KUKA College Training Documentation

KUKA Roboter GmbH

Safety Start-Up SafeRangeMonitoring 3.x

Target Group: Safety Maintenance & Robot Service Technicians

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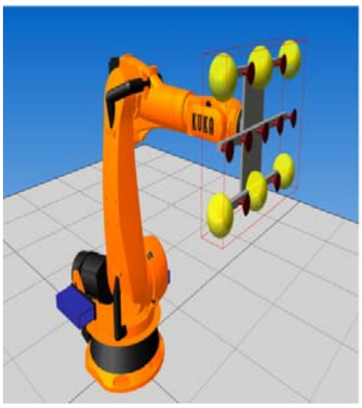
Version: SE Sicherheitsinbetriebnahme SafeRangeMonitoring 3.x V1 en



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Other functions not described in this documentation may be operable in the controller. The user has no claims to these functions, however, in the case of a replacement or service work.

We have checked the content of this documentation for conformity with the hardware and software described. Nevertheless, discrepancies cannot be precluded, for which reason we are not able to guarantee total conformity. The information in this documentation is checked on a regular basis, however, and necessary corrections will be incorporated in the subsequent edition.

Subject to technical alterations without an effect on the function.

Translation of the original documentation

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Contents

1 Safety – SafeRangeMonitoring

1.1 Overview of safety

The following contents are explained in this training module:

- Safety instructions for personnel
- System safety instructions

1.2 Safety instructions for personnel

Safety instructions for personnel

All persons working with the robot system must have read and understood the robot system documentation, including the safety chapter.

Fig. 1-1: Service symbols

A KUKA.SafeRangeMonitoring start-up training course is recommended for all persons working on a robot system with KUKA.SafeRangeMonitoring.

Start-up, maintenance and repair work on KUKA.SafeRangeMonitoring may only be carried out by trained personnel.

The safety parameters of KUKA.SafeRangeMonitoring may only be set and modified by authorized personnel. No other persons may be given access to the safety parameters.

The password for the “Safety Maintenance / Safety Recovery” user group must be changed before start-up and must only be communicated to authorized personnel.

1.3 System safety instructions

System safety instructions

During system planning, the safety functions must be planned. Required safety functions that are not implemented with SafeRangeMonitoring must be implemented using different safety measures.

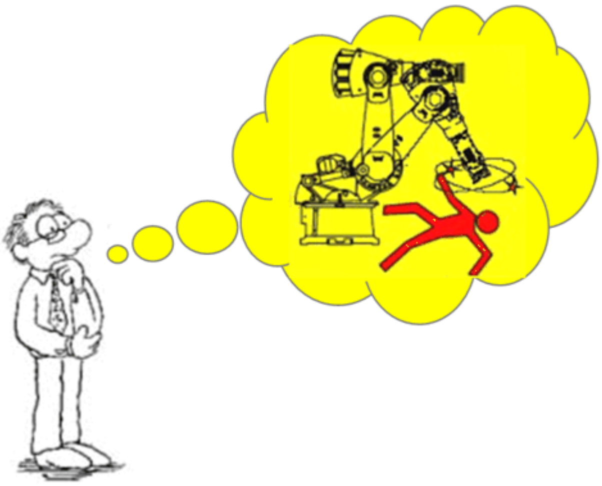


Fig. 1-2: Robot without safety equipment

Serious system errors, severe damage to the robot and injury or death can result from not carrying out the risk analysis. Risk analysis must be carried out before start-up and after any safety-relevant modification.

- Define axes that must be tested in the brake test.
- Determine brake test cycle time.
- Determine axis-specific limit value of maximum velocity for rotational and linear axes.
- Define axis-specific monitoring spaces.

> **DANGER** Safe monitoring with SafeRangeMonitoring is deactivated by default. The safety monitoring functions can only be configured or modified if safe monitoring is activated. If safe monitoring is deactivated, the configured safety monitoring functions are inactive.

Serious damage and injury or death can result from incorrect configuration. Consequently, SafeRangeMonitoring may not be operated until after safety acceptance has been carried out in accordance with the checklists. The checklists must be completed fully and confirmed in writing.

Before the robot is moved, it must be ensured that the correct machine data are on the RDC and confirmed.

Modifying the machine data may deactivate monitoring functions. Machine data may only be modified by authorized personnel.

2 Description of SafeRangeMonitoring 3.x

2.1 Overview of product description

The following contents are explained in this training module:

- Definition of SafeRangeMonitoring
- Terms
- Variants
- Areas of application
- Functional principle and interface
- Safe outputs
- Hardware and software
- Safe robot retraction
- Start-up mode
- User groups

2.2 Definition

What is SafeRangeMonitoring?

SafeRangeMonitoring is an option with software and hardware components that offers the following functions:

- Safe monitoring of a maximum of 16 user-defined, axis-specific monitoring spaces
- Safe monitoring of the maximum rotational and linear velocities
- Safe stop via safety controller
- Connection to a higher-level controller, e.g. to a safety PLC
- Safe outputs for status messages of the monitoring functions
- Creation and editing of the safety configuration on the robot controller or in WorkVisual.

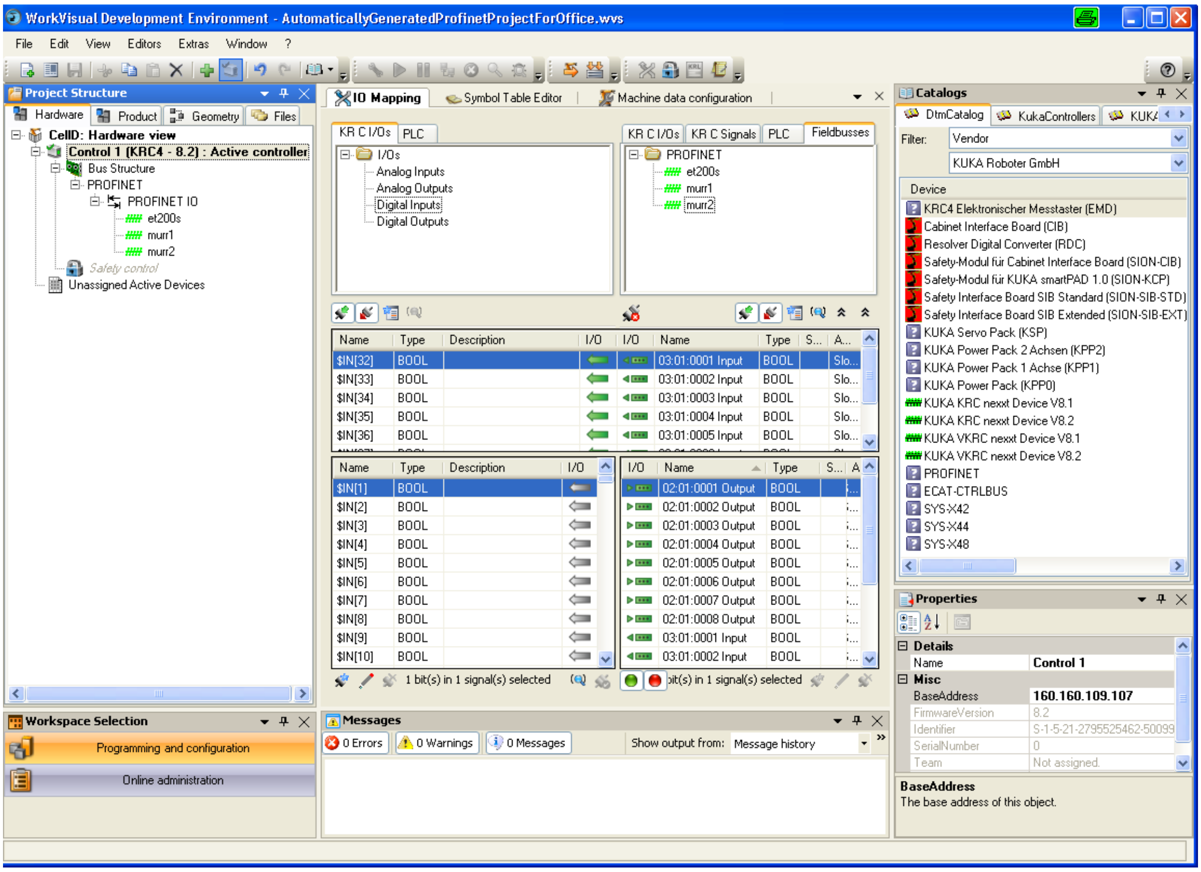


Fig. 2-1: WorkVisual graphical user interface

2.3 Terms used

Term	Description
Axis range	Range of each axis, in degrees or millimeters, within which it may move. The axis range must be defined for each axis.
Axis limit	An axis has 2 axis limits which define the axis range. There is an upper axis limit and a lower axis limit.
Stopping distance	Stopping distance = reaction distance + braking distance The stopping distance is part of the danger zone.
Workspace	Monitoring space that the defined axes must not leave. The axes or the tool must always move within the limits of the workspace.
Brake test	In the brake test, the robot controller checks the functionality and wear of the brakes.
Brake test cycle time	When this time has elapsed, the robot controller initiates a brake test. This cycle time is a parameterizable value.
Mastering test	The mastering test is used to check whether the current position of the robot and the external axes corresponds to a reference position.
CRR	Controlled robot retraction Operating mode for retracting the robot in the case of a workspace violation (=> #T1).

Term	Description
Alarm space	Monitoring space into and out of which the robot can move without being stopped. Only the corresponding safe output is used for the alarm.
Monitoring time	During the monitoring time, the user is prompted to perform a mastering test or the brake test.
Parking position	If a brake is identified as being defective, the robot can be moved to the parking position. The parking position must be selected in a position where the robot can sag safely.
PROFINET	PROFINET is an Ethernet-based interface for connecting a PLC or periphery to the robot controller.
PROFIsafe	PROFIsafe is a PROFINET-based safe interface for connecting a safety PLC to the robot controller. (PLC = Controller, robot controller = Device)
RDC	Resolver Digital Converter card for position evaluation and digitization of the position values.
Reference group	A reference group contains the axes of a kinematic system that are required for moving to a reference position and are to be subjected to safe monitoring.
Reference position	The reference position is a Cartesian position to which the robot moves during the mastering test.
Reference stop	Stop that is triggered if the mastering test has not been carried out. The reference stop can be activated for monitoring spaces.
Reference switch	A reference switch is necessary for carrying out the mastering test. The reference switch confirms the reference position.
Protected space	Monitoring space that the defined axes must not enter. The axes must always move outside the limits of the protected space.
SafeRangeMonitoring	KUKA option for industrial robot safety, but only for axis-specific monitoring spaces and reference run.
SIB	Safety Interface Board. There are two variants: ■ Standard SIB – robot safety – X11 ■ Extended SIB – SafeOperation or SafeRangeMonitoring – X13
Safety STOP 0	A stop that is triggered and executed by the safety controller. The safety controller immediately switches off the drives and the power supply to the brakes. **Note**: This stop is called safety STOP 0 in this document.

Term	Description
Safety STOP 1	A stop that is triggered and monitored by the safety controller. The braking process is performed by the non-safety-oriented part of the robot controller and monitored by the safety controller. As soon as the manipulator is at a standstill, the safety controller switches off the drives and the power supply to the brakes. **Note**: This stop is called safety STOP 1 in this document.
Safety STOP 2	In the case of a STOP 2, the drives are not deactivated and the brakes are not applied. The robot is braked with a dynamic braking ramp.
Monitoring space	A monitoring space is axis-specific and can be defined as a workspace or protected space.
WorkVisual	Offline configuration tool for the KR C4

2.4 Areas of application for SafeRangeMonitoring

Areas of application

- Human-robot cooperation
- Replacement of conventional axis range monitoring systems

Axis range monitoring

The original axis range monitoring functions of axes 1 to 3 can be replaced.

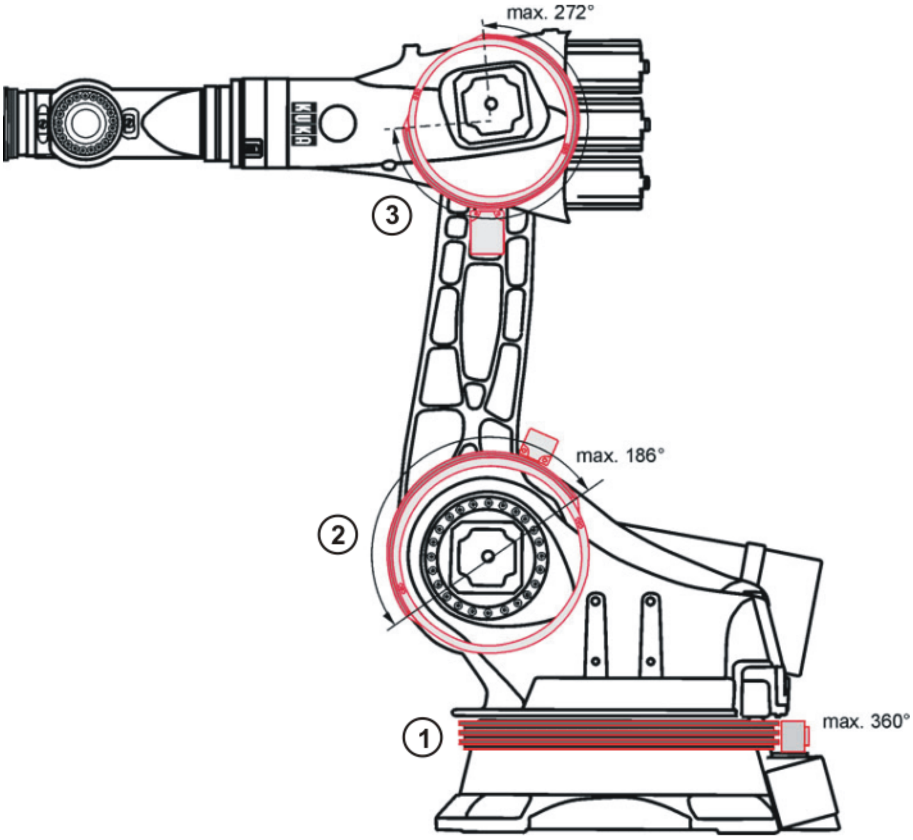


Fig. 2-2: Axis range monitoring for axes 1 to 3

In contrast to conventional axis range monitoring, it is now possible to monitor all axes of the robot.

2.5 Functional principle and interface

Functional principle

The components of the industrial robot can only move within the limits that have been configured and activated.

The safety controller monitors the industrial robot by means of the safety parameters that have been set. If a component of the industrial robot violates a monitoring limit or a safety parameter, the robot and external axes (optional) are stopped.

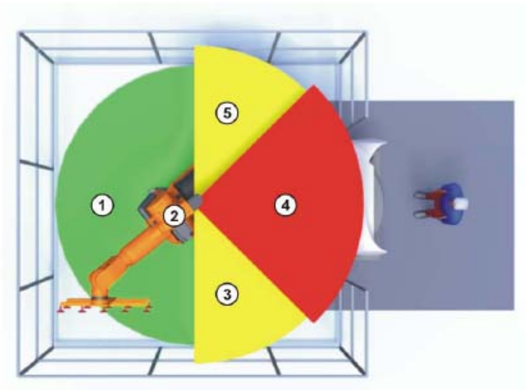


Fig. 2-3

Item	Description
1	Workspace
2	Robot
3	Stopping distance
4	Axis-specific protected space
5	Stopping distance

Stop reactions

Stop reaction	Description	Example
Safety stop 0	The stop is triggered if a monitoring function is already activated and the robot then exceeds the monitoring limit.	Robot exceeds the activated limit value of a protected space in Automatic mode.

Interfaces for SafeRangeMonitoring

The safe I/Os of the interfaces can be used, for example, to activate a protected space or signal a violation of safety monitoring functions.

Two different interfaces are available for connection to a higher-level controller.

- PROFINET/PROFIsafe
- Interface X13 via Extended SIB

2.6 SafeRangeMonitoring option

Components

The SafeRangeMonitoring option includes:

- The software option SafeRangeMonitoring
- The hardware reference switch module

A reference switch module consists of the following components:

- Inductive reference switch XS Ref
- Actuating plate

- Reference cable X42 - XS Ref

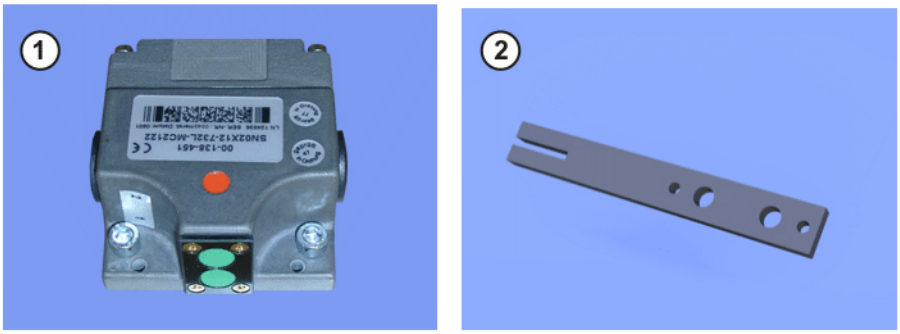


Fig. 2-4: Reference group hardware components

1	Inductive reference switch	2	Actuating plate

Reference switch connection

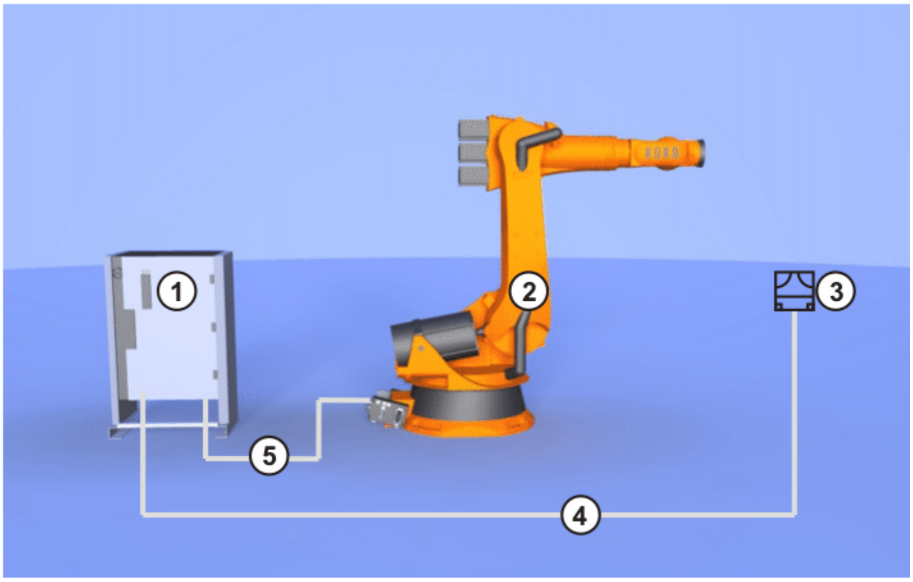


Fig. 2-5: Overview of connecting cables

This example shows the reference switch connection to the control cabinet.

Item	Description
1	Robot controller
2	Robot
3	Reference switch XS Ref
4	Reference cable X42 - XS Ref (maximum cable length 50 m)
5	Data cable X21

Hardware overview

Only 1 reference switch can be connected to the robot controller.

The X42 interface must be present on the controller (not included in the reference group option, must be taken into consideration when ordering the controller or retrofitted; art. no.: 00 180 300).

Alternatively, the reference switch can be connected to the safety PLC.

If multiple reference groups are required, a safety PLC is essential. The reference switches must be connected to the safety PLC and their signals transmitted via PROFIsafe.

2.7 Safe robot retraction

CRR mode

The operating mode CRR (**C**ontrolled **R**obot **R**etraction):

If the robot has violated a monitoring space and been stopped by the safety controller, it can only be moved out of the violated area in CRR mode.

CRR mode also only appears if a monitoring space has been violated.

The motion velocity in CRR mode corresponds to that in T1 mode.

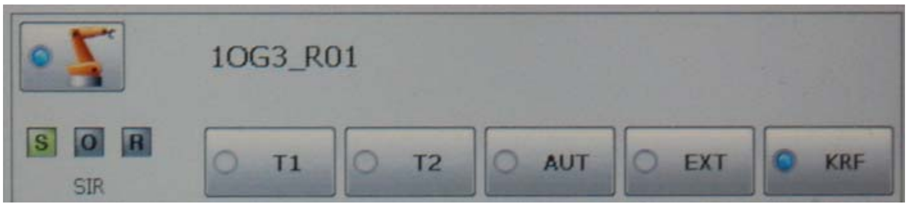
In CRR mode, the robot can be moved to any position. No stop is triggered if it passes through other monitoring limits. The velocity monitoring functions remain active in CRR mode.

Procedure

> If the operating mode is changed during operation, the drives are immediately switched off. The industrial robot stops with a safety stop 2.

1. On the smartPAD, turn the switch for the connection manager. The connection manager is displayed.

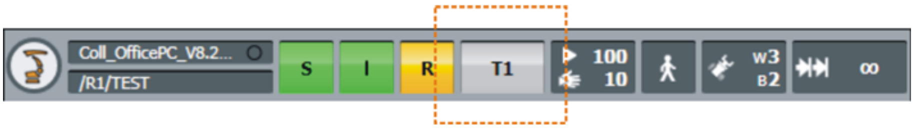
2. Select CRR mode.



3. Return the switch for the connection manager to its original position.

   The selected operating mode T1 is displayed in the status bar of the smartPAD.

   CRR cannot be displayed.



2.8 Activating Start-up mode

What is Start-up mode?

The industrial robot can be set to Start-up mode via a menu item of the smartHMI user interface. In this mode, the manipulator can be moved in T1 in the absence of the safety periphery.

If a connection to a higher-level safety system exists or is established, the robot controller prevents or terminates Start-up mode.

DANGER External safeguards are disabled in Start-up mode.

Active monitoring functions

The following monitoring functions remain active:

- Monitoring of maximum axis velocity
- Workspace monitoring functions that are configured as **always active**
- Velocity monitoring in T1

Activating Start-up mode

Preconditions:

- The controller must not be communicating with a higher-level controller.
- The “Expert” user group must be logged on.

Procedure:

1. Start-up mode can be activated and deactivated by means of the menu item **Configuration** > **Start-up** > **Service** > **Start-up mode**.

2.9 Selecting a user group

User groups for safety settings

The following user groups are relevant for the safety configuration of the robot:

- **Safety Recovery**

  This user can activate an existing safety configuration of the robot using an activation code. If no safe option, e.g. KUKA.SafeOperation or KUKA.SafeRangeMonitoring, is being used, the safety recovery technician has more extensive rights. In this case he is authorized, for example, to configure the standard safety functions.

  This user group is protected by means of a password.

  The factory setting for the password is **kuka**.

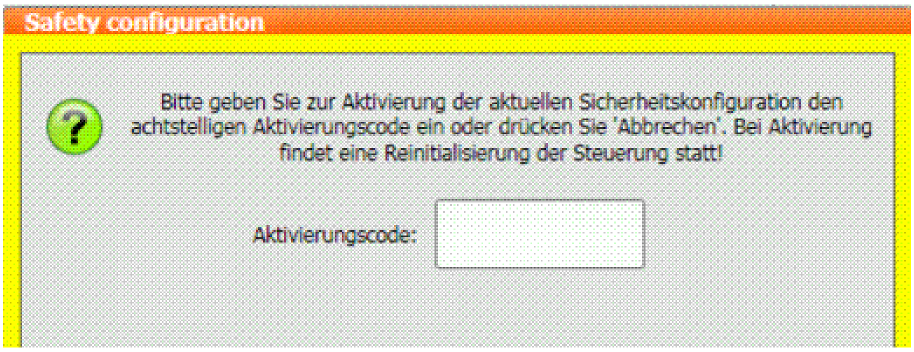


Fig. 2-6: Input box for activation code

- **Safety Maintenance**

  User group for the start-up technician. This user can edit the safety configuration and make safety-relevant changes.

  This user group is also protected by means of a password of its own.

  The factory setting for the password is **kuka**.

Safety Maintenance / Safety Recovery

The password for the “Safety Maintenance” and “Safety Recovery” user groups must be changed before start-up and must only be communicated to authorized personnel.

The safety maintenance technician must be specially trained in the configuration of safety functions. For this, we recommend training courses at KUKA College.

Procedure for changing user group

1. Select **Configuration** > **User group** in the main menu. The current user group is displayed.
2. To switch to a different user group: Press **Login...**. Select the user group **Safety maintenance**.
3. Enter password and confirm with **Log-on**.

3 Installing and activating SafeRangeMonitoring 3.x

3.1 Overview of installation and activation

The following contents are explained in this training module:

- Installing software
- Operating the SafeRangeMonitoring configuration tool
- Defining the PROFIsafe interface
- Defining the X13 interface and Extended SIB
- Activating safe monitoring
- Standards and checklists used

3.2 Installing SafeRangeMonitoring

The technology package

To work with SafeRangeMonitoring, the optional software must be installed.

The KUKA.SafeRangeMonitoring 3.x software can only be installed on KUKA System Software 8.x or VW System Software 8.x; it must be ensured that both versions match.

Preconditions

- Reference module is installed and connected.
- Software is on the KUKA.USBData stick.
- No program is selected.
- T1 or T2 operating mode
- “Expert” user group

⚠ CAUTION	KUKA.SafeRangeMonitoring must not be installed on a robot controller together with KUKA.SafeOperation.

Procedure

1. Plug in USB stick with the software.
2. Select **Start-up** > **Install additional software** in the main menu.
3. Press **New software**. If a software package that is on the USB stick is not displayed, press **Refresh**.
4. Select the entry **SafeRangeMonitoring** and press **Install**. Reply to the request for confirmation with **Yes**. The files are copied onto the hard drive.
5. Repeat step 4 if another software package is to be installed from this stick.
6. Remove USB stick.
7. It may be necessary to reboot the controller, depending on the additional software. In this case, a corresponding prompt is displayed. Confirm with **OK** and reboot the robot controller. Installation is resumed and completed.

3.3 Operating the SafeRangeMonitoring configuration tool

Operator control menu

Every modification to the safety configuration and every saving operation is automatically logged. The log can be displayed.

The safety-relevant machine data can be displayed.

The machine data can be checked.

The hardware can be defined.

Overview, operation

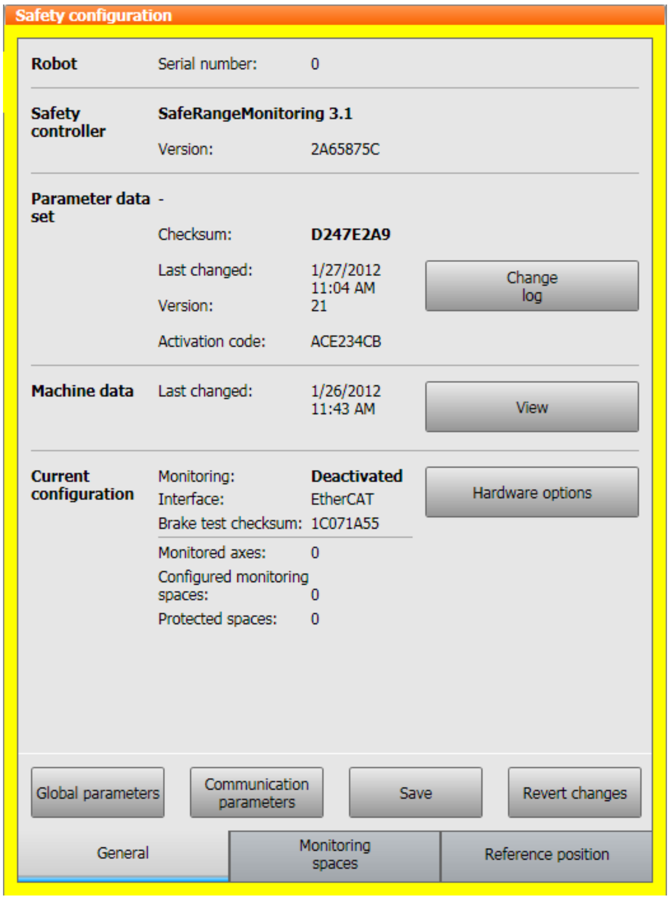


Fig. 3-1: Overview of the SafeRangeMonitoring configuration tool

Button	Description
Change log	The log of changes to the safety configuration is displayed.
View	The safety-relevant machine data are displayed.
Hardware options	The hardware settings can be defined. **Note**: Further information is contained in the Operating and Programming Instructions for System Integrators.
Global parameters	The global parameters of the safety configuration can be defined.
Communication parameters	The Profinet safety ID can be checked/changed.
Robot	Serial number of the robot
Safety controller	■ Version of SafeRangeMonitoring ■ Safety controller version (internal)
Parameter data set	■ Checksum of the safety configuration ■ Time stamp of the safety configuration (date and time last saved) ■ Safety configuration version ■ Activation code of the safety configuration
Machine data	Time stamp of the safety-relevant machine data (date and time last saved)

Button	Description
Current configuration	■ State of the safe monitoring (activated or deactivated) ■ Name of the active bus system ■ Checksum of the brake test configuration ■ Number of velocity-monitored axes ■ Number of monitoring spaces ■ Number of protected spaces ■ Number of safe tools
Save	Saves and activates the safety configuration for the robot.
Reset changes	Discard changes

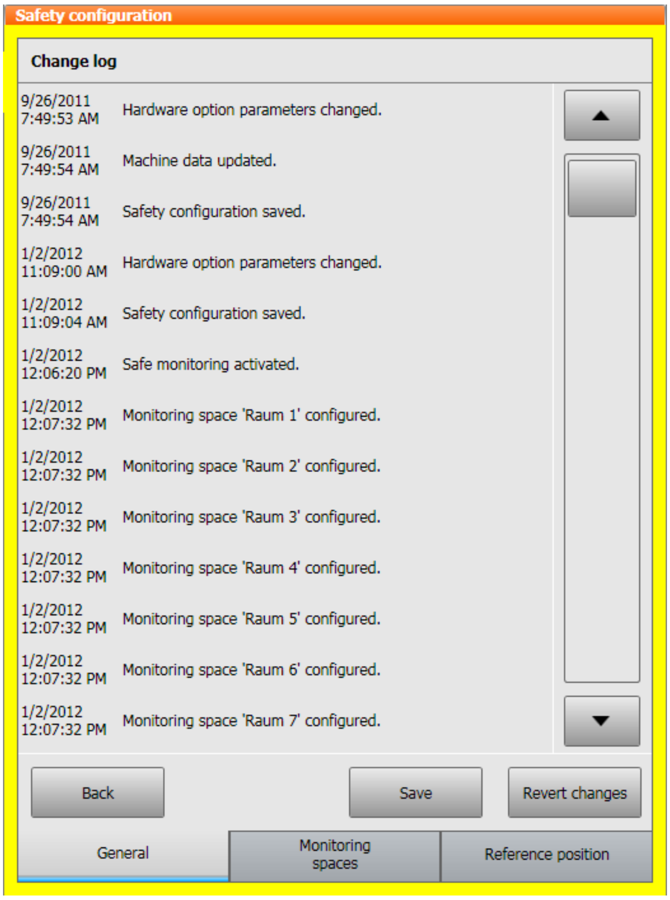


Fig. 3-2: Displaying the change log

Button	Description
Back	Back to the tab.
Save	Saves and activates the safety configuration for the robot.
Reset changes	Discard changes

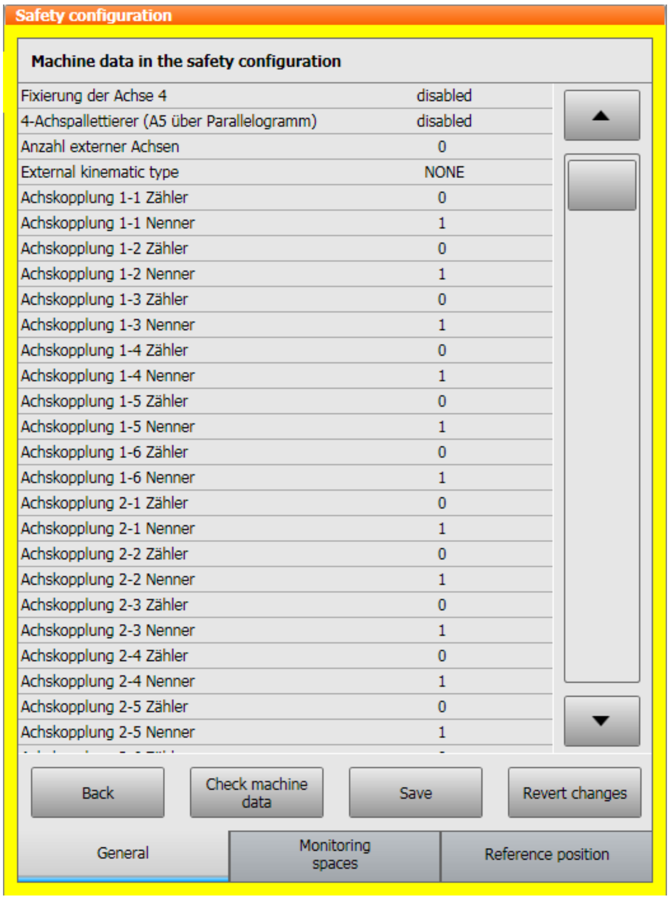


Fig. 3-3: Displaying machine data

Button	Description
Back	Back to the tab.
Check machine data	It is possible to check whether the machine data of the safety configuration are up to date.
Save	Saves and activates the safety configuration for the robot.
Reset changes	Discard changes

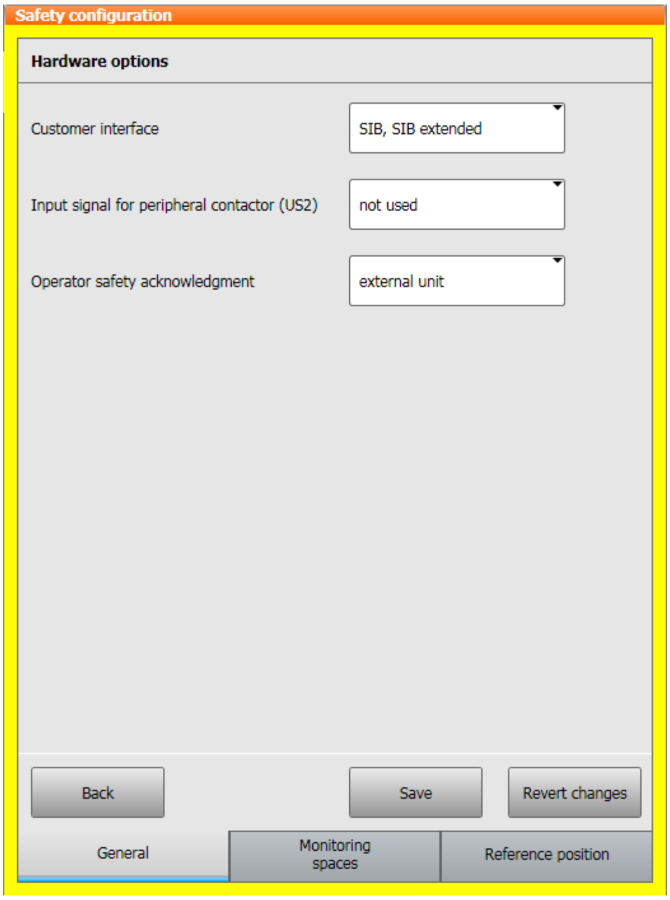


Fig. 3-4: Hardware options

Button	Description
Customer interface	Selection of the interfaces for transferring the safe inputs and outputs. **Possible settings:** Profisafe; SIB; SIB, SIB extended; SIB with operating mode output; SIB with operating mode output, SIB extended
Input signal for peripheral contactor (US2)	Switching of the safety-controlled 24 V power supply US2. **Possible settings:** Deactivated; By external PLC; By KRC
Operator safety acknowledgement	Acknowledgement of the operator safety. **Possible settings:** By acknowledgement button; By external unit
Back	Back to the tab.
Save	Saves and activates the safety configuration for the robot.
Reset changes	Discard changes

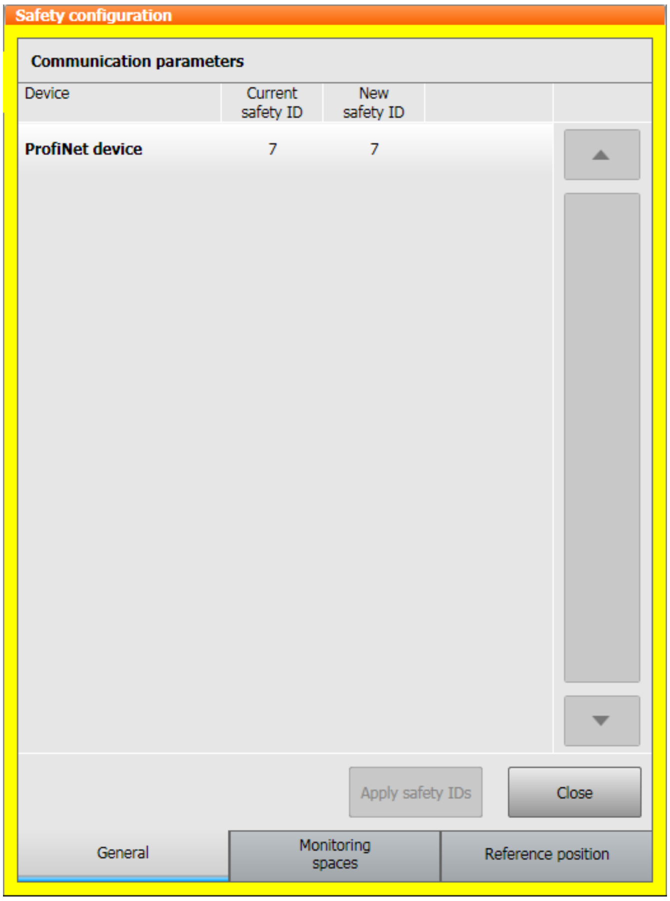


Fig. 3-5: Device management

Button	Description
Apply safety IDs	Once the ID has been changed, it can be applied. **Note**: Change the safety ID after configuration of the safety PLC; otherwise leave set to 7
Close	Closes the device management window

Procedure

Preconditions

- User group “Safety maintenance”
- T1 or T2 operating mode

General information

1. Select **Configuration** > **Safety configuration** in the main menu.
   The safety configuration opens with the **General** tab.

Display the change log

1. Select **Configuration** > **Safety configuration** in the main menu.
2. Press **Change log**.

View machine data

1. Select **Configuration** > **Safety configuration** in the main menu.
2. Press **View**.

Check communication parameters

1. Select **Configuration** > **Safety configuration** in the main menu.
2. Press **Communication parameters**.

Set hardware options

1. Select **Configuration** > **Safety configuration** in the main menu.
2. Press **Hardware options**.

3.4 Defining the PROFIsafe interface

Connection to a safety PLC

- There are 48 safe outputs available.
- Configuration is carried out via WorkVisual or directly on the robot controller.
- The function of the outputs is permanently defined.
- Data transmission is carried out via PROFINET / PROFIsafe.

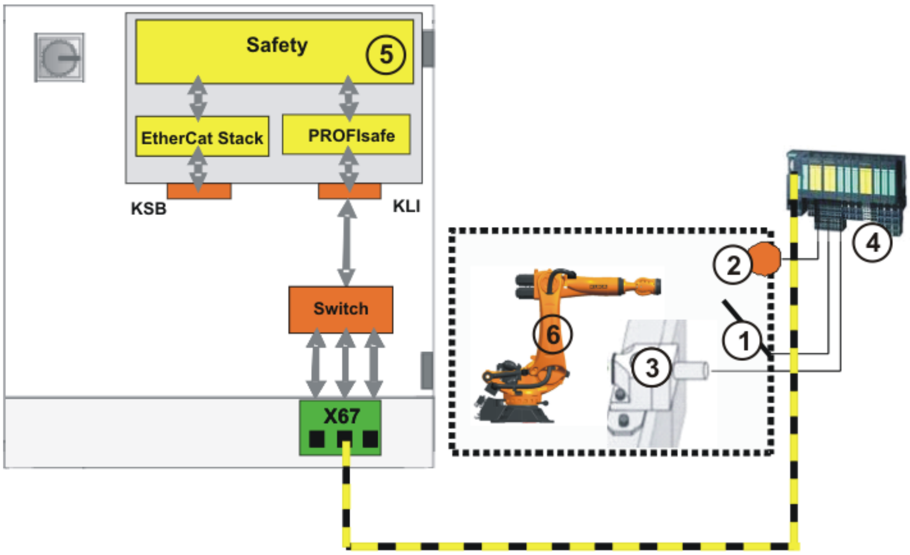


Fig. 3-6: SafeOperation via PROFIsafe

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

SafeRangeMonitoring via PROFIsafe

There are 6 bytes of safe outputs available which are specified as follows:

Output byte 2

Bit	Signal	Description
0	SO	SafeRangeMonitoring active SafeRangeMonitoring activation status **0** = SafeRangeMonitoring is not active. **1** = SafeRangeMonitoring is active.
1	RR	Robot referenced Mastering test display **0** = mastering test required. **1** = mastering test performed successfully.

Bit	Signal	Description
2	JF	Mastering error Space monitoring is deactivated because at least one axis is not mastered. **0** = mastering error. Space monitoring has been deactivated. **1** = no error.
3	RES	Reserved 20 ... 24

Output byte 3

Bit	Signal	Description
0 … 7	RES	Reserved 25 ... 32

Output byte 4

Bit	Signal	Description
0 … 7	MR1 … 8	Alarm space 1 … 8 Assignment: Bit 0 = alarm space 1 (associated monitoring space 1) … bit 7 = alarm space 8 (associated monitoring space 8) **0** = space is violated. **1** = space is not violated.

Output byte 5

Bit	Signal	Description
0 … 7	MR9 … 16	Alarm space 9 … 16 Assignment: Bit 0 = alarm space 9 (associated monitoring space 9) … bit 7 = alarm space 16 (associated monitoring space 16) **0** = space is violated. **1** = space is not violated.

Output byte 6

Bit	Signal	Description
0 … 7	RES	Reserved 48 ... 55

Output byte 7

Bit	Signal	Description
0 … 7	RES	Reserved 56 ... 63

Procedure

Preconditions

- User group “Safety maintenance”
- T1 or T2 operating mode

Set hardware options

1. Select **Configuration** > **Safety configuration** in the main menu.
2. Press **Hardware options**.
3. Under **Customer interface:** select the option **PROFIsafe**.
4. Under **Peripheral contactor circuit (US2):** select the circuit of the safety-controlled 24 V power supply US2.

5. Under **Operator safety acknowledgement:** select operator safety acknowledgement.

3.5 Defining the X13 interface and Extended SIB

Connection to X13 and Extended SIB

- 8 safe outputs are available.
- The function of the outputs is permanently defined.
- All safe outputs are of dual-channel design.
- Safe outputs are isolated taps of SIB board relay contacts.

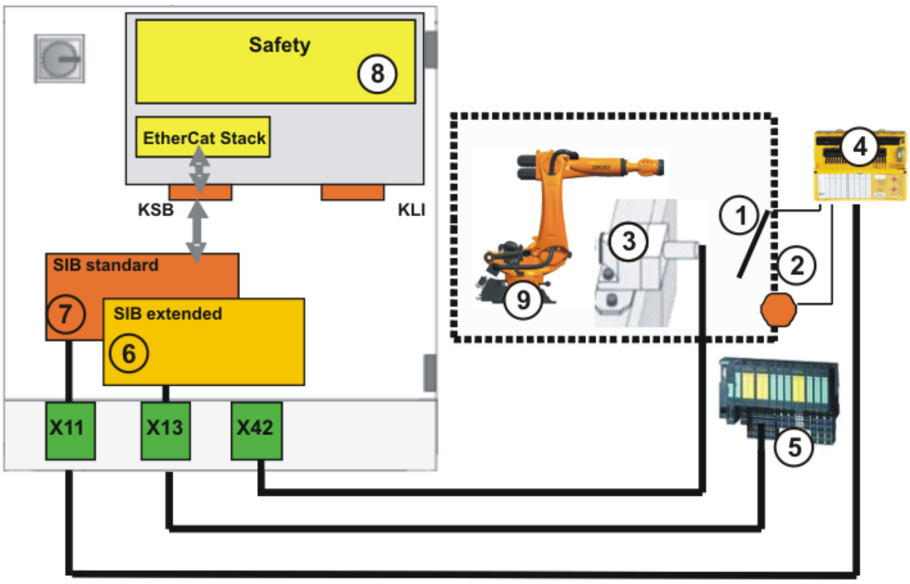


Fig. 3-7: SafeOperation via SIB

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 SafeRangeMonitoring option
7	Standard SIB for robot safety
8	Safety software stack
9	Manipulator

SE SafeRange-Monitoring via X13 and Extended SIB

Safe outputs

Signal	Description
SO	SafeRangeMonitoring active SafeOperation activation status **0** = SafeRangeMonitoring is not active. **1** = SafeRangeMonitoring is active.
RR	Robot referenced Mastering test display **0** = mastering test required. **1** = mastering test performed successfully.
MR1 … 6	Alarm space 1 … 6 Alarm space 1 (associated monitoring space 1) … alarm space 6 (associated monitoring space 8) **0** = space is violated. **1** = space is not violated.

Procedure

Preconditions

- User group “Safety maintenance”
- T1 or T2 operating mode

Set hardware options

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

3.6 Activating safe monitoring

Description of activation

> Configuration of the safety monitoring functions is only possible if safe monitoring has been activated.

> **WARNING** If safe monitoring is deactivated, the configured safety monitoring functions are inactive.

Preconditions:

- User group “Safety maintenance”
- T1 or T2 operating mode

Overview

Fig. 3-8: Defining global parameters

Parameter	Description
Safe monitoring	**Check box activated** = safe monitoring is activated. **Check box deactivated** = safe monitoring is deactivated. Default: Check box deactivated
Mastering test input	**at cabinet** = reference switch is connected to the robot controller. **via ProfiSafe** = reference switch is connected via PROFIsafe. Default: at cabinet
Maximum velocity rotational axis	Limit value for maximum velocity for rotational axes ■ **0.5 ... 5000°/s** Default: 100°/s
Maximum velocity translational axis	Limit value for maximum velocity for linear axes ■ **0.5 ... 5000 mm/s** Default: 5000 mm/s

Troubleshooting wizard

If there are discrepancies between the configuration and the checksum of the RDC (hard drive and RDC), the Troubleshooting wizard window is opened. A description of the problem and a list of possible causes is displayed. The user can select the applicable cause. The wizard then suggests a solution.

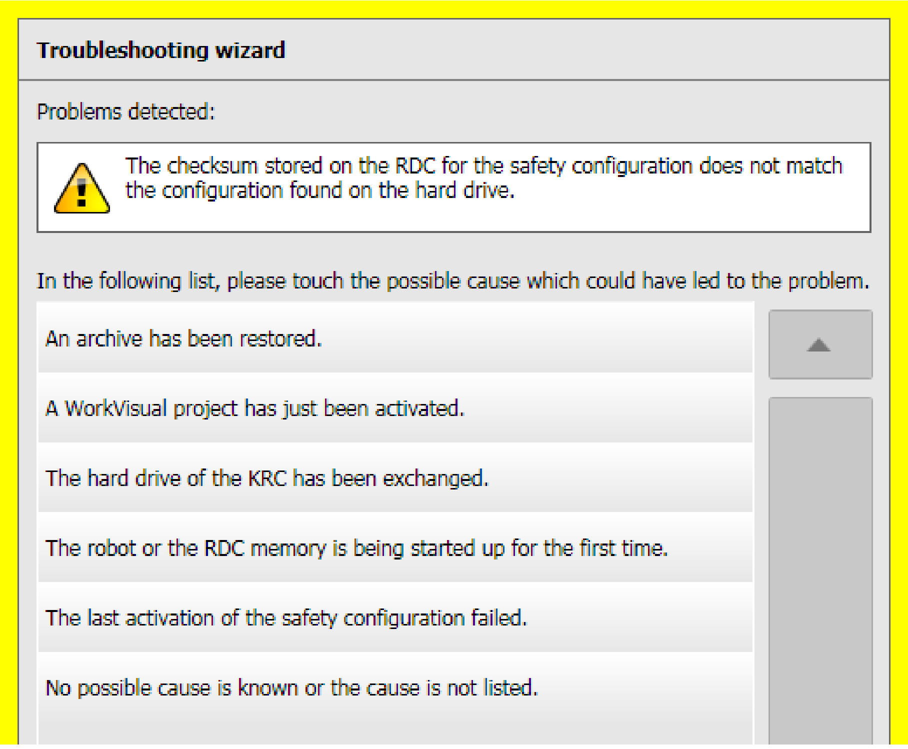


Fig. 3-9: Troubleshooting wizard

Procedure

1. Select **Configuration** > **Safety configuration** in the main menu.
2. The safety configuration checks whether there are any relevant deviations between the data in the robot controller and those in the safety controller.
   - If there are no deviations, the **Safety configuration** window is opened.
   - If there are deviations, the **Troubleshooting wizard** window is opened.
3. Press **Global parameters**.
4. Activate the **Safe monitoring** check box (set the check mark).
5. Define the connection for the reference switch under **Mastering test input**.
6. Set **maximum velocity** for rotational and linear axes.
7. Save the safety configuration or continue configuration.

3.7 Applied standards and directives; checklists

Applied standards and directives

The safety functions of KUKA.SafeRangeMonitoring meet the requirements of **Category 3** and **Performance Level d** in accordance with EN ISO 13849-1:2007. This corresponds to **SIL 2** in accordance with EN 62061.

Precondition for safety acceptance based on the checklists

Safety acceptance also includes documentation by means of checklists.

For training purposes, these are assigned to the exercises and adapted.

The original checklists can be found in the documentation of the KUKA.SafeOperation option.

The checklist for an axis-specific monitoring space is given here by way of example:

Precondition

- Mechanical and electrical installation of the industrial robot have been completed.

- Safety configuration is completed.

Checklist for KUKA College

A separate checklist must be completed for each monitoring space.

- Serial number of the robot: ____________________
- Activation code: ____________________
- Time stamp:_________________________
- Monitoring space checked (name, number): __________
- Type of space (protected space or workspace): ____________________
- Stop at boundaries (TRUE|FALSE): __________
- Reference stop (TRUE|FALSE): __________
- Space-specific velocity __________mm/s
- Space-specific velocity valid in: __________
- Safe tool used in test of velocity or space limit: _________________
- Always active (TRUE|FALSE): __________

The configured limit values must successively be violated to demonstrate the correct functioning of the monitoring space.

No.	Activity	Yes	Not relevant
1	Axis 1 has been correctly configured and checked.		
	Specified lower axis limit: __________ ° or mm Configured lower axis limit: __________ ° or mm Determined lower axis limit: __________ ° or mm		
	Specified upper axis limit: __________ ° or mm Configured upper axis limit: __________ ° or mm Determined upper axis limit: __________ ° or mm		
2	Axis 2 has been correctly configured and checked.		
	Specified lower axis limit: __________ ° Configured lower axis limit: __________ ° Determined lower axis limit: __________ °		
	Specified upper axis limit: __________ ° Configured upper axis limit: __________ ° Determined upper axis limit: __________ °		
3	Axis 3 has been correctly configured and checked.		
	Specified lower axis limit: __________ ° Configured lower axis limit: __________ ° Determined lower axis limit: __________ °		
	Specified upper axis limit: __________ ° Configured upper axis limit: __________ ° Determined upper axis limit: __________ °		

No.	Activity	Yes	Not relevant
4	Axis 4 has been correctly configured and checked.		
	Specified lower axis limit: ___________ ° Configured lower axis limit: ___________ ° Determined lower axis limit: ___________ °		
	Specified upper axis limit: ___________ ° Configured upper axis limit: ___________ ° Determined upper axis limit: ___________ °		
5	Axis 5 has been correctly configured and checked.		
	Specified lower axis limit: ___________ ° Configured lower axis limit: ___________ ° Determined lower axis limit: ___________ °		
	Specified upper axis limit: ___________ ° Configured upper axis limit: ___________ ° Determined upper axis limit: ___________ °		
6	Axis 6 has been correctly configured and checked.		
	Specified lower axis limit: ___________ ° Configured lower axis limit: ___________ ° Determined lower axis limit: ___________ °		
	Specified upper axis limit: ___________ ° Configured upper axis limit: ___________ ° Determined upper axis limit: ___________ °		

No.	Activity	Yes	Not relevant
9	The correct functioning of the reference stop has been checked?		

City, date	KUKA College,
Signature	

By signing, the signatory confirms the correct and complete performance of the safety acceptance test.

3.8 Exercise: Software installation

Aim of the exercise

On completion of this exercise, you will be able to carry out the following tasks:

- Installation of the KUKA.SafeRangeMonitoring software
- Activate monitoring of the safety parameters
- Set maximum velocity for rotational and linear axes

Task description

> **⚠ WARNING** The safety regulations contained in the safety instruction must be observed!

1. Install the software option KUKA.SafeRangeMonitoring 3.x. This is located on partition D: of the hard drive.

   Alternatively, it may be provided by the trainer on a USB stick.
2. Switch to the user group **Safety maintenance**.
3. Activate safe monitoring.

4. Reduce the maximum velocity for rotational axes to 200°/s.

What you should now know:

1. How many safe inputs and outputs are available via the Extended SIB board.

. . . .

. . . .

2. In which user group can you activate safe monitoring?

. . . .

. . . .

4 Programming a mastering test

4.1 Overview of mastering test

The following contents are explained in this training module:

- What is the mastering test?
- Programs for the mastering test
- Defining and teaching the reference position
- Performing a reference run (mastering test)

4.2 The mastering test

Overview, mastering test

The mastering test is used to check whether the current position of the robot (and the external axes) corresponds to a reference position.

If the deviation between the current position and the reference position is too great, the mastering test has failed. The robot stops with a safety stop 1 and can only be moved in T1 mode or CRR. If the mastering test run was successful, the robot can be safely monitored using the safety controller.

Two programs are used for this:

- MasRef_Main.SRC – is the main program and only checks whether a reference run is active.
- MasRef_User.SRC – is the application program with the motion points.

The position to be monitored is not verified until a mastering test has been carried out. It is advisable to perform the mastering test as quickly as possible.

Performing a mastering test

> ⚠ The safety maintenance personnel must carry out a risk assessment and decide whether additional system-specific safety measures are required, e.g. reference stop if the mastering test has not been carried out.

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

- After the robot controller has booted

  Once the robot controller has booted, the robot can be moved for 2 hours without a mastering test. Once the monitoring time has elapsed, the robot stops with a safety stop 1.
- 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 of the robot controller and automatic call of the program MasRef_Main.SRC
- Manual selection of the program MasRef_Main.SRC

If, during operation, the mastering test is requested via the external signal (signal must be active), the mastering test is performed next time the program MasRef_Main.SRC is automatically called.

4.3 Defining the reference position

Description of reference position

The reference position must be taught in the program MasRef_USER.SRC and in the safety configuration.

The reference position can be approached with the actuating plate or with a ferromagnetic part of the tool as follows:

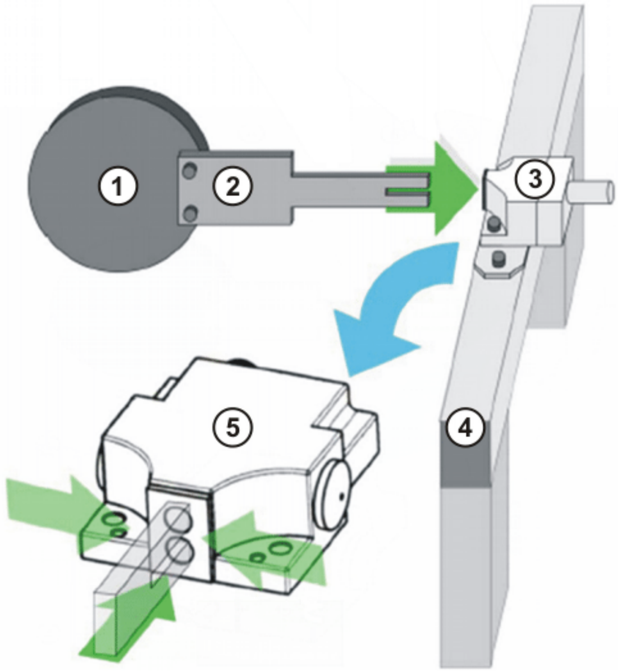


Fig. 4-1: Example: position of the actuating plate on the reference switch

1 Tool
2 Actuating plate
3 Reference switch
4 Mechanical mounting fixture for the reference switch
5 Actuated reference switch

Criteria, reference position

The reference run must be selected in accordance with the following criteria:

- The position of the reference switch and actuating plate must not interfere with the work sequence of the robot.
- The reference position must not be a position in which the axes are in a singularity.
- In the reference position, both proximity switch surfaces of the reference switch must be actuated by the switching surface (actuating plate or tool).
- In the reference position, the robot axes must be at least ±5° away from the mastering position.
- The position of the reference switch is within the motion range of the robot.

Procedure

1. Prepare a mechanical mounting fixture for mounting the reference switch.
2. Attach the reference switch to the mounting fixture.
3. If the actuating plate is being used, fasten the actuating plate to the robot flange or tool.

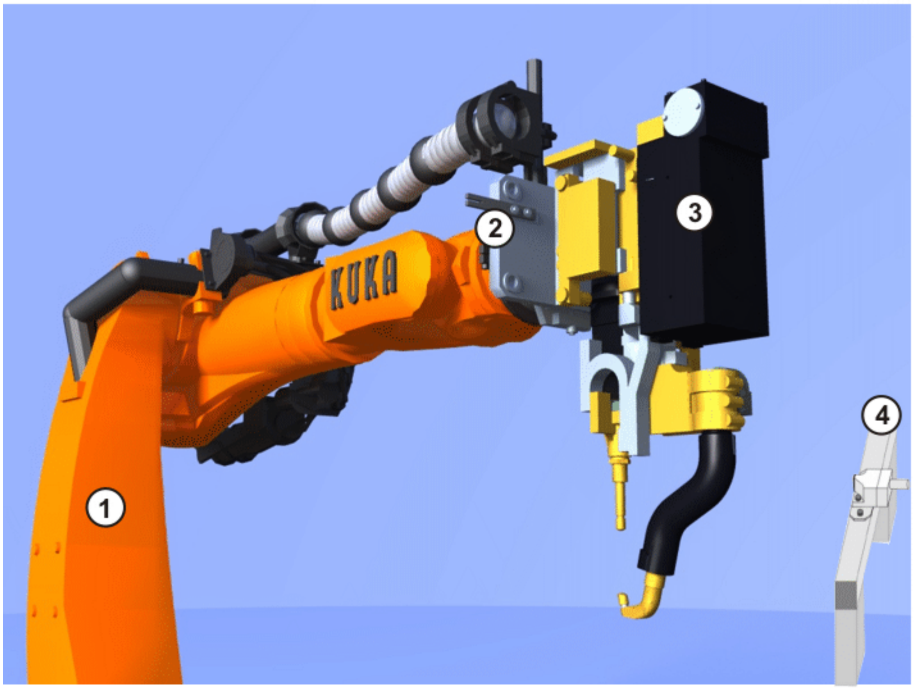


Fig. 4-2: Example of an actuating plate on the tool

1 Robot
2 Actuating plate on tool
3 Tool
4 Reference switch on mounting fixture

4.4 Defining the reference group

Description of the reference group

All axes of a reference group are mastered together.

When selecting the reference position, all axes that are together in a reference group must be taken into consideration.

Each axis that is to be subjected to safe monitoring must be assigned to a reference group. Robot axes are always assigned to reference group 1. External axes can be assigned to other reference groups, but also to reference group 1, e.g. in the case of a KL.

- **1**: robot axes
- **1 … 3**: external axes

4.5 Programming a mastering test

Description of programs

The following programs are used for the mastering test:

Program	Directory	Description
MasRef_Main.SRC	R1\System	The program checks whether a mastering test is required and must be executed as soon as possible after an internal request. If the program is not executed within 2 hours, the robot stops and the robot controller generates a message. If a mastering test is required, the robot performs it immediately. The program calls the program MasRef_USER.SRC that is used to address the reference position.
MasRef_USER.SRC	R1\Program	The program contains 3 subprograms for moving to reference positions 1 to 3 and 3 subprograms for the motion away from reference positions 1 to 3 after the mastering test has been performed. If the motion away from the reference position is not taught, the robot and external axes remain stationary after the mastering test. The robot controller generates an error message.

Precondition

- Reference switch is installed and connected.
- User group “Safety maintenance”
- T1 or T2 operating mode

During a mastering test, all axes of a reference group must be in the reference position, in order to actuate the reference switch. If not all the axes of a reference group are involved in actuating the reference switch, the position of the axes cannot be checked.

```
DEF MasRef_USER()
END

GLOBAL DEF MASREFSTARTG1()
Teach path and reference position for group 1

END

GLOBAL DEF MASREFSTARTG2()
Teach path and reference position for group 2

END

GLOBAL DEF MASREFSTARTG3()
Teach path and reference position for group 3

END

GLOBAL DEF MASREFBACKG1()
Teach path back for group 1

END

GLOBAL DEF MASREFBACKG2()
Teach path back for group 2

END

GLOBAL DEF MASREFBACKG3()
Teach path back for group 3

END
```

Line	Description
5	Program the motion to the reference position of reference group 1 and teach the reference position.
10	Program the motion to the reference position of reference group 2 and teach the reference position.
15	Program the motion to the reference position of reference group 3 and teach the reference position.
20	Teach the motion away from the reference position of reference group 1.
25	Teach the motion away from the reference position of reference group 2.
30	Teach the motion away from the reference position of reference group 3.

Procedure

1. Switch to the user group “Expert”.
2. **Open** the program MasRef_USER.SRC (under no circumstances may it be selected).
3. In the subprogram MASREFSTARTG**1**(), program a motion to a point approx. 10 cm before the reference switch and teach the required points.
4. Program a LIN motion to the reference switch so that it is actuated. This position is the reference position.

> The distance from the supplied reference switch must not exceed 2 mm. If the distance is greater, the reference switch will not be actuated.

5. Teach the reference position.
6. Do not move the robot.
7. Teach the reference position in the safety configuration.
8. In the subprogram MASREFBACKG**1**(), program the motion away from the reference position and teach the required points.
9. Steps 3 to 8 must be repeated with MASREFSTARTG*X*(), MASREFBACKG*X*() for further external axes of reference groups 2 and 3.
10. Close the program and save the changes.

4.6 Teaching the reference position

Precondition

- User group “Safety maintenance”
- T1 or T2 operating mode
- A safety configuration is open.
- Safe monitoring is active.

Procedure

1. Select the tool and base for Cartesian jogging.
2. Select the **Reference position** tab.
3. Move robot to the reference position.
4. Select one of the robot axes.
5. Press **Touch-up reference position for group** to accept the current flange position of the robot as the reference position for the axes in reference group 1.

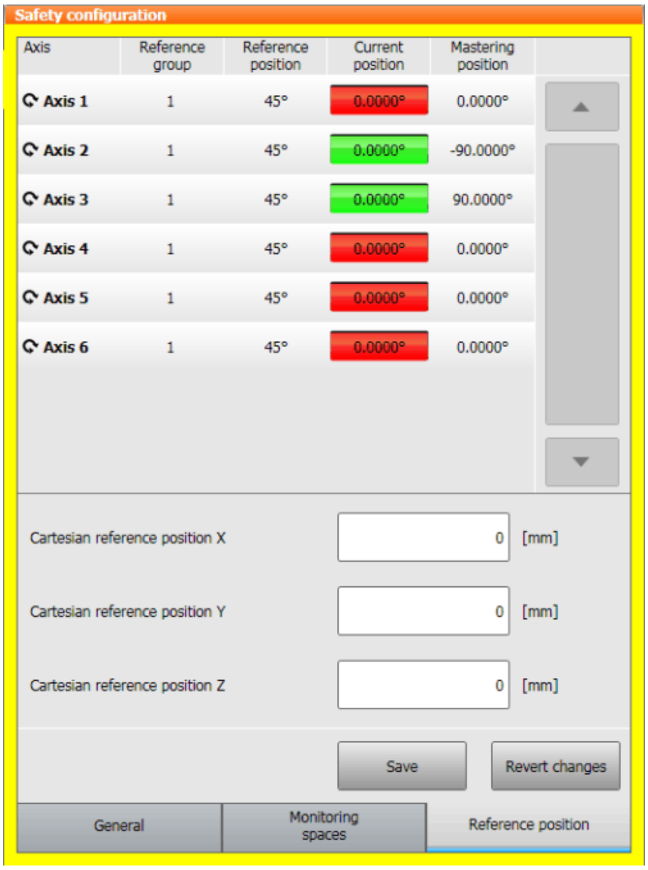


Fig. 4-3: Defining the reference position

Parameter	Description
Reference group	Each axis that is to be subjected to safe monitoring must be assigned to a reference group. Robot axes are always assigned to reference group 1. External axes can be assigned to other reference groups, but also to reference group 1, e.g. in the case of a KL. ■ **1**: robot axes ■ **1 … 3**: external axes Default: 1
Reference position	Axis-specific coordinates of the reference position To monitor the mastering, the axis angles of the robot axes are defined for a specific Cartesian reference position. During the mastering test, the robot moves to the Cartesian reference position and the actual position of the axes is compared with the command position. Rotational axes: ■ **-360° … +360°** Linear axes: ■ **-30,000 mm … +30,000 mm** Default value for rotational axes: 45° Default value for linear axes: 1,000 mm

Parameter	Description
Current position	Axis-specific actual position (display only) ■ **Red**: reference position not allowed, as too near mastering position ■ **Green**: reference position allowed
Mastering position	The axis angles at the mastering position are defined in the machine data. (display only)
Cartesian reference position X, Y, Z	X, Y and Z coordinates of the Cartesian reference position relative to the WORLD coordinate system (display for reference group 1) The coordinates of the Cartesian reference position refer to the center point of the mounting flange. ■ **-30,000 mm … +30,000 mm** Default: 0 mm

The coordinates of the Cartesian reference position are displayed in the configuration window.

Optional for configured external axes

1. For every external axis present, the number of the corresponding reference group must be entered.
2. Move external axes in reference group 2 to the reference position and save with **Touch-up reference position for group**.
3. Move external axes in reference group 3 to the reference position and save with **Touch-up reference position for group**.

4.7 Performing a reference run

Execution

The reference run can be performed in 2 different ways:

- Automatically by calling the main program in which the program MasRef_Main.SRC is called.
- Manually by calling the program MasRef_Main.SRC.

MasRefMain program

```
DEF MasRefMain()


Start conditions for mastering reference

RunTest_Group(1)

;RunTest_Group(2)

;RunTest_Group(3)

Finalize mastering reference

END
```

Precondition

- Reference switch is installed and connected.
- The reference position has been taught in the program MasRef_USER.SRC and in the safety configuration.
- The corresponding operating mode is selected.

⚠ WARNING The robot moves in T2 mode at the programmed velocity and can cause personal injury or material damage. Make sure that the robot cannot collide and that no persons are in the motion range of the robot.

Procedure

Manual execution

1. Select operating mode T1 or T2.
2. Select and execute the program MasRef_Main.SRC to the end of the program.

Automatic execution

1. Select operating mode Ext or Aut.
2. Select and execute through to the end the main program from which MasRef_Main.SRC is called.

4.8 Exercise: Performing a reference run (mastering test)

Aim of the exercise

On completion of this exercise, you will be able to carry out the following tasks:

- Determine whether a reference run is necessary.
- Program the reference run.
- Automatic and manual program call of the mastering test programs.

Task description

⚠ WARNING The safety regulations contained in the safety instruction must be observed!

1. In the program **MasRef_User.SRC**, teach the motions to the reference switch and back to the starting position.
2. Create a new main program **Startup** and call the program **MasRef_Main.SRC** in it as a global subprogram.
3. Select the program **Startup** and execute it through to the end.
4. Perform a manual reference run.

What you should now know:

1. When must a reference run be carried out?

. . . .

. . . .

. . . .

2. What is the name of the main program for the mastering test?

. . . .

. . . .

3. Why are the reference groups needed and how many can be defined?

. . . .

. . . .

. . . .

4. What happens in the mastering test?

. . . .

. . . .

. . . .

5 Programming the brake test

5.1 Overview of the brake test

The following contents are explained in this training module:

- What is the brake test?
- Programs for the brake test
- Performing a brake test
- Brake test self-test

5.2 The brake test

Availability

The brake test is part of the KUKA System Software (VW System Software). It is present on every controller as standard.

More detailed information can be found in the Operating and Programming Instructions for System Integrators.

5.3 Defining the brake test

Description of brake test

Each robot axis has a holding brake integrated into the motor. The brake test checks every axis at low speed and at the current temperature to see if the braking torque exceeds a certain minimum value. The absolute value of the braking torque is not calculated. The minimum braking torque for the individual axes is stored in the machine data.

A precondition for the brake test is that the robot is at operating temperature. This is the case after approx. 1 h in normal operation.

The brake test checks all brakes one after the other.

Functional principle:

- The robot accelerates to a defined velocity. (The velocity cannot be influenced by the user.)
- Once the robot has reached the velocity, the brake is applied and the result for this braking operation is displayed in the message window.
- If a brake has been identified as being defective, the brake test can be repeated for confirmation or the robot can be moved to the parking position.
- If a brake has reached the wear limit, the robot controller indicates this by means of a message.

  A worn brake will soon be identified as defective. Until then, the robot can be moved without restrictions.

The following system variables must be adapted in certain cases:

Variable	Description
BitfieldAxesActivated	Activation of the axes for the brake test; binary value Default = 4095: Robot and external axes are enabled for the brake test. Examples ■ **63:** Only the robot axes have been selected. ■ **1:** Only robot axis 1 has been selected. ■ **3:** Only robot axes 1 and 2 have been selected. ■ **0:** No axes have been selected.
TravAngleAx	Range of motion for the robot axes in ° x=1...6 Default=10
TravAngleEx	Range of motion for the external axes in ° or mm x=1...6 Default=0 ■ **15.0** In the case of a linear axis, a higher value must be entered (e.g. 100) in order for the permissible brake test distance to be sufficient.

Variable	Description
BrakeTestCycTime	Brake test cycle time in hours Default = 46.0

Brake test request

The following events cause a brake test to be requested:

- An external request, e.g. from a PLC
- Brake test cycle time has elapsed (internal request)
- Robot controller is rebooted (internal request)
- Manual start of the program BrakeTestReq.SRC (external request)
- Function test of the brake test (internal request)
- Reconfiguration of the I/O drivers (external request)

The cycle time is 46 h. It is deemed to have elapsed when the drives have been under servo-control for a total of 46 h. The robot controller then requests a brake test and generates the following message: *Brake test required*. The robot can be moved normally for another 2 hours. It then stops and the robot controller generates the following acknowledgement message: *Test cycle for brake test request exceeded*. Once the message has been acknowledged, the robot can be moved for another 2 hours.

Variable adaptation procedure

NOTICE Incorrectly configured parameters can result in serious damage to the industrial robot. The parameters for robot axes A1 to A6 are preconfigured for the brake test and may only be modified in consultation with KUKA Roboter GmbH.

1. “Expert” user group
2. The file **mdrBrakeTest.ini** is located in the directory C:\KRC\ROBOTER\Config\User\Common\Mada\MotionDrivers\. Adapt the following variables as required: **BitfieldAxesActivated**, **TravAngleAx**, **TravAngleEx**.
3. The file **mdrBrakeTest.ini** is located in the directory C:\KRC\ROBOTER\Config\User\Common\MotionDrivers\. Adapt the following variable as required: **BrakeTestCycTime**.

4. The file **motiondrv.ini** is located in the directory C:\KRC\ROBOTER\Config\User\Common\MotionDrivers\. The driver for the brake test is called in this file.

   Default: BRAKE_TEST,mdrBrakeTest.o

Example 1

```
BRAKE_TEST,mdrBRAKETest.o
;Driver is active and the brake test is executed
```

```
;BRAKE_TEST,mdrBRAKETest.o
;Driver is not active and the brake test is executed
```

Example 2

```
BRAKE_TEST,mdrBRAKETest.o
;Driver is active
```

```
BitfieldAxesActivated=0
;No axes are configured for the brake test
```

The brake test must be executed to delete the message.

5.4 Programming the brake test

Programs for the brake test

The programs are located in the directory C:\KRC\ROBOTER\KRC\R1\TP\BrakeTest.

Program	Description
BrakeTestReq.SRC	This program performs the brake test. It can be performed in the following ways: ■ Integrate the program into the application program in such a way that it is cyclically called as a subprogram. If a brake test is requested, the robot detects this and performs the brake test immediately. ■ Execute the program manually. ■ Test the function of the brake test. The robot controller executes BrakeTestReq.SRC with special parameterization.
BrakeTestPark.SRC	The parking position of the robot must be taught in this program. The robot can be moved to the parking position if a brake has been identified as being defective. Alternatively, the brake test can be repeated for confirmation.
BrakeTestStart.SRC	The start position of the brake test can be taught in this program. The robot starts the brake test from this position. If the start position is not taught, the robot performs the brake test at the actual position.
BrakeTestBack.SRC	The end position of the brake test can be taught in this program. The robot moves to this position after the brake test. If the end position is not taught, the robot remains at the actual position after the brake test.
BrakeTestSelfTest.SRC	The program checks whether the brake test has correctly detected a defective brake. For this purpose, the robot controller executes BrakeTestReq.SRC with special parameterization.

Programs for the brake test

BrakeTestReq.SRC file:

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

NOTICE It is not necessary to modify this program; this program is only called.

BrakeTestStart.SRC file:

```
DEF BrakeTestStart ( )
INI
;teach here as required the position where the brake test should be
performed and the path to there
PTP Home vel=100% default
PTP Start1 cont vel=100% PDAT1 Tool[0] Base[0]
PTP Start2 cont vel=100% PDAT2 Tool[0] Base[0]
PTP BrakeTest_pos  vel=100% PDAT3 Tool[0] Base[0]
```

NOTICE The collision-free motion to the position at which the brake test is performed is taught here.
If no motion is taught, the brake test is performed at the current robot position.

BrakeTestBack.SRC file:

```
DEF BrakeTestBack ( )
INI
;teach here as required the path after brake test
PTP Start2 cont vel=100% PDAT2 Tool[0] Base[0]
PTP Start1 cont vel=100% PDAT1 Tool[0] Base[0]
PTP Home vel=100% default
END
```

NOTICE The collision-free motion from the brake test position back to the starting position is taught here.
If no motion is taught, the robot remains at the current position.

BrakeTestPark.SRC file:

```
DEF BrakeTestPark ( )
INI
;teach here the park position for this case that brake test has
fallen through and the path to there
PTP Start1 cont vel=100% PDAT1 Tool[0] Base[0]
PTP Park_pos vel=100% PDAT4 Tool[0] Base[0]
END
```

NOTICE The collision-free motion from the brake test position to the parking position is taught here.

Procedure

1. Open the program BrakeTestStart.SRC in the directory R1\TP\BrakeTest.
2. Teach the motions to the start position of the brake test.
   - The motions must be taught in such a way that the robot cannot cause a collision on the way to the start position.
   - In the start position, every robot axis must have an available motion range of ±10°.
3. Save and close the program.
4. Open the program BrakeTestBack.SRC in the directory R1\TP\BrakeTest.
5. Teach the motions from the start position to the end position of the brake test.

The start and end position of the brake test can be identical.

6. Save and close the program.

7. Open the program BrakeTestPark.SRC in the directory R1\TP\BrakeTest.
8. Program the motions from the end position to the parking position of the robot.
9. Save and close the program.

5.5 Performing a brake test

Execution

The brake test can be performed in 2 different ways:

- Automatically by calling the main program in which the program BrakeTestReq.SRC is called.
- Manually by calling the program BrakeTestReq.SRC.

Preconditions

- No persons or objects are present within the motion range of the robot.
- In the start position, every robot axis has an available motion range of ±10°. (Or, if no start position has been taught, in the actual position.)
- The parking position has been taught in the program BrakeTestPark.SRC.
- “Expert” user group
- Program run mode GO
- Operating mode T2, AUT or EXT
- The robot is at operating temperature (= after approx. 1 h in normal operation).

Procedure

Manual execution

1. Select operating mode T2.
2. Select and execute the program BrakeTestReq.SRC to the end of the program.

Automatic execution

1. Select operating mode Ext or Aut.
2. Select and execute through to the end the main program from which BrakeTestReq.SRC is called.

Results of the brake test:

- Successful:
  - If a brake is OK, the following message is displayed: *Brake X OK*
  - If all brakes are OK, the following message is displayed: *Brake test successful*
- Defective:
  - If a brake is defective, the following message is displayed: *Insufficient holding torque of brake X*

    Options

    i. Repeat brake test for checking purposes
    ii. Move the robot to the parking position

5.6 Brake test self-test

Description of self-test

It is possible to check whether the brake test has correctly detected a defective brake: the program BrakeTestSelfTest.SRC simulates a fault in the brakes and triggers a brake test. If the brake test detects the simulated fault, it is functioning correctly.

Preconditions for self-test

- No persons or objects are present within the motion range of the robot.
- In the start position, every robot axis has an available motion range of ±10°. (Or, if no start position has been taught, in the actual position.)

- The parking position has been taught in the program BrakeTestPark.SRC.
- “Expert” user group
- Program run mode GO
- Operating mode T2, AUT or EXT
- The robot is at operating temperature (= after approx. 1 h in normal operation).

Procedure

1. Select the program BrakeTestSelfTest.SRC in the directory C:\KRC\ROBOTER\KRC\R1\TP\SAFEROBOT and press the Start key.
2. The following message is displayed: *Performing self-test for brake test - please acknowledge*. Acknowledge the message with **OK**.
3. Press the Start key.

> **DANGER** Program override is automatically set to 100%. The robot moves at high velocity. Make sure that the robot cannot collide and that no persons are in the motion range of the robot.

Result of the function test:

- Message *Insufficient holding torque of brake 3*: The brake test has correctly detected the simulated fault. The brake test is functioning correctly.

  Deselect the program BrakeTestSelfTest.SRC.

  Perform a manual brake test. This ensures that the simulated fault does not remain active.
- Any other message, or no message, means: The brake test has not detected the simulated fault. The brake test is not functioning correctly.

> **DANGER** If the function test establishes that the brake test is not functioning correctly:
>
> - The robot must no longer be moved.
> - KUKA Roboter GmbH must be contacted.

5.7 Exercise: Performing a brake test

Aim of the exercise

On completion of this exercise, you will be able to carry out the following tasks:

- Determine whether a brake test is necessary.
- Program the brake test.
- Automatic and manual program call of the brake test programs

Task description

> **WARNING** The safety regulations contained in the safety instruction must be observed!

1. Teach positions for the brake test.
   - Teach the parking position in the program BrakeTestPark.SRC
   - Teach the start position for the brake test in the program BrakeTestStart.SRC
   - Teach the end position for the brake test in the program BrakeTestBack.SRC

> The home position is not suitable as a position for the brake test at KUKA College!

2. Open the program **Startup.SRC** and call the program **BrakeTestReq.SRC** from it as a global subprogram.
3. Select the program **Startup.SRC** and execute it through to the end.
4. Perform a manual brake test self-test.

5. Perform a manual brake test.

What you should now know:

1. When must a brake test be carried out?

. . . .

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2. Which programs are required for the brake test?

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3. What is defined using the variable **BitfieldAxesActivated**?

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4. What happens during the brake test?

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6 Configuring safety parameters on the robot

6.1 Start-up overview

The following contents are explained in this training module:

- Defining an axis-specific monitoring space
- Testing an axis-specific monitoring space
- Defining the maximum rotational and linear velocity

6.2 Defining axis-specific monitoring spaces

Description of axis-specific monitoring spaces

Safe monitoring can be activated/deactivated.

Maximum velocities for rotational and linear axes can be configured.

A maximum of 16 monitoring spaces can be configured.

The axis limits can be set and monitored individually for each axis via the software. The resulting axis range is the permissible range of an axis within which the robot may move. The individual axis ranges together make up the overall workspace, which may consist of up to 8 axis ranges. 6 robot axes and 2 external axes can be defined in a workspace.

Each monitoring space can be defined as a workspace or protected space.

For each monitoring space, a reference stop can be set that stops the robot if no mastering test has been carried out.

Monitoring can be activated and deactivated for each individual monitoring space.

Safe outputs are permanently assigned to the monitoring spaces. The safe outputs are set if a monitoring space is violated.

Whether or not a stop is triggered at the space limit is a function that can be activated.

If interface X13 is used, outputs are only available for monitoring spaces 1 … 6.

Stopping distance

If the robot is stopped by a monitoring function, it requires a certain stopping distance before coming to a standstill.

This stopping distance must also be taken into consideration when dimensioning axis-specific monitoring spaces.

The maximum stopping distances are the same as those already mentioned in the context of the cell area and Cartesian monitoring spaces.

Workspace and protected space

The workspace is the area within which the robot may move. The axis range is the motion range of an axis. The individual axis ranges together make up the overall workspace, which may consist of up to 8 axis ranges.

The protected space is the area within which the robot may not move. The individual axis ranges together make up the overall protected space, which may also consist of up to 8 axis ranges.

If an axis violates a workspace or protected space, the following reactions can occur:

- A safe output is set (alarm space).
- Robot is stopped (if configured).

Example of an axis-specific workspace

The diagram shows an example of an axis-specific workspace. The workspace of axis 1 is configured from -110° to +130° and corresponds to the permissible motion range of the robot. Axes A2-A6 can be moved throughout their entire range of motion.

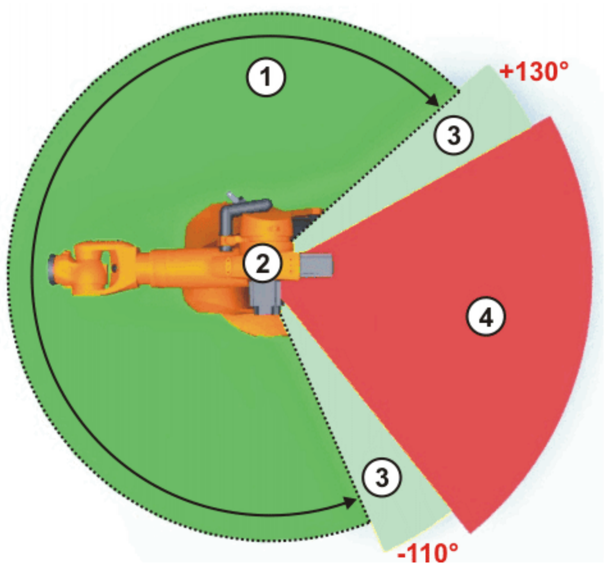


Fig. 6-1: Example of an axis-specific workspace

1	Workspace	3	Stopping distance
2	Robot	4	Protected space

Example of an axis-specific protected space

The diagram shows an example of an axis-specific protected space. The safeguarded space and the stopping distances correspond to the configured protected space. The motion range of axis 1 is limited to -185° to +185° by means of software limit switches. The protected space is configured from -110° to -10°. This results in 2 permissible motion ranges for the robot, separated by the configured protected space. Axes A2-A6 can be moved throughout their entire range of motion.

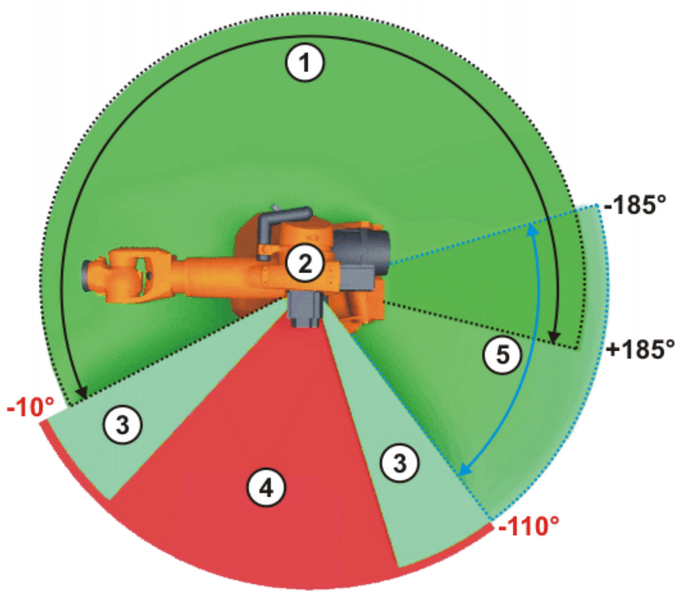


Fig. 6-2: Example of an axis-specific protected space

1	Permissible range 1	4	Protected space
2	Robot	5	Permissible range 2
3	Stopping distance		

Example of an axis-specific protected space through which the robot can move

⚠ WARNING In the case of axes that can rotate more than 360°, e.g. axis 1, the configured axis ranges refer to the position of the axis (including sign) and not to the sector of a circle. Serious injury and severe damage to the robot can be caused. If, for example, a protected space of +90° to +270° is configured, the robot can move through the protected space in the other direction from -90° to -185°. In this case, it is advisable to configure a workspace from -90° to +90°.

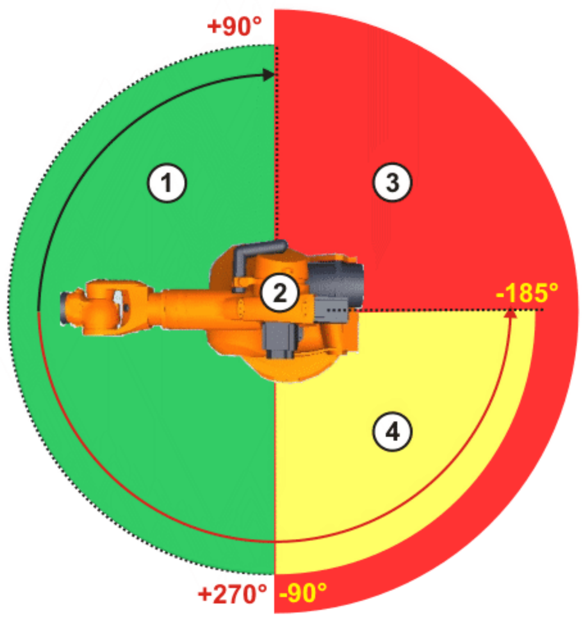


Fig. 6-3: Example of an axis-specific protected space through which the robot can move

1	Workspace	3	Protected space
2	Robot	4	Protected space through which the robot can move

Procedure

1. Select the user group “Safety maintenance”.
2. Select operating mode T1 or T2.
3. Open safety configuration.

   Safe monitoring is active.
4. Select the **Monitoring spaces** tab and select the monitoring space from the list.

   The parameters of the monitoring space are displayed.
5. Enter the name of the monitoring space (max. 24 characters).
6. Select the space type **Axis space** and set the parameters of the monitoring space.

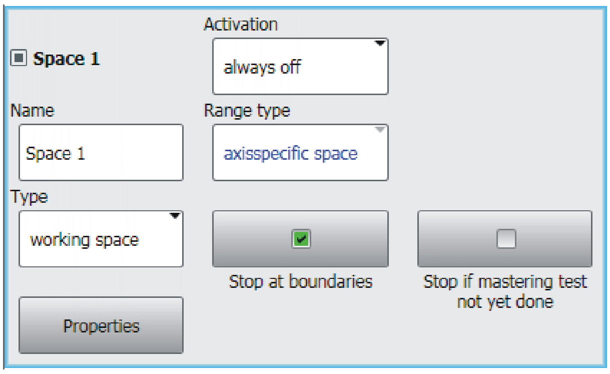


Fig. 6-4: Defining an axis-specific monitoring space

Parameter	Description
Type	Type of monitoring space **Working space** = monitoring space is a work-space. **Protected space** = monitoring space is a protected space. Default: Workspace
Activation	Activation of monitoring space **always off** = monitoring space is not active. **always active** = monitoring space is always active.
Stop at boundaries	A stop is triggered if the space is violated. **Check box activated** = robot stops if the monitoring space limits are exceeded. **Check box deactivated** = robot does not stop if the monitoring space limits are exceeded. Default: Check box activated
Stop if mastering test not yet done	Activation of reference stop **Check box activated** = reference stop is activated for the monitoring space. **Check box deactivated** = reference stop is deactivated for the monitoring space. Default: Check box deactivated

7. Press **Properties**.

   The **Axis-specific properties of** *[NameMonitoringSpace]* window is opened.

Fig. 6-5: Defining axis-specific properties

Icon	Description
	Icon for rotational and infinitely rotating axes
	Icon for linear axes

Parameter	Description
Monitoring	**Check box activated** = axis limits are activated for the monitoring space. **Check box deactivated** = axis limits are deactivated for the monitoring space. Default: Check box deactivated
Lower limit (lower axis limit)	The lower limit of an axis-specific workspace must be at least 0.5° or 1.5 mm less than the upper limit. The axis-specific protected space is dependent on the maximum axis velocity. A defined minimum size for the axis-specific protected space is derived from the maximum axis velocity; the size must not fall below this value. If this minimum value is violated, a message is displayed. Rotational axes: ■ **-360° … +360°** Linear axes: ■ **-30,000 mm … +30,000 mm** Default value for rotational axes: -360° Default value for linear axes: -30,000 mm
Current position	Axis-specific actual position (display only) ■ **Red**: axis position not allowed, as monitoring space is violated ■ **Green**: axis position allowed
Upper limit (upper axis limit)	The upper limit of an axis-specific workspace must be at least 0.5° or 1.5 mm greater than the lower limit. The axis-specific protected space is dependent on the maximum axis velocity. A defined minimum size for the axis-specific protected space is derived from the maximum axis velocity; the size must not fall below this value. If this minimum value is violated, a message is displayed. Rotational axes: ■ **-360° … +360°** Linear axes: ■ **-30,000 mm … +30,000 mm** Default value for rotational axes: 360° Default value for linear axes: 30,000 mm

8. Select axis from the list.

   The axis-specific properties are displayed.
9. Activate monitoring by means of the check box (set the check mark).
10. Move the axis to the upper axis limit in axis-specific mode.
11. Press **Touch-up** to save the current axis position.
12. Move the axis to the lower axis limit in axis-specific mode.
13. Press **Touch-up** to save the current axis position.

    Alternatively, enter the axis angles directly.

14. Repeat steps 8 to 13 to define the axis limits for additional axis ranges.

6.3 Testing an axis-specific monitoring space

Testing an axis-specific monitoring space

The configuration of the space limits must be checked. If “Stop at boundaries” is not configured, an alarm space is used for this.

Stopping distance

If the robot is stopped by a monitoring function, it requires a certain stopping distance before coming to a standstill.

The stopping distance depends on the following factors:

- Robot type
- Velocity of the robot
- Extension
- Payload
- Stop reaction

DANGER The actual stopping distance values must be determined by the person/department responsible by means of a risk analysis.

WARNING The stopping distance must be taken into consideration when dimensioning monitoring spaces.

Terms used

Term	Description
m	Mass of the rated load and the supplementary load on the arm.
Phi	Angle of rotation (°) about the corresponding axis. This value can be entered in the controller via the KCP and is displayed on the KCP.
Extension	Distance (l in %) between axis 1 and the intersection of axes 4 and 5. With parallelogram robots, the distance between axis 1 and the intersection of axis 6 and the mounting flange.

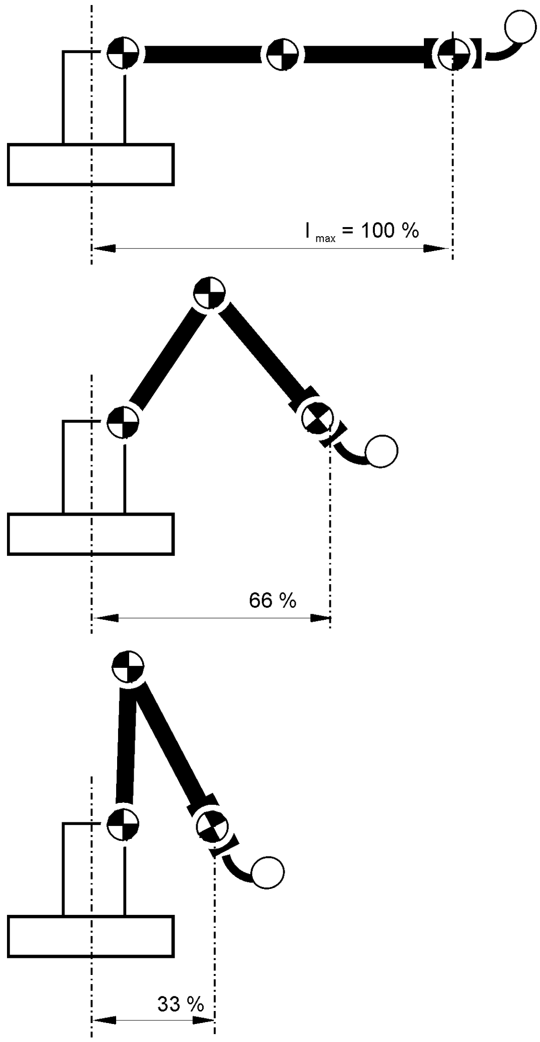


Fig. 6-6: Extension

The following table shows the stopping distances and stopping times after a STOP 0 of the KR16-2 is triggered. The values refer to the following configuration:

- Extension l = 100%
- Program override POV = 100%
- Mass m = maximum load (rated load + supplementary load on arm)

	Stopping distance (°)	Stopping time (s)
Axis 1	41.40	0.368
Axis 2	39.76	0.354
Axis 3	31.68	0.243

More detailed information can be found in the relevant robot documentation.

The following figures show the stopping distances after a STOP 1 of the KR16-2 is triggered:

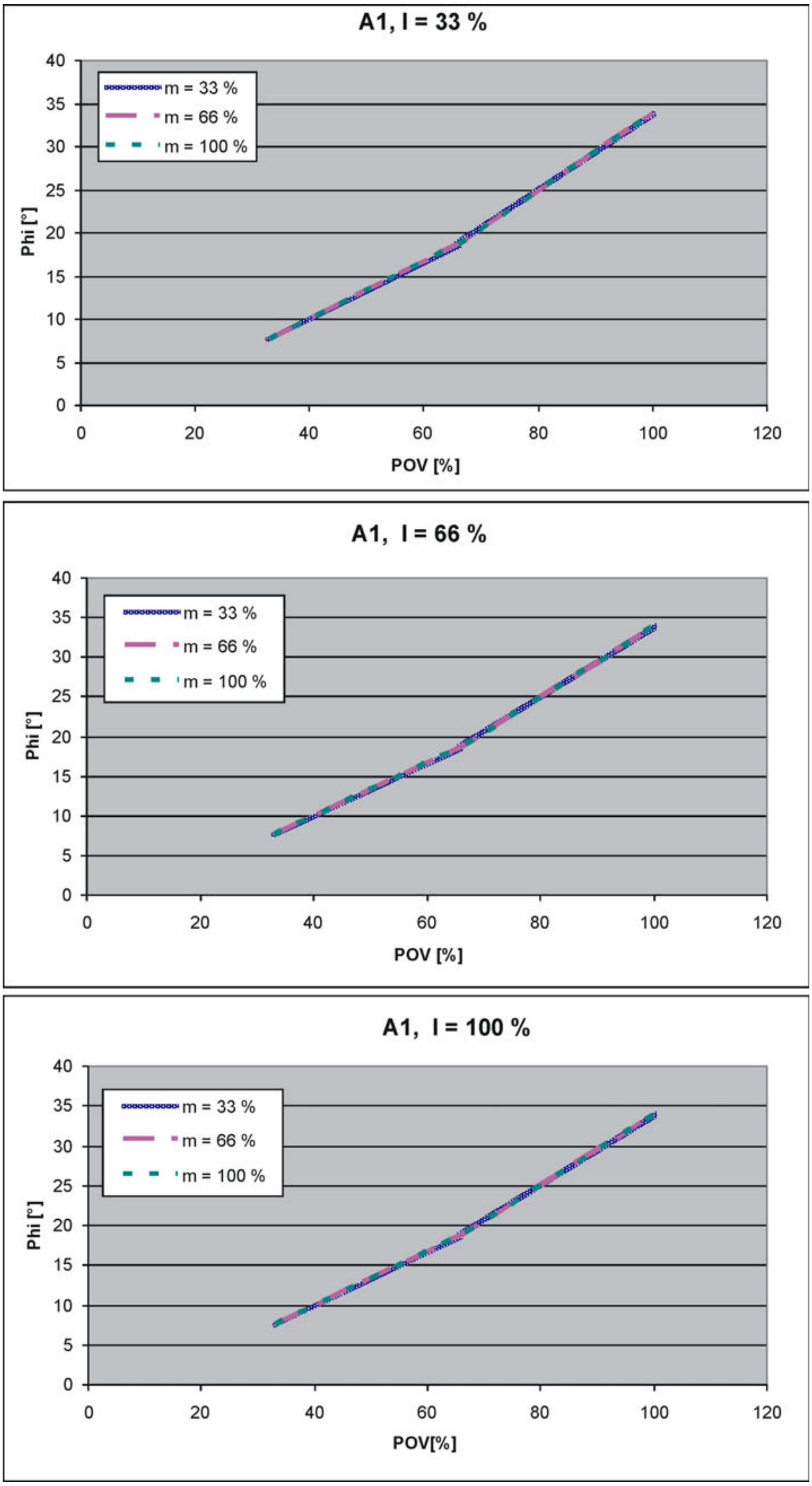


Fig. 6-7: Stopping distances for STOP 1, axis 1

Procedure

1. Configure an axis-specific monitoring space.
   Space limit approach is deactivated.
2. Jog each axis once to the upper and lower boundaries of the monitoring space in T1 mode using the jog keys or Space Mouse.

6.4 Exercise: Defining axis-specific monitoring spaces

Aim of the exercise

On completion of this exercise, you will be able to carry out the following tasks:

- Work with the SafeRangeMonitoring configuration tool
- Defining axis-specific workspaces
- Defining axis-specific protected spaces

Task description

⚠ WARNING	The safety regulations contained in the safety instruction must be observed!

- In Figure 1, mark the workspace and protected space of axis 1.

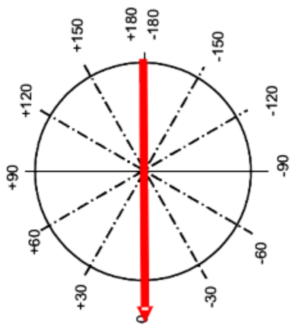


Fig. 1:

Workspace 14 / axis 1

Axis angles: (-15° to +25°) or configure according to the specific cell situation in +/-

- Enter the workspace marked in Figure 1 in the configuration tool under monitoring space 14; all other axes remain set to the default values.
- In Figure 2, mark the protected space and workspace of axis 1.

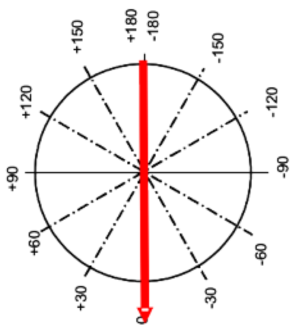


Fig. 2:

Protected space 15 / axis 1

Axis angles: (+20° to +45°) or configure according to the specific cell situation in +/-

- Enter the protected space from Figure 2 in the configuration tool under monitoring space 1; permanently active and signaled with a safe output MR 1.
- Test the monitoring spaces in accordance with the test instructions.
- Complete the corresponding checklist for configuration of the workspace around the table.

Checklist for KUKA College

A separate checklist must be completed for each monitoring space.

- Serial number of the robot: ____________________
- Activation code: ____________________
- Time stamp:_________________________
- Monitoring space checked (name, number): __________
- Type of space (protected space or workspace): ____________________
- Stop at boundaries (TRUE|FALSE): __________
- Reference stop (TRUE|FALSE): __________
- Space-specific velocity __________mm/s

- Space-specific velocity valid in: ___________
- Safe tool used in test of velocity or space limit: ___________________
- Always active (TRUE|FALSE): ___________

The configured limit values must successively be violated to demonstrate the correct functioning of the monitoring space.

No.	Activity	Yes	Not relevant
1	Axis 1 has been correctly configured and checked.		
	Specified lower axis limit: ___________ ° or mm Configured lower axis limit: ___________ ° or mm Determined lower axis limit: ___________ ° or mm		
	Specified upper axis limit: ___________ ° or mm Configured upper axis limit: ___________ ° or mm Determined upper axis limit: ___________ ° or mm		
2	Axis 2 has been correctly configured and checked.		
	Specified lower axis limit: ___________ ° Configured lower axis limit: ___________ ° Determined lower axis limit: ___________ °		
	Specified upper axis limit: ___________ ° Configured upper axis limit: ___________ ° Determined upper axis limit: ___________ °		
3	Axis 3 has been correctly configured and checked.		
	Specified lower axis limit: ___________ ° Configured lower axis limit: ___________ ° Determined lower axis limit: ___________ °		
	Specified upper axis limit: ___________ ° Configured upper axis limit: ___________ ° Determined upper axis limit: ___________ °		
4	Axis 4 has been correctly configured and checked.		
	Specified lower axis limit: ___________ ° Configured lower axis limit: ___________ ° Determined lower axis limit: ___________ °		
	Specified upper axis limit: ___________ ° Configured upper axis limit: ___________ ° Determined upper axis limit: ___________ °		
5	Axis 5 has been correctly configured and checked.		
	Specified lower axis limit: ___________ ° Configured lower axis limit: ___________ ° Determined lower axis limit: ___________ °		
	Specified upper axis limit: ___________ ° Configured upper axis limit: ___________ ° Determined upper axis limit: ___________ °		

No.	Activity	Yes	Not relevant
6	Axis 6 has been correctly configured and checked.		
	Specified lower axis limit: ___________ ° Configured lower axis limit: ___________ ° Determined lower axis limit: ___________ °		
	Specified upper axis limit: ___________ ° Configured upper axis limit: ___________ ° Determined upper axis limit: ___________ °		

No.	Activity	Yes	Not relevant
9	The correct functioning of the reference stop has been checked?		

City, date	KUKA College,
Signature	

By signing, the signatory confirms the correct and complete performance of the safety acceptance test.

What you should now know:

1. What is the difference between an axis range and a workspace?

. . . .

2. How many monitoring spaces can be signaled with one safe output?

. . . .

7 Configuration of SafeRangeMonitoring with WorkVisual

7.1 Overview of functionality

The following contents are explained in this training module:

- Operator control – WorkVisual
- Downloading a project from the controller
- Configuring SafeRangeMonitoring
- Loading the project back onto the controller and activating it

7.2 WorkVisual graphical user interface

Brief description of WorkVisual

The **WorkVisual** software package is the engineering environment for KR C4 controlled robotic cells.

Functionalities:

- Transferring projects from the robot controller to WorkVisual

  On any robot controller to which a network connection is established, any project can be selected and transferred to WorkVisual. This is also possible if this project is not yet present on this PC.
- Comparing a project with another project and accepting differences where necessary

  A project can be compared with another project. This can be a project on a robot controller or a locally saved project. The user can decide for each individual difference whether to leave the state as in the current project or to transfer the state from the other project.
- Transferring projects to the robot controller
- Configuring and connecting field buses
- Editing the safety configuration
- Programming robots offline
- Managing long texts
- Diagnostic functionality
- Online display of system information about the robot controller
- Configuring traces, starting recordings, evaluating traces (with the oscilloscope)

Structure and function of the WorkVisual graphical user interface

Not all elements on the graphical user interface are visible by default, but they can be shown or hidden as required.

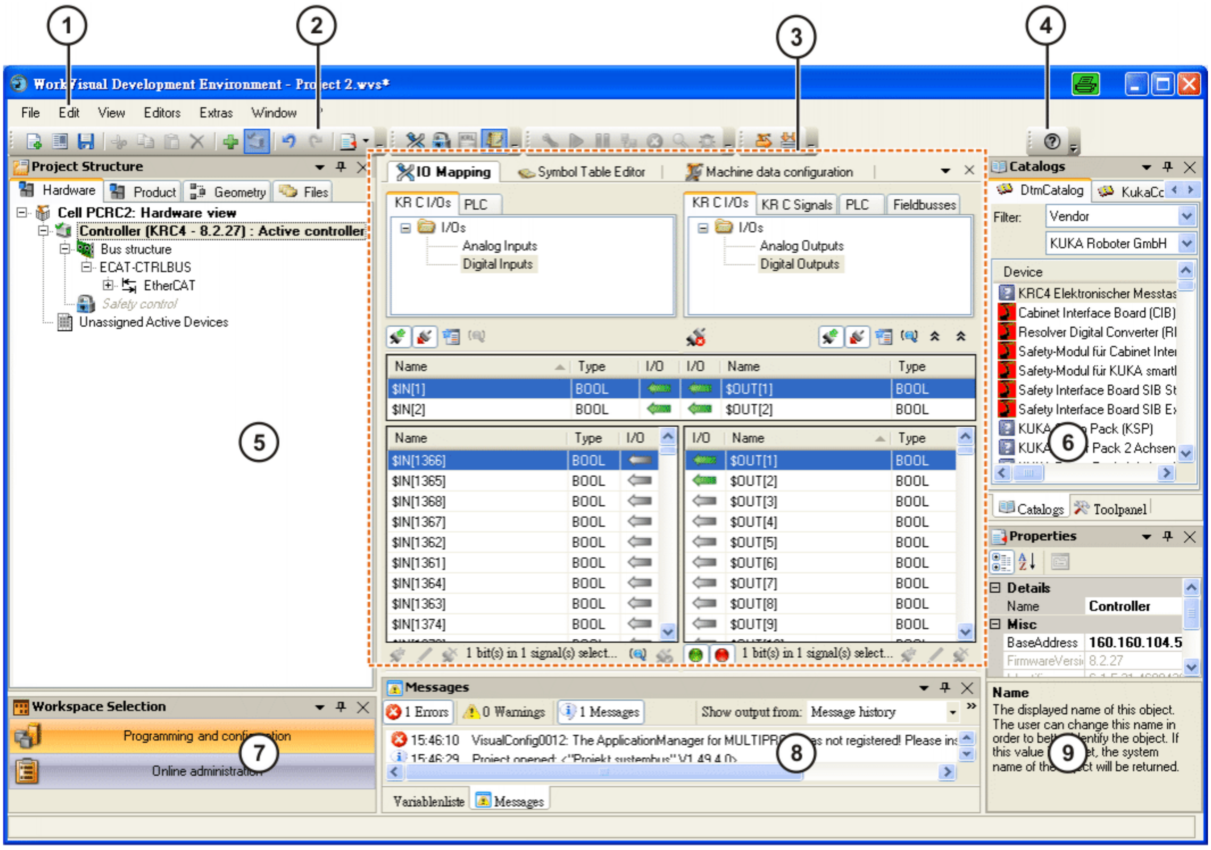


Fig. 7-1: Overview of the graphical user interface

Item	Description
1	Menu bar
2	Button bars
3	Editor area If an editor is open, it is displayed here. More than one editor can be open simultaneously – as shown here in the example. In this case, they are stacked one on top of the other and can be selected via tabs.
4	Help button
5	"Project structure" window
6	"Catalogs" window All catalogs added are displayed in this window. The elements in the catalogs can be inserted by Drag&Drop on the **Hardware** or **Geometry** tabs in the window.
7	**Workspace Selection** window
8	**Messages** window
9	**Properties** window If an object is selected, its properties are displayed in this window. The properties can be changed. Individual properties in gray boxes cannot be changed.

There are other windows and editors available in addition to those shown here. These can be displayed via the **Window** and **Editors** menus.

Project Structure window

- The “Project structure” window contains the following tabs:

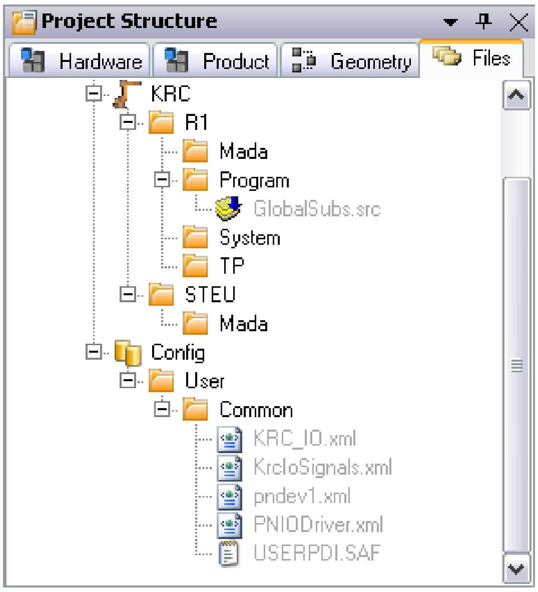


Fig. 7-2: Example: automatically generated files in gray

- **Hardware:**

  The **Hardware** tab shows the relationship between the various devices. Here, the individual devices can be assigned to a robot controller.
- **Product:**

  The **Product** tab is used mainly in WorkVisual Process and less in WorkVisual. This displays all the tasks required for a product in a tree structure.
- **Geometry:**

  The **Geometry** tab is used mainly in WorkVisual Process and less in WorkVisual. This displays all the 3D objects used in the project in a tree structure.
- **Files:**

  The **Files** tab contains the program and configuration files belonging to the project.

  Coloring of file names:
  - Files generated automatically (with **Generate code** function): Gray
  - Files inserted manually in WorkVisual: Blue
  - Files transferred to WorkVisual from the robot controller: Black

Project Explorer

- The Project Explorer offers the following options:

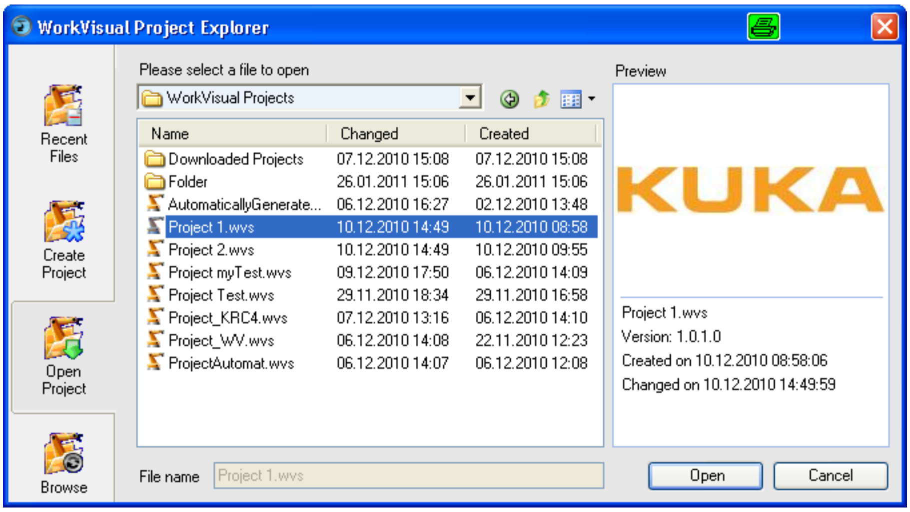


Fig. 7-3: Project Explorer

- **Recent Files** displays the most recently used files
- **Create Project** generates
  - a new, empty project
  - a new project using a template
  - a new project on the basis of an existing project
- **Open Project** is used to open existing projects
- **Browse** is required in order to load a project from the robot controller.

Procedure for loading a project with WorkVisual

On every robot controller **to which a network connection is established**, a project can be selected and transferred to WorkVisual.

This is also possible if this project is not yet present on this PC.

The project is saved in the directory: My Files\WorkVisual Projects\Downloaded Projects.

This is how it is done:

1. Select the menu sequence: **File** > **Browse for project**. The **Project Explorer** is opened. On the left, the **Search** tab is selected.
2. In the **Available cells** area, expand the node of the desired cell. All the robot controllers of this cell are displayed.
3. Expand the node of the desired robot controller. All projects are displayed.
4. Select the desired project and click on **Open**. The project is opened in WorkVisual.

7.3 Creating a safety configuration with WorkVisual

Description of safety configuration

The safety configuration can be edited in WorkVisual. The changes always apply to the robot controller which is currently set as active.

Before a project can be transferred to the robot controller, the corresponding software option (SafeOperation/SafeRangeMonitoring) must be installed.

When a project is transferred to the real robot controller, the safety configuration is always transferred at the same time.

Both **KUKA.SafeOperation** and **KUKA.SafeRangeMonitoring** can be configured.

Configuration menu

The active controller here is: **1OG4_R06**

The safety configuration is located in the project structure under Hardware:

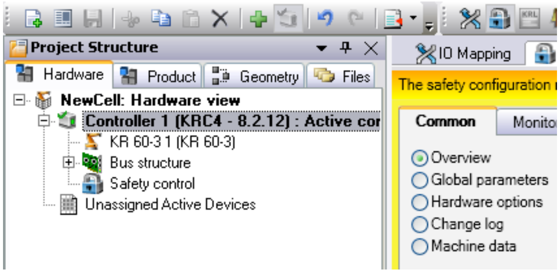


Fig. 7-4: Project structure

The configuration cannot be opened until the controller is active and the correct machine data are assigned.

The overview is the start window, which has a similar layout to that on the smartPAD.

The desired option must be selected here.

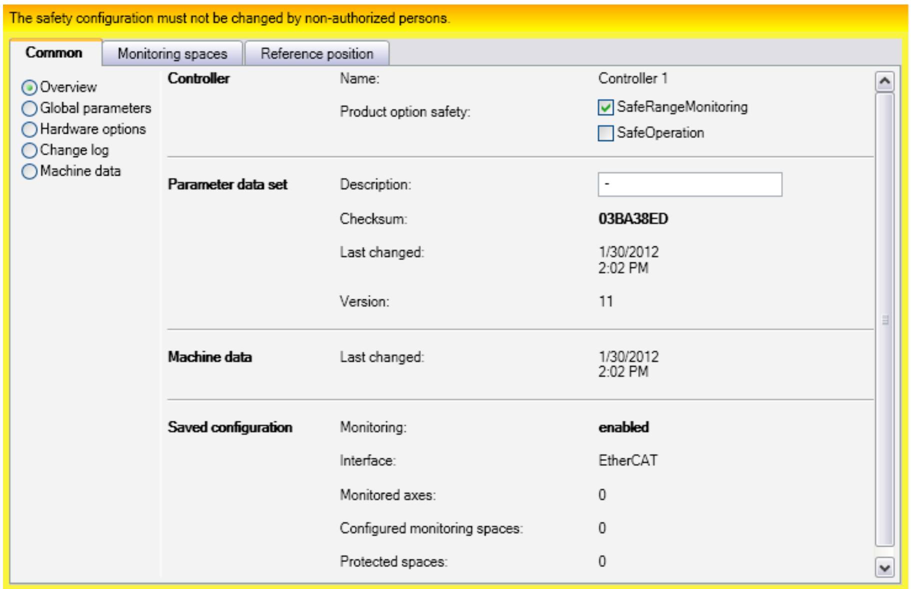


Fig. 7-5: Overview of SafeRangeMonitoring

Button	Description
Global parameters	The global parameters of the safety configuration can be defined.
Hardware options	The hardware settings can be defined.
Change log	Every modification to the safety configuration and every saving operation are automatically logged.
Machine data	The machine data of the safety controller are displayed here.
Controller	Name of the controller ■ Check box for activation of SafeRangeMonitoring ■ Check box for activation of SafeOperation
Parameter data set	■ Description ■ Checksum of the safety configuration ■ Time stamp of the safety configuration (date and time last saved) ■ Safety configuration version

Button	Description
Machine data	Time stamp of the safety-relevant machine data (date and time last saved)
Saved configuration	■ State of the safe monitoring (activated or deactivated) ■ Name of the active bus system ■ Number of velocity-monitored axes

The monitoring is activated under “Global parameters”.

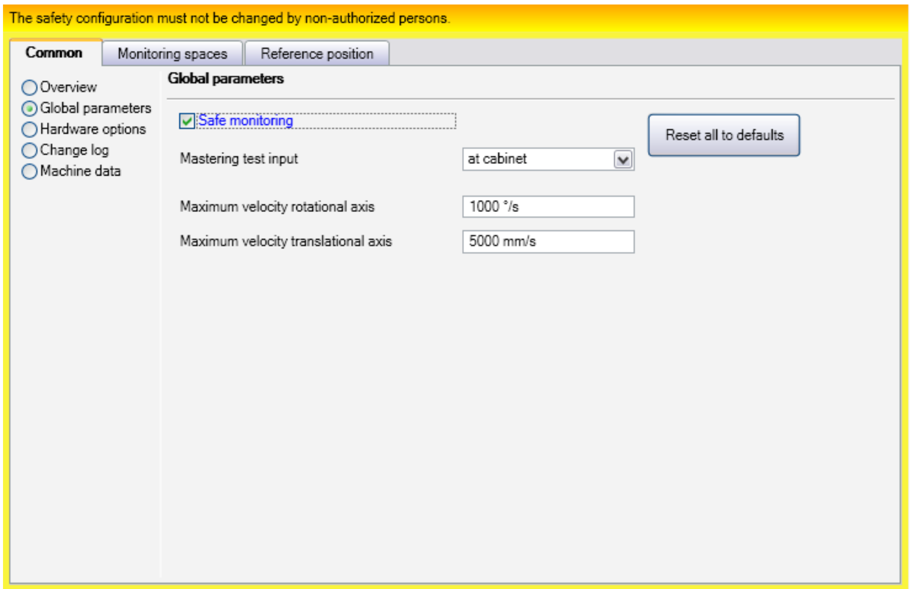


Fig. 7-6: Global parameters

Parameter	Description
Safe monitoring	**Check box activated** = safe monitoring is activated. **Check box deactivated** = safe monitoring is deactivated. Default: Check box deactivated
Mastering test input	**at cabinet** = reference switch is connected to the robot controller. **via ProfiSafe** = reference switch is connected via PROFIsafe. Default: at cabinet
Maximum velocity rotational axis	Limit value for maximum rotational velocity ■ **...1000°/s...** Default: 1000°/s
Maximum velocity linear axis	Limit value for maximum velocity of a linear axis ■ **...5000... mm/s** Default: 5000 mm/s
Reset all to defaults	Sets all values to factory settings.

The customer interface is defined under “Hardware options”.

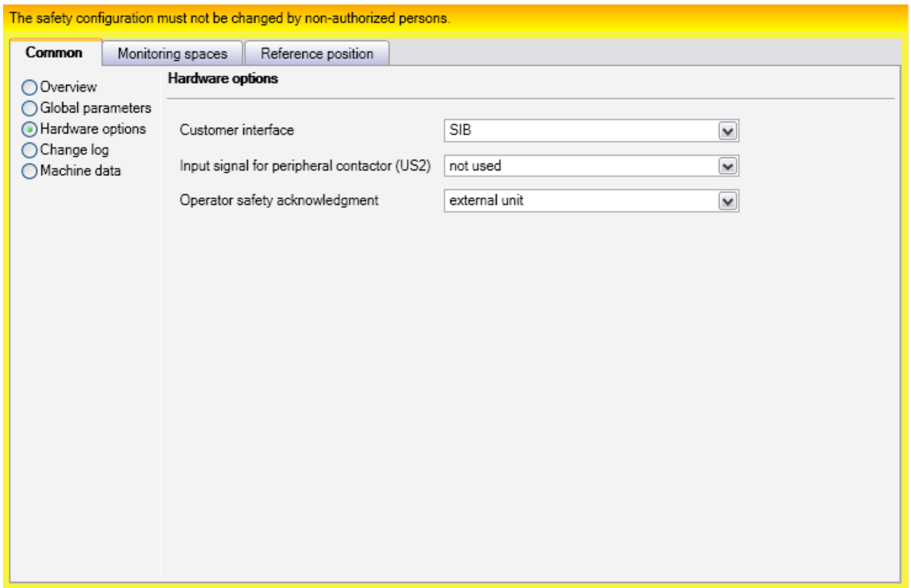


Fig. 7-7: Hardware options

Parameter	Description
Customer interface	Select here which interface is used: ■ **ProfiSafe** ■ **SIB** ■ **SIB, Extended SIB** ■ **SIB with operating mode output** ■ **SIB with operating mode output, Extended SIB** This option is available with System Software version 8.2.4 or higher.
Input signal for peripheral contactor (US2)	Main contactor 2 can be used as a peripheral contactor, i.e. as a switching element for the power supply to peripheral devices. **Deactivated**: Peripheral contactor is not used. (Default) **By external PLC**: The peripheral contactor is switched by an external PLC via input US2. **By KRC**: The peripheral contactor is switched in accordance with the motion enable. If motion enable is present, the contactor is energized.
Operator safety acknowledgement	If the Operator Safety signal is lost and reset in Automatic mode, it must be acknowledged before operation can be continued. **By acknowledgement button**: Acknowledgement is given e.g. by an acknowledgement button (situated outside the cell). Acknowledgement is communicated to the safety controller. The safety controller re-enables automatic operation only after acknowledgement. **External unit**: Acknowledgement is given by the system PLC.

Every modification to the safety configuration and every saving operation are automatically logged. The log is displayed here.

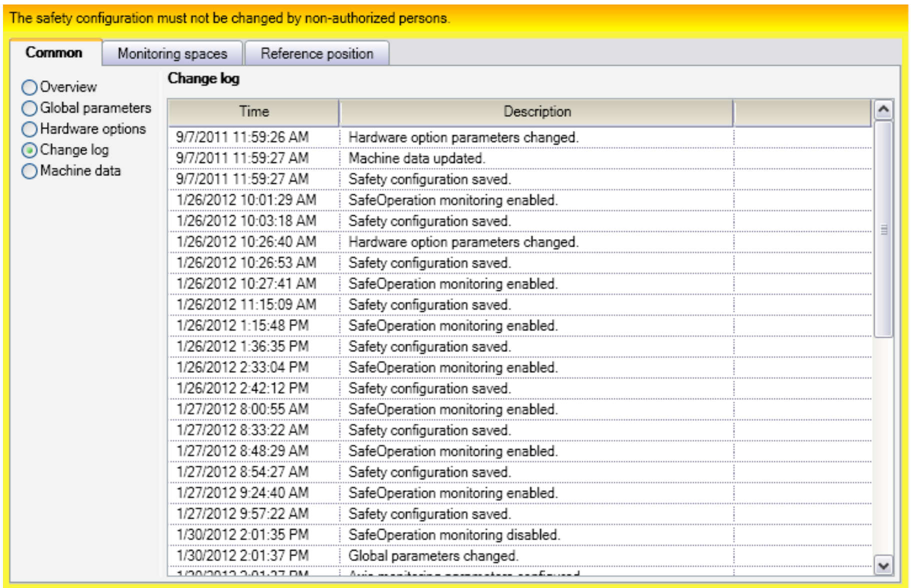


Fig. 7-8: Change log

The machine data of the safety controller are displayed here.

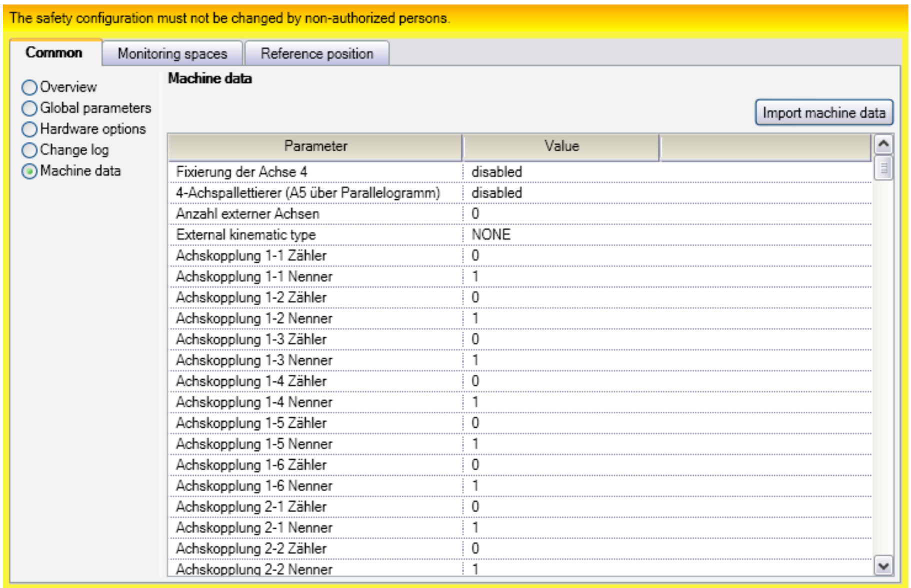


Fig. 7-9: Displaying machine data in WorkVisual

The remaining configuration of monitoring spaces is analogous to configuration on the smartPAD.

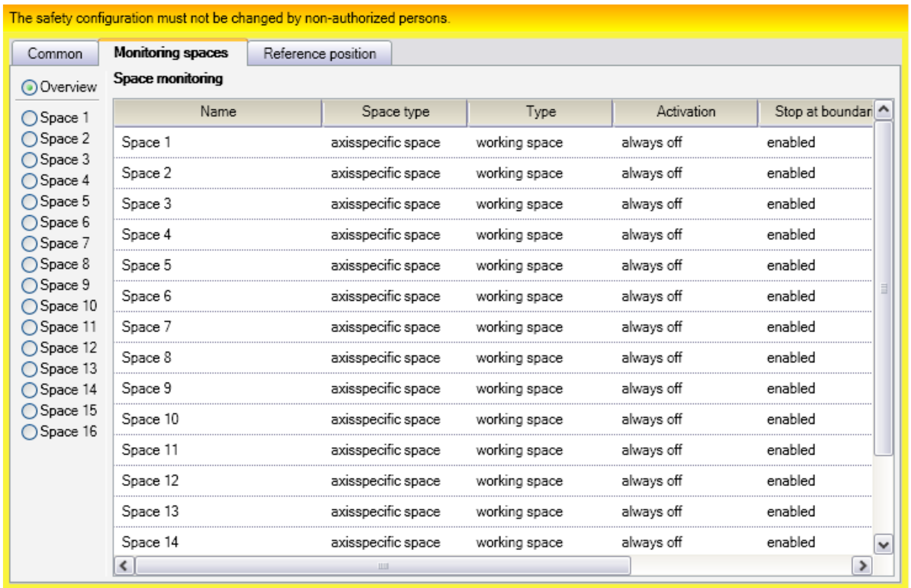


Fig. 7-10: Configuring the monitoring range

Procedure

1. The project has been downloaded or the robot controller has been added and set as active.

   Note: The controller can be set to active by double-clicking on it.
2. Select the menu sequence **Editors** > **Safety configuration**. The **Safety parameters** window is opened.

   Alternatively, click on the  icon.
3. If this has not already been done:

   In the **Overview** area of the **Common** tab, select the option used: Safe-Operation, SafeRangeMonitoring, or none.
4. If SafeOperation or SafeRangeMonitoring is used: Activate the **Safe monitoring** checkbox in the **Global parameters** area of the **Common** tab. (Only then are the monitoring functions displayed and can be edited.)
5. Modify the parameters as required.
6. Close the **Safety parameters** window.

7.4 Transferring the project to the KR C4 controller

Description

This procedure is used to transfer the project from WorkVisual to the real robot controller.

If the project is also to be activated, the user group “Expert” must be active on the real controller.

> If a project was transferred to the real robot controller at an earlier time and has not yet been activated then this will be overwritten if a further project is transferred.
> Transferring and activating a project overwrites a project of the same name that already exists on the real robot controller (after a request for confirmation).

This section describes the procedure for transferring a project to a real robot controller with KUKA System Software/ VW System Software 8.2.

Transferring and activating a project

1. Click on the **Deploy…** button in the menu bar. The **Project deployment** window is opened.

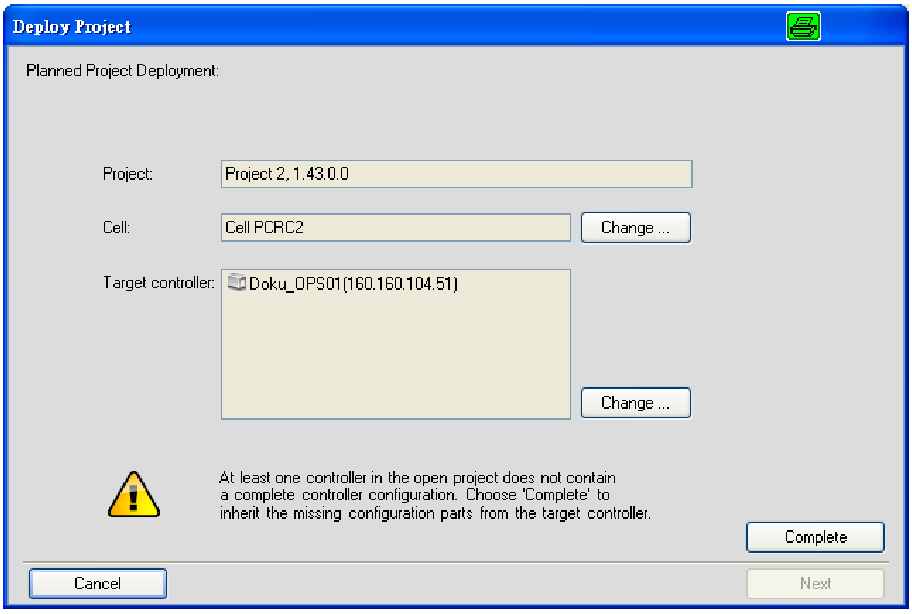


Fig. 7-11: Overview with warning about incomplete configuration

2. If the project has never been transferred back to WorkVisual from a robot controller before, it will not yet contain all the configuration files. This is indicated by a message. (The configuration files include machine data files, safety configuration files and many others.)
   - If this message is not displayed: Continue with step 13.
   - If this message is displayed: Continue with step 3.
3. Click on **Complete**. The following confirmation prompt is displayed: **The project must be saved and the active controller will be reset! Do you want to continue?**
4. Answer the query with **Yes**. The **Merge projects** window is opened.

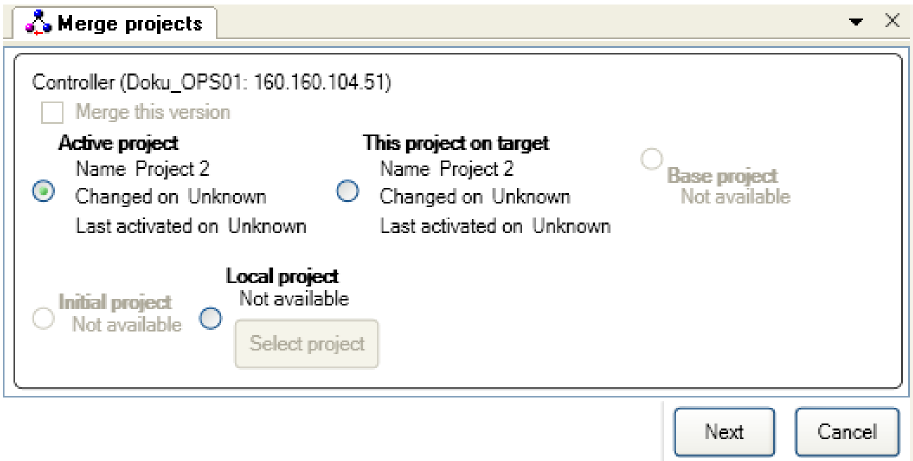


Fig. 7-12: Selecting a project for "Complete"

5. Select a project from which the configuration data are to be transferred, e.g. the active project on the real robot controller.

> If a RoboTeam project is being transferred to the robot controller, always select the active project.

6. Click on **Next**. A progress bar is displayed. (If the project contains more than one controller, a bar is displayed for each one.)

7. When the progress bar is full and the message **Status: Ready for merge** is displayed: Click on **Show differences**.

   The differences between the projects are displayed in an overview.

8. For each difference, select which state to accept. This does not have to be done for all the differences at one go.

   If suitable, the default selection can also be accepted.

> If a RoboTeam project is being transferred to the robot controller for the first time, accept the complete state of the real robot controller. For this, activate the check box for every robot controller in the **Comparison value (2)** column.

9. Press **Merge** to transfer the changes.
10. Repeat steps 8 to 9 as many times as required. This makes it possible to work through the different areas bit by bit.

    When there are no more differences left, the following message is displayed: **No further differences were detected.**
11. Close the **Comparing projects** window.
12. Click on the button **Deploy...** in the menu bar. The overview of the cell assignment is displayed again. The message about the incomplete configuration is no longer displayed.

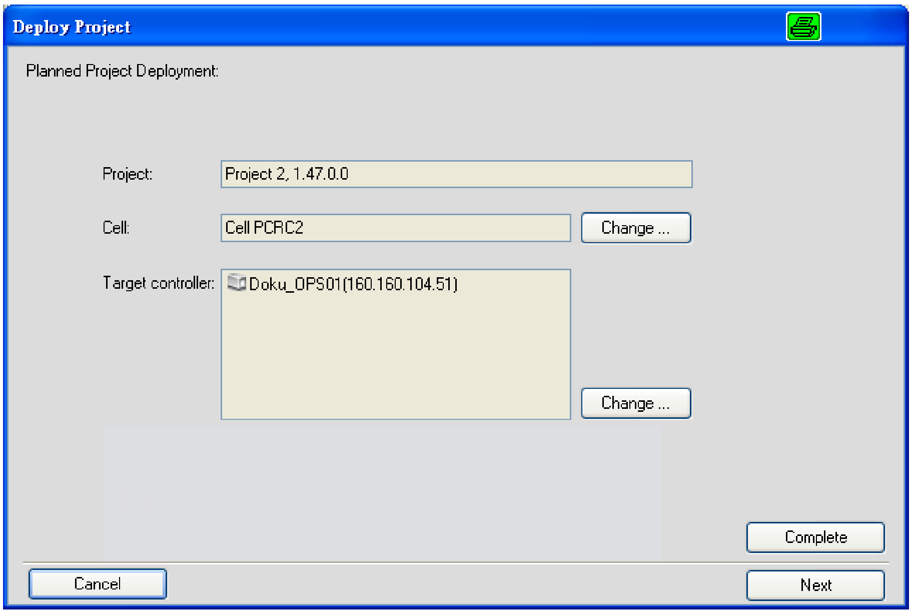


Fig. 7-13: Overview

13. Click on **Next**. Program generation begins. When the progress indicator bar reaches 100%, the program is generated and the project is transferred.
14. Click on **Activate**.

> **WARNING** In the operating modes AUT and AUT EXT, the project is activated without any request for confirmation if there are only program changes.

15. Only in operating modes T1 and T2: The KUKA smartHMI displays the request for confirmation *Do you want to activate the project [...]?*. In addition, a message is displayed as to whether the activation would overwrite a project, and if so, which.

If no relevant project will be overwritten: Confirm with **Yes** within 30 seconds.

16. An overview is displayed of the changes which will be made in comparison to the project that is still active on the robot controller. The check box **Details** can be used to display details about the changes.

> **⚠ WARNING** If changes are listed in the overview under the heading **Safety-relevant communication parameters**, this means that the behavior of the Emergency Stop and "Operator safety" signal may have changed compared with the previous project.
> After activation of the project, the Emergency Stop and the "Operator safety" signal must be checked for safe functioning. If the project is activated on several robot controllers, this check must be carried out for every robot controller. Failure to carry out this check may result in death to persons, severe physical injuries or considerable damage to property.

17. The overview displays the request for confirmation *Do you want to continue?*. Confirm with **Yes**. The project is activated on the robot controller. A confirmation is displayed in WorkVisual.

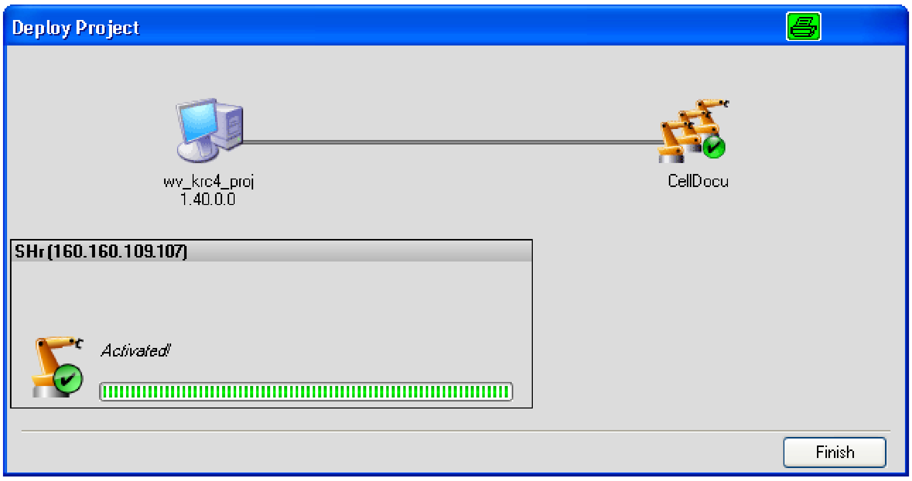


Fig. 7-14: Confirmation in WorkVisual

18. Close the **Project deployment** window by selecting **Finish**.
19. If the request for confirmation on the robot controller is not answered within 30 seconds, the project is still transferred, but is not activated on the robot controller. The project can then be activated separately.

Checking the safety configuration of the robot controller

The safety configuration of the robot controller must be checked in the following cases:

- After activation of a WorkVisual project on the robot controller
- Generally after changes to the machine data (independent of WorkVisual).

> **⚠ WARNING** If the safety configuration is not checked and updated where necessary, it may contain incorrect data. Death to persons, severe physical injuries or considerable damage to property may result.

Procedure

1. Select the menu sequence **Configuration** > **Safety configuration**.
2. The safety configuration checks whether there are any relevant deviations between the data in the robot controller and those in the safety controller.
3. The following situations can now occur:

a. If there are no deviations, the **Safety configuration** window is opened. No message is displayed. No further action is necessary.

b. If there are deviations regarding the machine data, a dialog message is displayed. This indicates which machine data in the robot controller deviate from those in the safety controller.

   The message asks whether the safety controller should be updated. Confirm the request with **Yes**.

   The system asks whether the deviations should now be accepted. Confirm the request with **Yes**.

c. The safety configuration also checks whether there are any other deviations (other than in the machine data) between the robot controller and the safety controller.

   If so, the **Troubleshooting wizard** window is opened. A description of the problem and a list of possible causes is displayed. The user can select the applicable cause. The wizard then suggests a solution.

7.5 Importing or exporting a safety configuration

Description

The Export / Import function can be used, for example, to import an existing safety configuration to another project, thereby copying it.

The safety configuration is saved as an SCG file.

Importing a safety configuration

1. Select the menu sequence **File** > **Import / Export**. The **Import/Export Wizard** window is opened.
2. Select **Import safety configuration** and click on **Next**.
3. Navigate to the path where the SCG file is located and select it. Click on **Open**.
4. Click on **Finish**.
5. If the configuration was imported successfully, this is indicated by a message. Close the **Import/Export Wizard** window.

After importing a safety configuration to WorkVisual, this safety configuration must be checked! If this is not done, the safety configuration can lead to the possibility of the robot being operated with incorrect data when the project is subsequently transferred to the real robot controller.

Export safety configuration

1. Select the menu sequence **File** > **Import / Export**. The **Import/Export Wizard** window is opened.
2. Select **Export safety configuration** and click on **Next**.
3. Specify a directory and a file name. Click on **Finish**.
4. If the configuration was exported successfully, this is indicated by a message. Close the **Import/Export Wizard** window.

7.6 Printing the safety configuration

Description

This function can be used to print the parameters of an existing safety configuration for use as a checklist.

Procedure

1. Select the menu sequence **File** > **Print**. The **Print** window is opened.

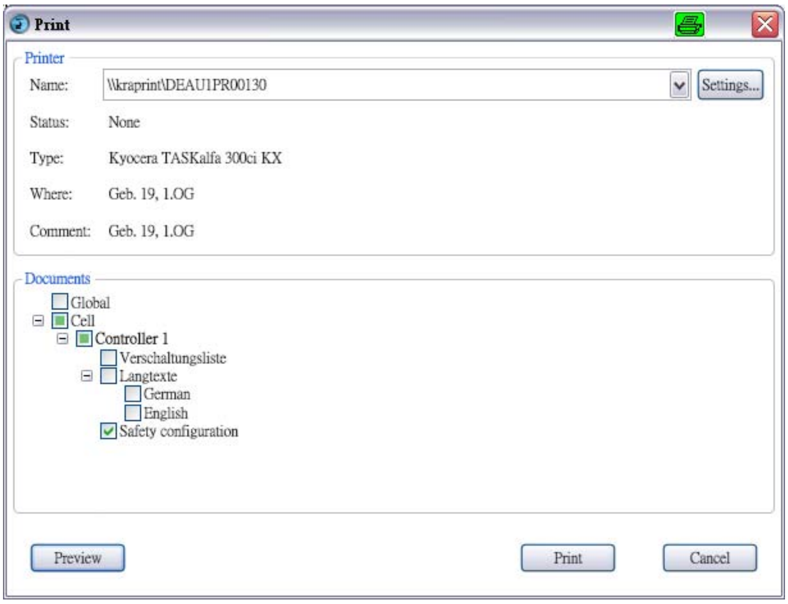
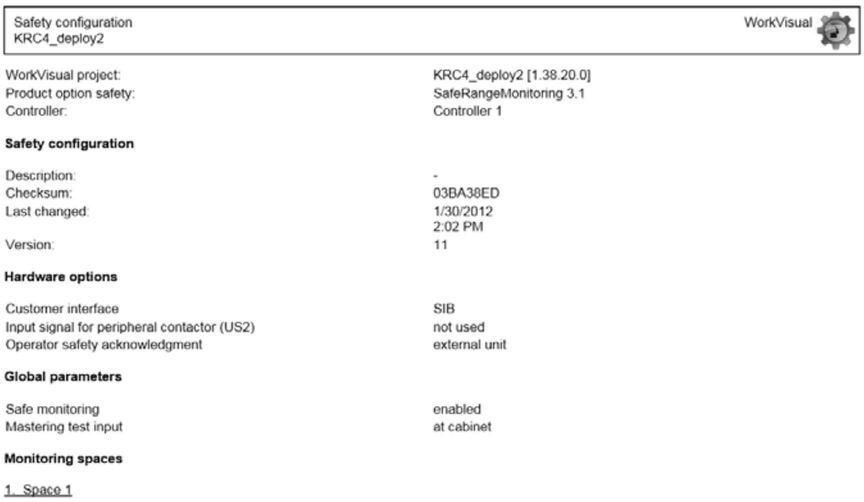


Fig. 7-15: Configuration printout

2. Select the correct printer under **Name** and the cell and the safety configuration under **Documents**.
3. The lists with the settings can be viewed under **Preview**.


Safety configuration
KRC4_deploy2

WorkVisual

WorkVisual project:	KRC4_deploy2 [1.38.20.0]
Product option safety:	SafeRangeMonitoring 3.1
Controller:	Controller 1

Safety configuration

Description:	-
Checksum:	03BA38ED
Last changed:	1/30/2012 2:02 PM
Version:	11

Hardware options

Customer interface	SIB
Input signal for peripheral contactor (US2)	not used
Operator safety acknowledgment	external unit

Global parameters

Safe monitoring	enabled
Mastering test input	at cabinet

Monitoring spaces

1. Space 1

Fig. 7-16: Print preview

4. If everything is correct, press **Print** and close. The lists are printed.

7.7 Exercise: Defining axis-specific monitoring spaces with WorkVisual

Aim of the exercise

On completion of this exercise, you will be able to carry out the following tasks:

- Work with WorkVisual
- Define axis-specific workspaces offline
- Transfer created configurations to the controller

Task description

⚠ WARNING The safety regulations contained in the safety instruction must be observed!

1. Load the current safety configuration from the controller onto your PC. Open the safety configuration.

2. Now enter the area of axis 1 under monitoring space 2 in the configuration tool in such a way that a safe output (MR 2) is set if the robot moves in this space. The robot is not to be stopped when leaving the alarm space.
3. Test the monitoring space in accordance with the test instructions.

Checklist for KUKA College

A separate checklist must be completed for each monitoring space.

- Serial number of the robot: ____________________
- Activation code: ____________________
- Time stamp:_________________________
- Monitoring space checked (name, number): __________
- Type of space (protected space or workspace): ____________________
- Stop at boundaries (TRUE|FALSE): __________
- Reference stop (TRUE|FALSE): __________
- Space-specific velocity __________mm/s
- Space-specific velocity valid in: __________
- Safe tool used in test of velocity or space limit: ____________
- Always active (TRUE|FALSE): __________

The configured limit values must successively be violated to demonstrate the correct functioning of the monitoring space.

No.	Activity	Yes	Not relevant
1	Axis 1 has been correctly configured and checked.		
	Specified lower axis limit: __________ ° or mm Configured lower axis limit: __________ ° or mm Determined lower axis limit: __________ ° or mm		
	Specified upper axis limit: __________ ° or mm Configured upper axis limit: __________ ° or mm Determined upper axis limit: __________ ° or mm		
2	Axis 2 has been correctly configured and checked.		
	Specified lower axis limit: __________ ° Configured lower axis limit: __________ ° Determined lower axis limit: __________ °		
	Specified upper axis limit: __________ ° Configured upper axis limit: __________ ° Determined upper axis limit: __________ °		
3	Axis 3 has been correctly configured and checked.		
	Specified lower axis limit: __________ ° Configured lower axis limit: __________ ° Determined lower axis limit: __________ °		
	Specified upper axis limit: __________ ° Configured upper axis limit: __________ ° Determined upper axis limit: __________ °		

No.	Activity	Yes	Not relevant
4	Axis 4 has been correctly configured and checked.		
	Specified lower axis limit: ___________ ° Configured lower axis limit: ___________ ° Determined lower axis limit: ___________ °		
	Specified upper axis limit: ___________ ° Configured upper axis limit: ___________ ° Determined upper axis limit: ___________ °		
5	Axis 5 has been correctly configured and checked.		
	Specified lower axis limit: ___________ ° Configured lower axis limit: ___________ ° Determined lower axis limit: ___________ °		
	Specified upper axis limit: ___________ ° Configured upper axis limit: ___________ ° Determined upper axis limit: ___________ °		
6	Axis 6 has been correctly configured and checked.		
	Specified lower axis limit: ___________ ° Configured lower axis limit: ___________ ° Determined lower axis limit: ___________ °		
	Specified upper axis limit: ___________ ° Configured upper axis limit: ___________ ° Determined upper axis limit: ___________ °		

No.	Activity	Yes	Not relevant
9	The correct functioning of the reference stop has been checked?		

City, date	KUKA College,
Signature	

By signing, the signatory confirms the correct and complete performance of the safety acceptance test.

What you should now know:

1. What must be done first with WorkVisual in order to be able to edit the safety configuration?

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2. What must be taken into consideration when transferring a finished configuration?

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8 System variables

8.1 Overview of system variables

The following contents are explained in this training module:

- SafeRangeMonitoring variable overview

8.2 Defining SafeRangeMonitoring system variables

Description of the variable

> ⚠ **WARNING** These signals are not redundant in design and can supply incorrect information. Do not use these signals for safety-relevant applications.

The following variable groups exist:

- Variables for override reduction
- Variables for the mastering test
- Variables for diagnosis
- Variables for the brake test

Variables for override reduction

The variables for override reduction are contained in the file $CUSTOM.DAT in the directory C:\KRC\ROBOTER\KRC\STEU\MADA.

Variable	Description
$SR_OV_MSG_SHOW	A message is generated in Automatic mode if the velocity is reduced by means of the override reduction function **TRUE** = message generated in Automatic mode **FALSE** = no message generated in Automatic mode Default: **FALSE** **Note**: The variable is reset to FALSE after every cold start.
$SR_OV_RED	Maximum velocity limit with override reduction activated for the velocity. The percentage value refers to the lowest activated velocity limit. ■ **10 … 95 %** Default: **95 %**
$SR_TIME_N	Safety factor for override reduction in monitoring spaces ■ **0.0 … 1.0** Default: **0.1** = 10 % safety factor **Note**: The variable is declared in $MACHINE.DAT and may only be modified in consultation with KUKA Roboter GmbH.

Variable	Description
$SR_VEL_RED	Activation of the override reduction function for the velocity **TRUE** = override reduction is activated. **FALSE** = override reduction is not activated. Default: **TRUE**
$SR_WORKSPACE_RED	Activation of override reduction for the activated monitoring spaces **TRUE** = override reduction is activated. **FALSE** = override reduction is not activated. Default: **TRUE**

Variables for the mastering test

All signals for the mastering test are declared in the file $MACHINE.DAT in the directory C:\KRC\ROBOTER\KRC\STEU\MADA.

Variable	Description
$MASTERINGTEST_REQ_INT	Internal request of the mastering test from the safety controller **TRUE** = mastering test is requested. **FALSE** = mastering test is not requested. Default: FALSE
$MASTERINGTEST_REQ_EXT	External request for mastering test, e.g. from the safety PLC **TRUE** = mastering test is requested. **FALSE** = mastering test is not requested. Default: FALSE **Note**: This signal is declared in the file KRC:\ROBOTER\KRC\STEU\MADA\$MACHINE.DAT and must be assigned to a suitable input.
$MASTERINGTESTSWITCH_OK	Check of the function of the reference switch **TRUE** = reference switch is OK. **FALSE** = reference switch is defective. Default: TRUE

Variables for SafeRangeMonitoring diagnosis

All signals for diagnosis are declared in the file $MACHINE.DAT in the directory C:\KRC\ROBOTER\KRC\STEU\MADA.

Variable	Description
$SR_AXISSPEED_OK	Reduced axis acceleration exceeded **TRUE** = axis velocity has not been exceeded. **FALSE** = axis velocity has been exceeded. The variable is set to FALSE when the excessive value is detected and then set immediately back to TRUE.
$SR_DRIVES_ENABLE	Enabling of the drives by the safety controller **TRUE** = drives are enabled. **FALSE** = drives are not enabled.

Variable	Description
$SR_MOVE_ENABLE	Enabling by the safety controller **TRUE** = motion enable **FALSE** = no motion enable
$SR_SAFEMON_ACTIVE	Status of the safe monitoring **TRUE** = monitoring is activated. **FALSE** = monitoring is not activated.
$SR_SAFEREDSPEED_ACTIVE	Status of the monitoring of the reduced velocity **TRUE** = monitoring is activated. **FALSE** = monitoring is not activated.

Variables for the brake test

All signals for the brake test are declared in the file $MACHINE.DAT in the directory C:\KRC\ROBOTER\KRC\STEU\MADA.

By default, the input signal is routed to $IN[1026], i.e. there is no active request for a brake test.

The output signals are preset to FALSE. There is no compelling need to assign outputs to them. It is only necessary to assign outputs if there is a need to be able to read the signals (e.g. via the variable correction function or program execution.)

Signal	Description
$BRAKETEST_REQ_EX	External brake test request ■ **TRUE** = brake test is being requested externally (e.g. by PLC). The robot controller confirms the signal with $BRAKETEST_REQ_INT = TRUE and generates message 27004. ■ **FALSE** = brake test is not being requested externally.
$BRAKETEST_MONTIME	Stop due to elapsed monitoring time ■ **TRUE** = robot was stopped due to elapsed monitoring time. Acknowledgement message 27002 is generated. ■ **FALSE** = acknowledgement message 27002 is not active. (Not generated, or has been acknowledged.)
$BRAKETEST_REQ_INT	Internal brake test request ■ **TRUE** = message 27004 is active. The signal is not set to FALSE again until a brake test is carried out with a positive result, i.e. with message 27012. ■ **FALSE** = brake test is not requested (either internally or externally).

Signal	Description
$BRAKETEST_WORK	Performance of the brake test ■ **TRUE** = brake test is currently being performed. ■ **FALSE** = brake test is not being performed. If no defective brakes have been detected, message 27012 is generated. Edge **TRUE** --> **FALSE**: ■ Test was successfully completed. No brake is defective. Message 27012 is generated. ■ Or at least 1 defective brake was detected and the robot has moved to the parking position. ■ Or the program was canceled during execution of the brake test.
$BRAKES_OK	Brake state ■ Edge **FALSE** --> **TRUE**: Output was set to FALSE by the previous brake test. The brake test was carried out again and no defective brake was detected. ■ Edge **TRUE** --> **FALSE**: A brake has just been detected as defective. Message 27007 is generated.
$BRAKETEST_WARN	Warning that wear limit has been reached ■ Edge **FALSE** --> **TRUE**: At least 1 brake has been detected as having reached the wear limit. Message 27001 is generated at the same time. ■ Edge **TRUE** --> **FALSE**: Output was set to TRUE by the previous brake test. The brake test was carried out again and no worn brake was detected.

8.3 Exercise: Defining system variables (optional)

Aim of the exercise

On completion of this exercise, you will be able to carry out the following tasks:

- Work with system variables
- Make assignments in $MACHINE.DAT
- Work with the inputs and outputs on the control panel

Task description

> ⚠ **WARNING** The safety regulations contained in the safety instruction must be observed!

1. Open the file $MACHINE.DAT in the directory C:\KRC\ROBOTER\KRC\STEU\MADA.
2. Assign free inputs and outputs to the system variables or use the preset values in the brackets:

   $MASTERINGTEST_REQ_EXT ==> E... (e.g. input 12)

   $MASTERINGTEST_REQ_INT ==> A... (e.g. output 9)

   $MASTERINGTESTSWITCH_OK ==> A... (e.g. output 10)
3. Now externally force a reference run by activating the input you have configured for this purpose. Execute the program **Startup** manually.
4. Open the file $MACHINE.DAT in the directory C:\KRC\ROBOTER\KRC\STEU\MADA.
5. Assign inputs/outputs to the following system variables:

   $BRAKETEST_REQ_EX ==> input 13

   $BRAKETEST_REQ_INT ==> output 14

$BRAKETEST_WORK ==> output 15

$BRAKES_OK ==> output 16

6. Now externally force a brake test by activating input 13 and execute the program **Startup** manually.
7. Observe the state of the configured outputs!

What you should now know:

1. Which signal is used to force a reference run externally?

. . . .

. . . .

. . . .

2. Which signal is used to force a brake test externally?

. . . .

. . . .

9 Diagnosis

9.1 Overview of diagnosis

The following contents are explained in this training module:

- Diagnosis with the diagnostic monitor
- Messages during operation

9.2 Starting the diagnostic monitor

Diagnostic monitor functions

The **diagnostic monitor** makes it possible to display diagnostic data concerning numerous software modules of the kernel system.

This allows errors in the hardware or configuration to be localized.

For SafeOperation there is a separate module with the name **Bus process data image (system bus X48).**

This can be visualized in two ways:

- Directly on the local HMI
- Via the WorkVisual software on the master control station

The following image shows an overview of the different safe inputs and outputs of SafeOperation / SafeRangeMonitoring:

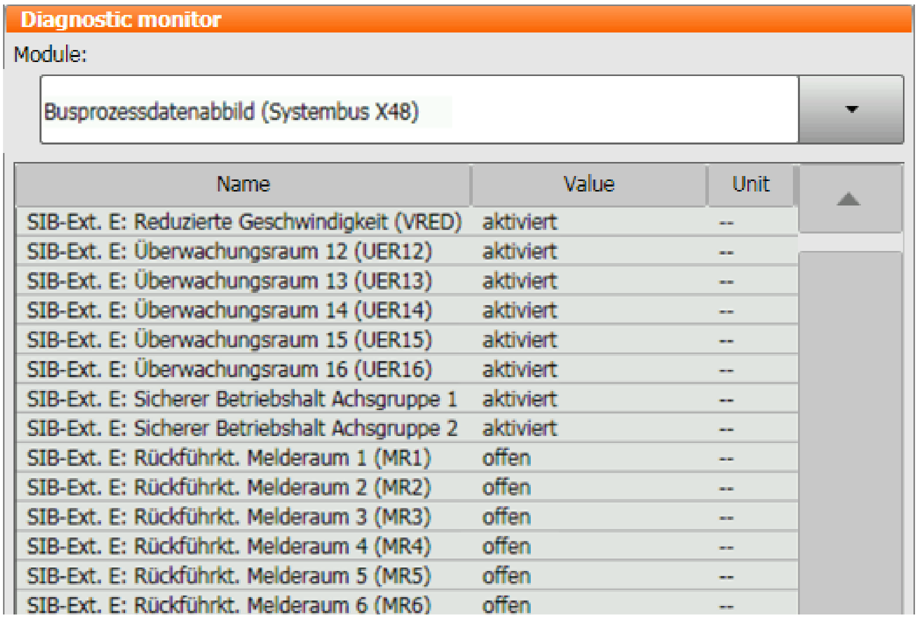

Fig. 9-1: Bus process data image

Procedure

1. Select **Diagnosis** > **Diagnostic monitor** in the main menu.
2. Select the **Bus process data image** *[System bus X48]* module in the **Module** box.
3. Evaluate the safe input and output data.

9.3 Messages during operation

Configuration or operator errors may result in error messages in an application.

No.	Message	Cause	Remedy
15020	*Start-up mode active, EMERGENCY STOP has LOCAL effect ONLY*	Start-up mode of the safety controller is activated.	Deactivate Start-up mode.
15035 15036	*No tool activated in safety controller* *Ackn.: No tool activated in safety controller*	No tool is active in the safety controller. Tool 1 must be active.	Activate tool 1.
15045 15046	*Error at mastering reference switch* *Ackn.: Error at mastering reference switch*	The CIB signals an error at the reference switch input.	Check the reference switch connection. Check the reference switch and exchange if defective.
15047	*Mastering test required (internal)*	The mastering test is requested internally after the robot controller has booted or after mastering.	Perform mastering test.
15048	*Ackn.: Mastering test time interval expired*	The monitoring time has elapsed.	Perform mastering test.
15049	*Mastering test failed*	The mastering test has failed. The cause of the error is indicated in a separate message. See messages no. 15051 to 15066.	Eliminate error and carry out mastering test.
15050	*Reference stop*	Reference stop is activated. (= function **Stop if mastering test not yet done**)	Perform mastering test.
15051	*Ackn.: Mastering test position not reached*	It was not possible to move to the reference position.	Check the reference position in the program MasRef_USER.SRC and in the safety configuration and teach again if required. Check mastering.
15052	*Ackn.: Mastering reference switch not actuated*	Robot is in mastering position and the reference switch is not actuated: ■ Reference switch is defective. ■ The distance between the reference switch and the reference position is too great.	Exchange the reference switch. Check the reference position in the program MasRef_USER.SRC and in the safety configuration and teach again if required. Check mastering.
15053	*Ackn.: Not all mastering reference groups referenced*	The mastering test for one or more reference groups could not be carried out because of a missing reference position or because of a missing motion away from the reference position.	Teach the missing reference positions or missing motion away from the reference position in the program MasRef_USER.SRC.
15054	*Workspace monitoring functions deactivated (mastering error)*	Loss of mastering of one or more axes: the workspace monitoring functions are deactivated.	Master unmastered axes.

No.	Message	Cause	Remedy
15065 15066	*Ackn.: Level at mastering reference switch is unexpectedly "low"* *Level at mastering reference switch is unexpectedly "low"*	The reference switch is actuated although no mastering test is currently being carried out.	Check the reference switch and exchange if defective.
15079 15080	*Monitoring space no. {Number of monitoring space} violated* *Ackn.: Monitoring space no. {Number of monitoring space} violated*	One or more axes are no longer situated in the permissible range of the monitoring space. The monitoring was only activated after the robot had moved over the space limit.	Move the robot back into the permissible range of the monitoring space in CRR mode.
15081 15082	*Monitoring space no. {Number of monitoring space} exceeded* *Ackn.: Monitoring space no. {Number of monitoring space} exceeded*	One or more axes have exceeded the permissible range of the monitoring space. The monitoring was already activated when the robot moved over the space limit.	Move the robot back into the permissible range of the monitoring space in CRR mode.

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