\KRC\ROBOTER\KRC\R1\TP\SAFEROBOT.
- Confirm the message
- Press the Start key

Safety parameters/settings

Global parameters

The safety parameters can be modified in the **Configuration > Safety configuration** menu only by the “Safety Maintenance” user group.

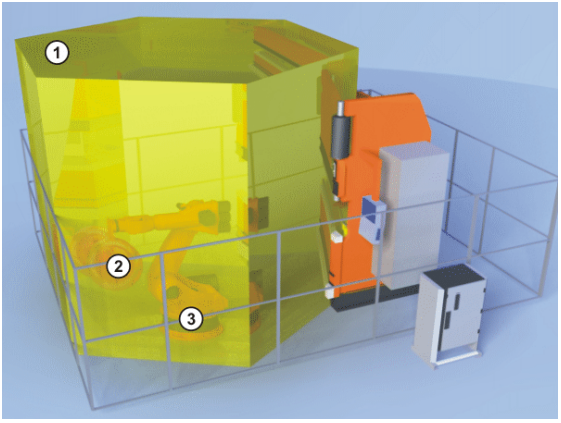


Parameter	Description
Safe monitoring	Activating/deactivating safe monitoring
Mastering test input	Connection of the reference switch
Cartesian maximum velocity	Maximum Cartesian velocity Default: 10000 mm/s
Reduced Cartesian velocity	Reduced Cartesian velocity Default: 30000 mm/s
Reduced Cartesian velocity T1	Reduced Cartesian velocity in T1 Default: 250 mm/s

Monitoring ranges

With SafeOperation 3.x, the cell area and 16 additional freely configurable monitoring spaces can be configured.

Cell area

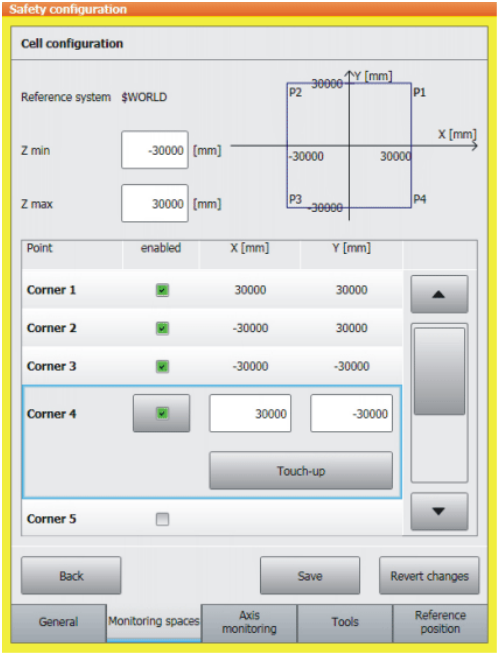


Number	Description
1	Cell area
2	Spheres on tool
3	Robot

Characteristics

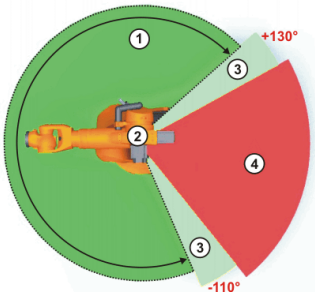
- 3 .. 10 corners must be used
- The cell area can be limited upward and downward
- The cell area is freely configurable
- The shape must be a convex polygon
- Can be created numerically or by “Touch-up”
- Is permanently monitored
- Is always active
- Is monitored by means of spheres around the tool

Configuration



Parameter	Description
Reference system	Always $WORLD
Zmin/max	Upward and downward limitation Default: ±30000 mm
enabled	Activation of the corners
X/Y [mm]	Coordinates of the corners Default: ±30000 mm
Touch-up	Saving of the current robot position as a corner

Axis-specific space

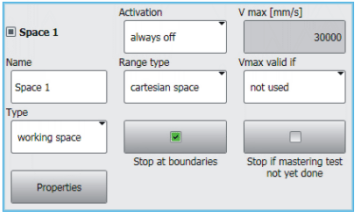


Characteristics

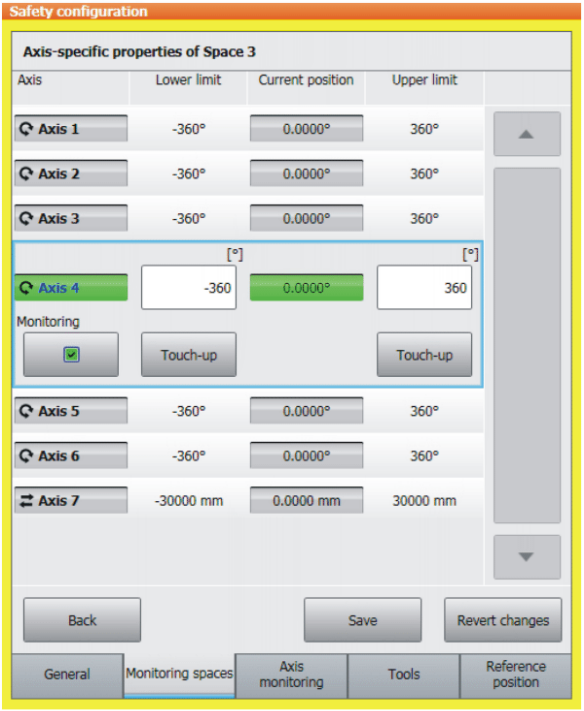
- Configurable for 6 robot axes and 2 external axes
- Space-specific velocity per monitoring space
- Can be a workspace or a protected space
- Can be activated using safe inputs
- Status reporting using safe outputs

Number	Description
1	Workspace
2	Robot
3	Braking distance
4	Protected space

Configuration

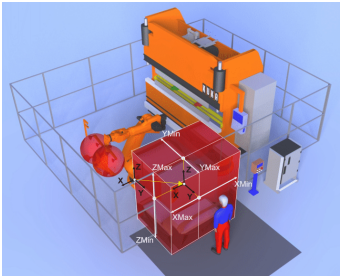


Parameter	Description
Activation	always off/always active/by input
Name	Name of the monitoring space
Range type	Cartesian space/Axis space
Vmax valid if	Validity range of Vmax
Type	Workspace/Protected space
Properties	Configuration of the axis values



Parameter	Description
Lower limit	Lower axis limits
Upper limit	Upper axis limits
Touch-up	Saving of the current axis position
Monitoring	Activating/deactivating monitoring

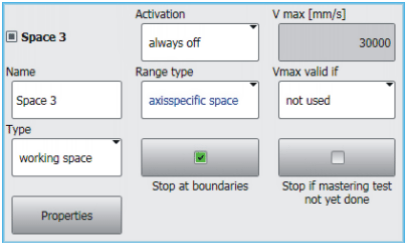
Cartesian space



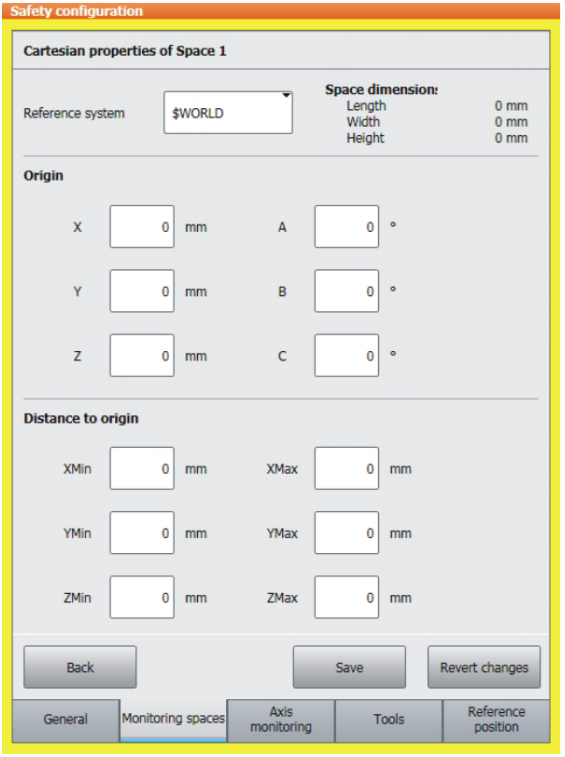
Characteristics

- Definition as a Cartesian cuboid
- Can be a workspace or a protected space
- Space-specific Caresian velocity per monitoring space relative to the safe TCP
- Validity inside or outside
- Can be activated using safe inputs
- Status reporting using safe outputs

Configuration



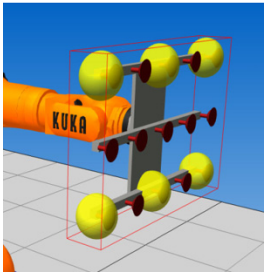
Parameter	Description
Activation	always off/always active/by input
Name	Name of the monitoring space
Range type	Cartesian space/Axis space
Vmax valid if	Validity range of Vmax
Type	Workspace/Protected space
Properties	Configuration of the Cartesian values



Parameter	Description
Reference system	Reference system for monitoring space
Origin X, Y, Z	Position of the origin
Origin A, B, C	Rotational offset relative to the reference system
Distance to origin	Dimensions relative to the origin

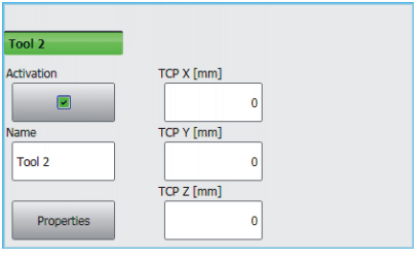
Tools

Characteristics

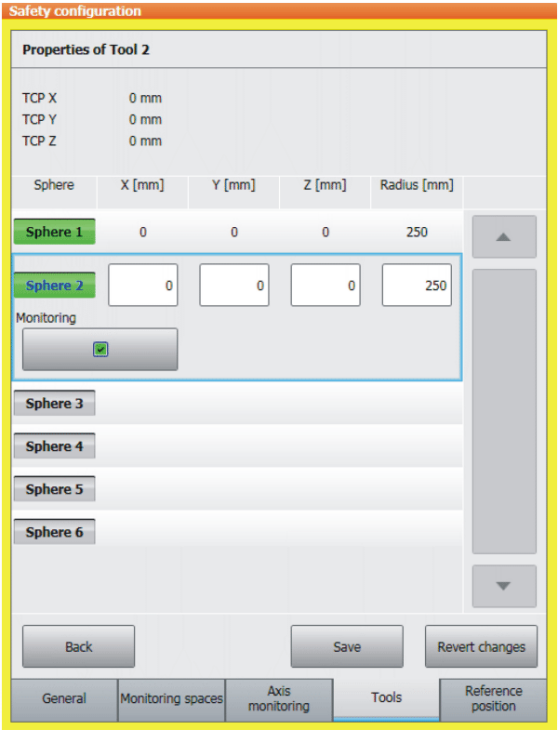


- A maximum of 16 tools can be configured
- With one TCP per tool
- Cartesian velocities are monitored at the TCP
- 6 monitoring spheres per tool
- The spheres are monitored against the Cartesian monitoring spaces and should therefore completely enclose the tool
- Each tool has one safe input and one safe output

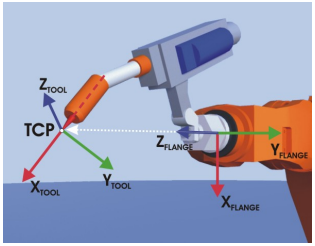
Configuration



Parameter	Description
Activation	Activation of the tool
Name	Tool name
Properties	Configuration of the spheres
TCP X, Y, Z	Position of the TCP relative to the flange coordinate system



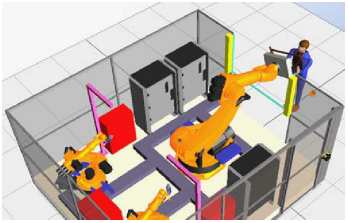
Parameter	Description
Sphere	Selection of a sphere
X, Y, Z	Position of the sphere center point relative to the flange coordinate system
Radius	Sphere radius
Monitoring	Activating/deactivating a sphere



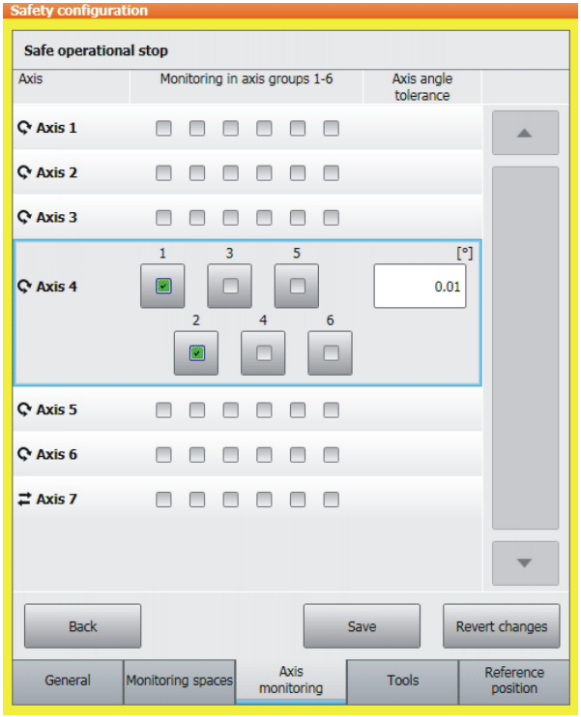
- The “Safe TCP” of the monitored tool can be identical to that of the kernel system
- The X, Y, Z coordinates of the TCP define the distance from the flange center point to the TCP
- The X, Y, Z coordinates of the sphere center point define the distance from the flange center point to the center point of the given sphere
- A defined minimum value for the radius

is derived from the radius of the given sphere about the sphere center point and the global velocity; the radius must not be less than this value.

Standstill monitoring



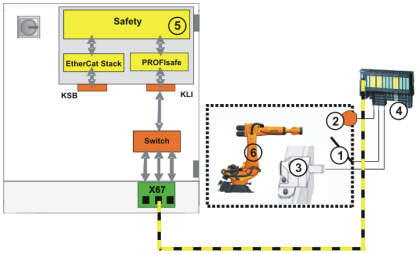
- Safe standstill of the axes can be monitored
- Up to 6 axis groups can be configured
- Can be activated using one predefined safe input in each case
- The standstill window can be configured



Parameter	Description
Axis	Configurable axes
Monitoring in axis groups 1 - 6	Allocation of the axes to axis groups
Axis angle tolerance	Tolerance for configuration of the standstill window

Interfaces

PROFIsafe interface



ITEM	Description
1	Safety gate
2	EMERGENCY STOP
3	Reference switch
4	Safety PLC
5	Safety software stack
6	Manipulator

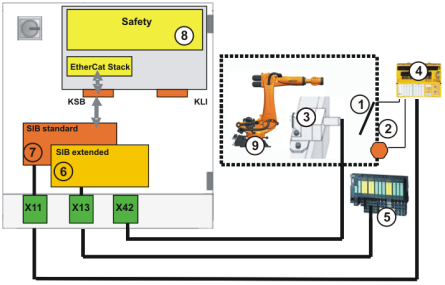
Characteristics

- 48 safe inputs and 48 safe outputs
- Configuration is carried out via WorkVisual or directly on the robot controller
- The function of the inputs and outputs is **permanently defined**
- Data transmission is carried out via PROFINET / PROFIsafe

Procedure

- Select **Configuration** > **Safety configuration** in the main menu
- Select **Hardware options**
- Under **Customer interface**: select the option **Profisafe**
- Under **Input signal for peripheral contactor (US2):** select the switching mode of the safety-oriented 24 V power supply US2.
- Under **Operator safety acknowledgement:** select operator safety acknowledgement

X13 and Extended SIB interface



ITEM	Description
1	Operator safety
2	EMERGENCY STOP
3	Reference switch
4	Safety switching device for connection of robot safety
5	Safety PLC
6	Extended SIB for the SafeOperation option
7	Standard SIB for robot safety
8	Safety software stack
9	Manipulator

Characteristics

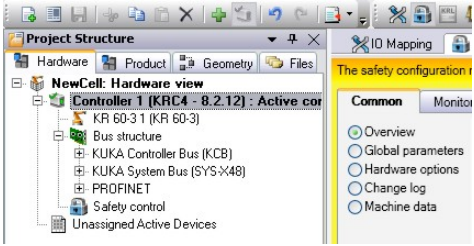
- 8 safe inputs and 8 safe outputs
- The function of the inputs and outputs is permanently defined and implemented in dual-channel configuration
- The corresponding test output must be used for switching a safe input
- Safe outputs are isolated taps on the SIB board
- Only 1 monitoring tool

Procedure

- Select **Configuration** > **Safety configuration** in the main menu
- Select **Hardware options**
- Under **Customer interface**: select the option **SIB, SIB extended**
- Under **Input signal for peripheral contactor (US2)**: select the switching mode of the safety-oriented 24 V power supply US2.
- Under **Operator safety acknowledgement:** select operator safety acknowledgement

Configuration in WorkVisual

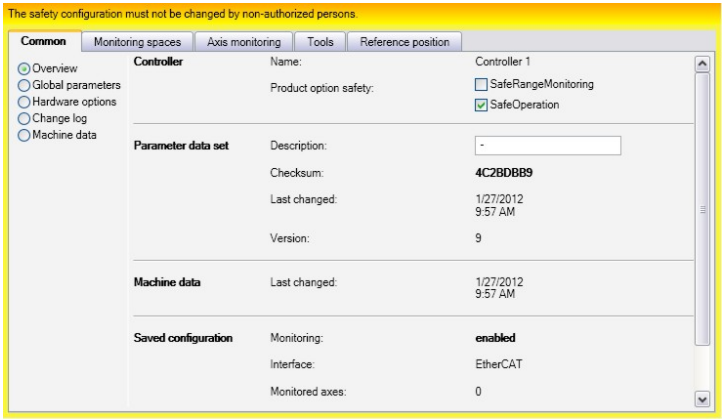
Creating the safety configuration



- Transfer a project from the robot controller to WorkVisual (or create a new one)
- Activate the controller
- Open the safety controller unter **Devices** in the project structure
- or select  in the toolbar
- An overview of the safety configuration is opened (see Page 23)
  Edit the safety configuration
- Save and deploy

	The parameters to be set in WorkVisual are identical to those existing on the HMI (see Pages 9 - 19).

	When deploying the project after editing in WorkVisual, it must be ensured that the option configured in WorkVisual is also installed on the controller.



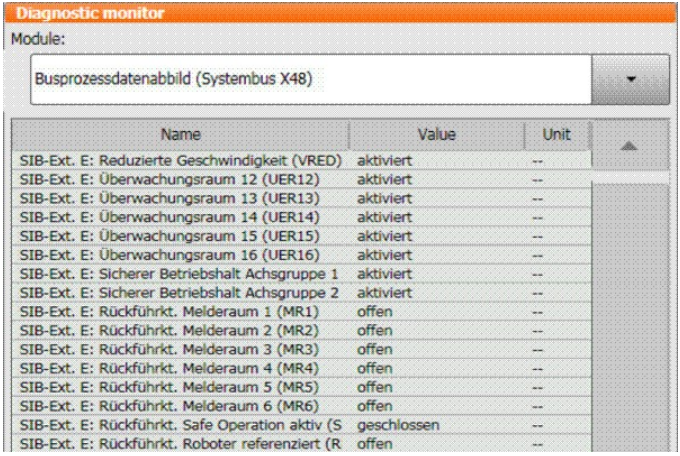
Parameter	Description
Overview	General information and activation of the SafeOperation option
Global parameters	Global parameters of the safety configuration
Hardware options	Hardware settings
Change log	Automatic logging of the changes
Machine data	Machine data in the safety configuration
Monitoring spaces	Configuration of the Cartesian monitoring spaces
Axis monitoring	Configuration of the axis-specific monitoring spaces
Tools	Configuration of the tools
Reference position	Configuration of the reference position

After deployment of the project from WorkVisual, the safety configuration must be confirmed in the “Safety Maintenance” user group.

Diagnostic monitor

Characteristics

- Makes it possible to display diagnostic data concerning software modules of the kernel system
- Errors in the hardware or configuration can be localized
- There are two modules for SafeOperation: bus process data image [system bus X48] or bus process data image [Profinet]
- The diagnostic monitor can be displayed on the HMI or also in WorkVisual



Procedure

- In the main menu, select Diagnosis > Diagnostic monitor
- Select the **Bus process data image***[system bus X48]* or *[Profinet]* in the Module box
- Evaluate the safe input and output data

CRR mode (safe robot retraction)

If the robot has violated a monitoring function and been stopped by the safety controller, it can only be moved out of the violated area in CRR mode. The motion velocity in CRR mode corresponds to the safely reduced Cartesian velocity for T1 mode defined in the safety configuration.
In CRR mode, the robot can be moved to any position.
No stop is triggered if it passes through other monitoring limits. The velocity monitoring functions remain active in CRR mode.