Controller

KR C2 edition2005

KUKA.SafeRobot

Release 1.0
for KUKA System Software (KSS) Release 5.4

Issued: 28 Sep 2005 Version: 03

Contents

1 Introduction

1.1 Target group for this documentation

This user manual is intended for use by the system integrator.

Info
Information about KUKA training programs is available from www.kuka.com or from your KUKA Roboter GmbH representative.

1.2 Short description

"KUKA.SafeRobot" – based on the controller KR C2 with ESC safety logic – is an automatically controlled programmable robot system for use in automated production systems.

"KUKA.SafeRobot" features safe hardware and software and allows the position of the robot to be continuously monitored. The principle of the safe functions is based on safe monitoring of limit values.

If the robot moves outside the permitted ranges the Electronic Safety Circuit (ESC) safety system disconnects the drives.

A basic description of the individual functions of the "KUKA.SafeRobot" technology is contained in Chapter 3 of this documentation. Chapter 4 describes the individual components of "KUKA.SafeRobot", its layout and interfaces.

Commissioning is described in Chapter 4. In this chapter the installation of the configuration program and its operation are also described.

Information on operation can be found in Chapter 6.

Chapter 7 contains information on programming and program examples for extended KRL programs, brake tests and reference runs, as well as the extended "SPS.SUB".

The "KUKA.SafeRobot" error messages are described in Chapter 8.

Chapter 9 describes the removal and installation of the Safe RDC.

Chapter 10 contains a summary of the technical data and the checklists for the acceptance test of "KUKA.SafeRobot".

"KUKA.SafeRobot" satisfies category 3 to EN 954-1, and SIL 2 to EN 61508, and has been approved by the German Technical Inspectorate (TÜV).

1.3 Conditions, instructions, restrictions

1.3.1 Robot hardware

"KUKA.SafeRobot" can be used with all KUKA robot variants in the following list:

Low payloads

KR 6; KR 6 KS; KR 6 ARC;
KR 16; KR 16 CR; KR 16 EX; KR 16 KS; KR 16 L6; KR 16 L6 ARC; KR 16 L6 KS

Medium payloads

KR 30-3; KR30-3 KS; KR 30 HA; KR 30 L16;
KR 60-3; KR 60-3 KS; KR 60 HA

High payloads

KR 100 comp, KR 140 comp, KR 200 comp;
KR 150-2; KR; KR 150-2 K; KR 150 W; KR 180-2; KR 180-2 K; KR 180 L130-2 CR;
KR 210-2; KR 210-2 K; KR240-2

Heavy-duty robots

KR 360; KR 500

1.3.2 Controller hardware

The following are necessary for "KUKA.SafeRobot":

- Robot controller KR C2 edition2005 with KPC 2004
- ESC CI 3 Tech
- MFC3 Tech and
- KCP2 standard edition2005 with brought-out operating modes T1 and T2.
- Safe RDC
- DSE-IBS C33
- Reference switch with actuating plate

1.3.3 System software

KUKA System Software (KSS) Release 5.4.

1.3.4 Restrictions

Note

Master/slave axes and CR (RoboTeam) are not supported..

The functions of "KUKA.SafeRobot" do not replace the limit switches and mechanical end stops for range limitation of robot axes A1, A2 and A3.

Because of the design and quality assurance the robot mechanical parts operate safely. The probability of malfunctions is very slight, nevertheless there remains a small residual risk.

Therefore even in ranges which are safeguarded only by the control technology of the robot, cognizance must be taken of possible incorrect movements by the robot.

1.4 Terms and abbreviations used

The following terms and abbreviations are used in this documentation:

Working range	Permissible range within which the robot can work and move; all the robot axes are contained within this range
Process range	Permissible range within which the robot may move
Safety range	Non-permissible range within which the robot may neither work nor move
Axis range 1	Continuously monitored axis range
Axis ranges 2 ... 7	Monitoring using safe inputs
Axis ranges 8 ... 10	Status reporting using safe outputs
Reduced velocity range	Permissible range within which the robot may move but only at reduced velocity
I/O	**I**nputs / **O**utputs
KR C2 edition2005	Control cabinet for KUKA robots
KCP2 Standard edition2005	**K**UKA **C**ontrol **P**anel - Teach pendant with extended functionality for KUKA.SafeRobot
HMI	**H**uman **M**achine **I**nterface
KRL	**K**UKA **R**obot **L**anguage

KUKA.SafeRobot	Controller variant with software-controlled axis disconnection
Safe RDC	Circuit board for the **R**esolver **D**igital **C**onverter with safe monitoring
Safe RDC Box	Housing for the Safe RDC (in the robot base)
I/O Print	Piggyback circuit board on the Safe RDC
ESC	**E**lectronic **S**afety **C**ircuit – safety logic of the controller
ENA	**E**xterner **N**OT-**A**US – ESC input triggering a category 1 EMERGENCY STOP
QE	Local STOP – ESC input triggering a category 0 EMERGENCY STOP
MFC 3 Tech	**M**ulti **F**unction **C**ard – plug-in card in the PC
CI 3 Technology	Safety bus for monitoring safety-relevant components.
DSE-IBS	**D**igital **S**ervo **E**lectronics – piggyback circuit board on the MFC 3 Tech
KGD	**K**UKA **G**uiding **D**evice – unit for manual movement of axes
EMT	**E**lectronic **M**easuring **T**ool
Meas	"Fast Measurement" input
DSP	**D**igital **S**ignal **P**rocessor
SSI	**S**tandard **S**erial **I**nterface
PLC	**P**rogrammable **L**ogic **C**ontroller (within customer's system)
CR	**C**ooperating **R**obots (RoboTeam, Option)

1.5 Service

Procedure for dealing with queries or problems

If any questions or problems arise while using the robot system, please first try to solve them with the aid of these operating instructions.

Should this not bring about the desired result, please contact one of our Service Centers. So that the situation can be resolved easily and quickly, it is advisable for you to be at the robot with access to the control panel when you call.

The operating handbook [**KR C2edition2005** / **Introduction** / **Service**] will tell you what information is important and which service support point you should contact.

2 Safety

2.1 Symbols and icons

The following safety symbols and pictograms are used in these operating instructions:

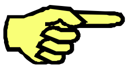
2.1.1 Safety symbols

Text passages indicated by the following safety symbols are relevant to safety and must be observed.

WARNING!
Following these safety warnings carefully can prevent personal injury.

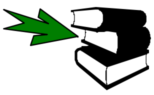
CAUTION!
Following these safety warnings carefully can prevent material damage.

2.1.2 Icons



NOTE
Indicates special features for particular attention.

Info
Indicates passages which are of particular significance or are useful for greater understanding.



See also
Indicates sections or chapters containing further information and explanations.

2.2 General information

- All pertinent safety regulations as well as the booklet [Safety and Installation Instructions] are to be observed when working on the system.
- The KUKA safety chapter [KR C Safety, General] is supplied with the robot system and must be read and understood before commencing work.
- The safety instructions in the KR C2 Operating Handbook must be observed.

During operation of the robot a continuous ground conductor circuit must exist between the control cabinet and the robot (equipotential bonding).

Before commissioning the robot this must be tested by means of a ground conductor measurement to DIN EN 60204-20.2.

If the result of the test is negative, the robot must not be put into operation!

2.3 Additional safety instructions for “KUKA.SafeRobot”

- Installation, exchange and service work on this option or individual components thereof may be performed only by qualified personnel specially trained for this purpose and acquainted with the risks involved.
- The axis ranges that are configured using the configuration and parameterization program must be checked by movement.
- Changes to the configuration are recorded and must be checked by moving once again to the parameterized limits.
- Changes to the machine data must be checked for correctness.
- Changes to the safety parameters must be checked for correctness.
- A reference run (mastering test) must be performed before the start of each shift and before starting work.
- A brake test must be performed before the start of each shift and before starting work.
- After reinstallation, maintenance work and after every change to the system, the system must be subjected to an acceptance test in accordance with the checklists in Section 5.5.

2.4 Designated use

"KUKA.SafeRobot" is intended exclusively for use in accordance with the properties described in this documentation.

Using the system for any other or additional purpose is considered contrary to its designated use. The manufacturer cannot be held liable for any damage resulting from such use. The risk lies entirely with the user.

In addition the regulations and instructions contained in the KR C user manual, chapter [KR C Safety, General], section [Designated Use] must be complied with.

"KUKA.SafeRobot" must be used only in conjunction with an effective safeguard (safety fence, light barrier etc.).

The applicable national laws, regulations, standards and guidelines must be observed and complied with.

"KUKA.SafeRobot" can be used in conjunction with all KUKA applications for which it is approved. Examples of KUKA applications are:

- Welding
- Assembly
- Handling
- Coating
- Measuring/inspection
- Machining

2.5 Liability

"KUKA.SafeRobot" has been designed, built, and programmed using state-of-the-art technology and in accordance with the recognized safety rules. Nevertheless, improper installation of this system or its employment for a purpose other than the intended one may constitute a risk to life and limb of operating personnel or of third parties, or cause damage to or failure of the control cabinet, resulting in damage to or failure of the entire robot system and other material property.

"KUKA.SafeRobot" may only be used in technically fault-free condition in accordance with its designated use and only by safety-conscious persons who are fully aware of the risks involved in its operation. Connection and use must be carried out in compliance with this documentation.

3 Product description

3.1 General

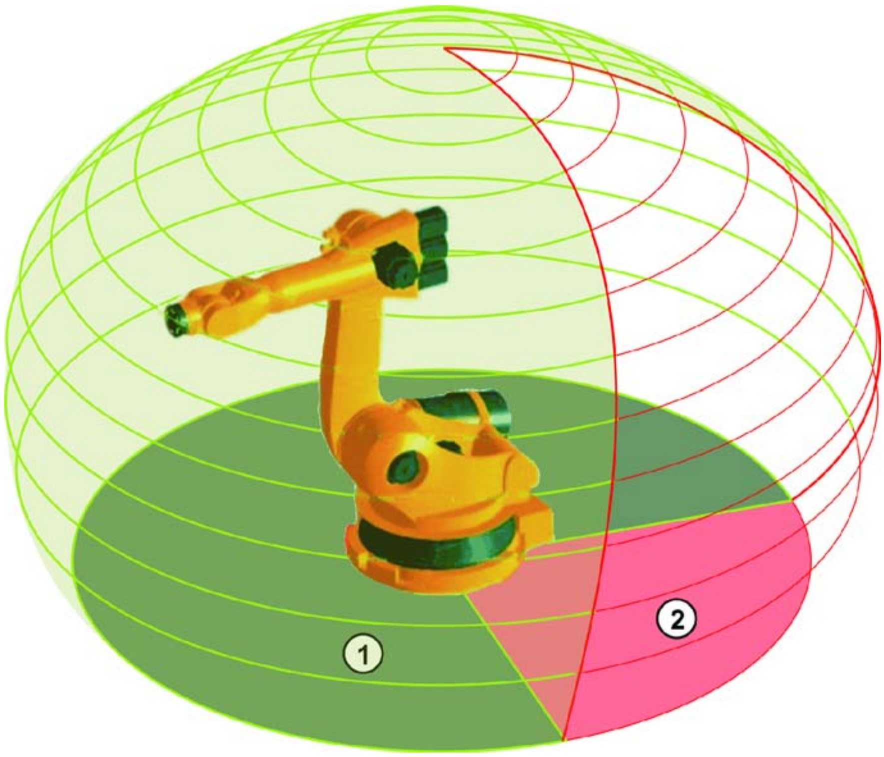
The “KUKA.SafeRobot” technology permits continuous safe monitoring of the movement limits of a robot.

In contrast to mechanical-electrical technology for working range monitoring using mechanical limit switches on the axis ranges, “KUKA.SafeRobot” evaluates signals obtained from the resolvers on the motor shafts. This permits quick reaction times.

“KUKA.SafeRobot” permits not only the monitoring of the main axes (A1 ... A3) but also the monitoring of the wrist axes (A4 ... A6).

“KUKA.SafeRobot” features safe hardware and software-based functions and allows the position of the robot to be continuously monitored, with safe axis disconnection.

3.1.1 Ranges



1 Working range
2 Safety range

Fig. 1 Working range, safety range

“KUKA.SafeRobot” allows working ranges and safety ranges to be defined for the robot. These ranges are shown schematically in Fig. 1.

Definition of the ranges

- **Working range** All the robot axes are contained within this range
- **Safety range** No axes may be in this range

The monitoring of the ranges is performed by "KUKA.SafeRobot" using redundantly safeguarded position monitoring with detection of the respective axis positions. The axis ranges can thus easily be restricted and the safeguarded working ranges defined.

3.1.2 Configuration of the ranges

The configuration of the ranges is performed using the "KUKA.SafeRobot" configuration program. Detailed information on this can be found in Section 5.3 of this documentation.

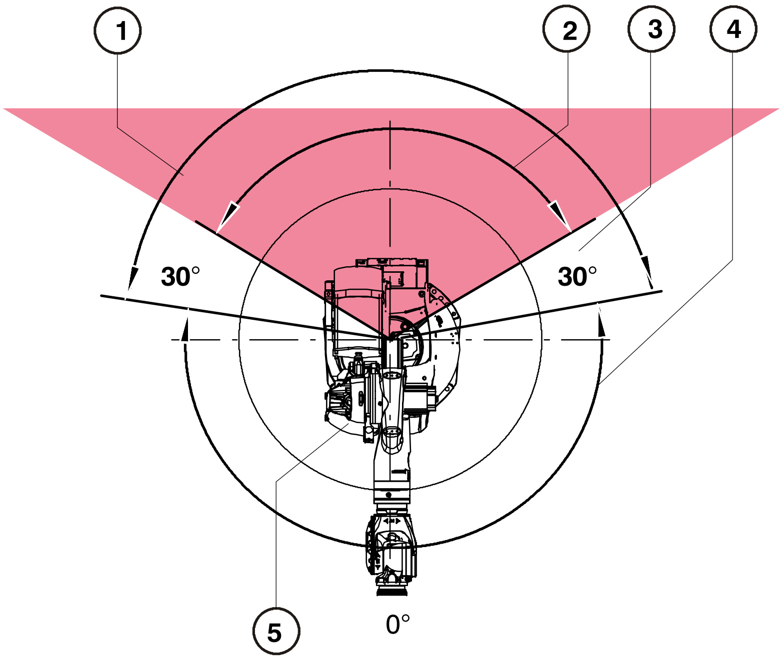
3.1.3 Braking reactions

Two types of STOP are defined as braking reactions in the event of an error or the violation of configured settings:

- **STOP 0**:
  If, at the point in time when the robot moves into a non-permissible range, the monitoring of this range is active, the robot will be stopped with a category 0 stop (STOP 0). To trigger a STOP 0 the ESC signal "QE" is set to LOW via a safe output of the Safe RDC. This leads to direct disconnection of the drives.
- **STOP 1**:
  If, at the point in time when monitoring is activated, the robot is already within a non-permissible range, the robot will be stopped with a category 1 stop (STOP 1).
  To trigger a STOP 1 the ESC signal "ENA" is set to LOW via a safe output of the Safe RDC. This leads to delayed disconnection of the drives.

3.1.4 Braking distance of the robot mechanical system (stopping distance)

When the robot is stopped due to triggering of a monitoring function, the drives are disconnected and the brakes are applied. Due to the mass inertia and other influences, the robot has a certain stopping distance.



1	Safety range without stopping distances	4	Actual working range
2	Actual safety range	5	Robot
3	Braking distance (max. stopping distance)		

Fig. 2 Working range, safety range, braking distance

Fig. 2 shows schematically the stopping distance (braking ramp), when the robot is stopped. The extent of the controlled braking ramp, and thus the actual braking distance, depends on the direction of the path and the kinetic energy of the robot at the time of disconnection.

The braking distance of the robot at maximum velocity is approx. 30°. The exact value can only be determined by measuring the stopping distance.

3.2 Functions

3.2.1 Safe functions

The safe functions include:

- Safe reduced velocity/acceleration (axis-specific)
- Safe reduced velocity (Cartesian) at the flange
- Safe position sensing system
- Safe axis range monitoring
- Safe operational stop
- Safe stop (ESC function)
- Monitoring of the robot mastering
- Brake test
- Safe disconnection of drives in accordance with “STOP 0” or “STOP 1”

3.2.2 Conditions for the safe monitoring of the robot

The following conditions must be satisfied for the safe monitoring of the robot:

- The safety parameters have been confirmed in the configuration program (see Chapter 7 of this documentation).
- The KUKA.SafeRobot acceptance test has been performed successfully in accordance with the checklists (see Section 5.5 of this documentation).

Exceptions to this are the braking test (see Section 5.4.1) and the reference run (see Section 5.4.2).

3.2.3 Monitoring of the safe inputs and outputs

To ensure the safety of the digital inputs and outputs of the Safe RDC, their functions are checked cyclically during operation.

This entails monitoring of the

- inputs for cross-connections and dual-channel operation

and the

- outputs for cross-connections, short circuits and cable breaks

In the event of a fault, the robot will be stopped (STOP 0) and a message displayed.

3.2.4 Safe reduced velocity, axis-specific

This monitoring function "safe reduced velocity, axis-specific" is activated by a safe input on the Safe RDC. This causes limit values and actual values to be compared for every axis by the Safe RDC. If the actual velocity exceeds the limit value, the drives are disconnected (STOP 0).

Monitoring is active under the following conditions:
- Operating mode T1 (Test 1)
- Safe robot retraction activated
- Safe operational stop activated
- dV signal LOW activated

In the operating mode "Automatic" the monitoring of the safe reduced velocity is activated by an input "dV" to the Safe RDC.

3.2.5 Safe reduced velocity, Cartesian

The monitoring function "safe reduced velocity, Cartesian" to EN 775 relates to the flange center point and is used for monitoring the safe reduced velocity.

The Safe RDC calculates the respective Cartesian position and velocity of the flange, based on the resolver data. The velocity is monitored using a limit value configured with the aid of the configuration program.

Monitoring is active under the following conditions:
- Operating mode T1 (Test 1)
- Safe robot retraction activated
- Safe operational stop activated
- dV signal LOW activated

3.2.6 Safe position sensing system

The safe position sensing system operates via a dual-channel link to the Safe RDC.

The software checks the reported values for plausibility. If deviations are found, the robot will be stopped (STOP 0).

3.2.7 Safe axis range monitoring

A total of 10 axis ranges are available for the function “safe axis range monitoring”. Each axis range can be defined as a working range or safety range.

If a working or safety range is violated a corresponding message will be displayed. If the robot moves back into the permissible range, a corresponding acknowledgement message will be displayed.

The respective axis range is deactivated if a High signal is present at the input. After disconnection, the robot can only be moved into the permissible range in “safe retraction” mode.

The axis ranges are divided into three groups:

- **Axis range 1** Continuously monitored
- **Axis ranges 2 ... 7** Monitoring using safe inputs
- **Axis ranges 8 ... 10** Status reporting using safe outputs

Axis range 1

Axis range 1 is continuously monitored. If the configured axis range is exceeded the drives are disconnected and a category 0 stop performed (STOP 0).

Fig. 3 Axis range 1

Axis ranges 2 to 7 (safe inputs)

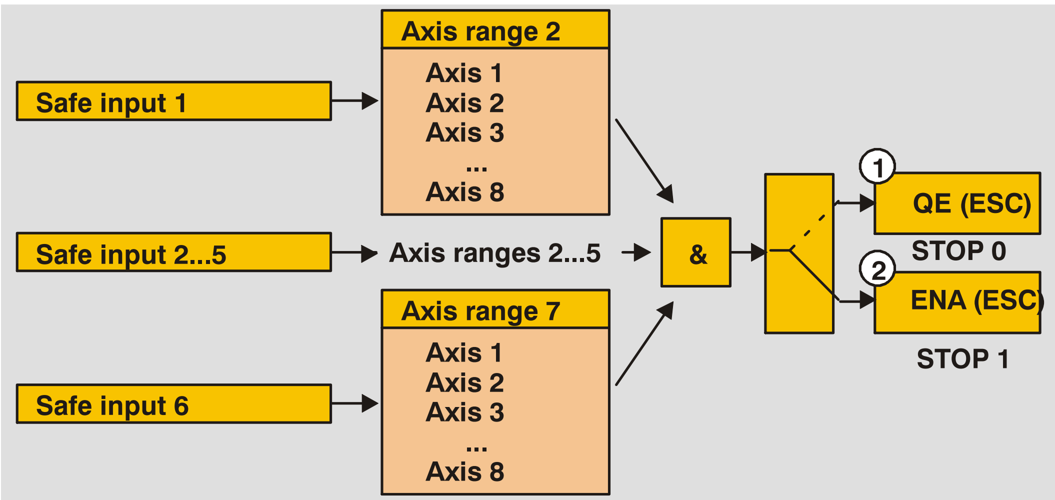
Axis ranges 2 to 7 are monitored by safe inputs 1 to 6. The assignment of the inputs to the respective axis ranges cannot be changed. The monitoring of these axis ranges is activated by the LOW signal for the respective axis range.

Info
The designation of the safe inputs has the following relationship with hardware and software:

Software	Hardware
Input 1	E0
Input 2	E1
...	...
Input 6	E5

The stop reaction of the axis ranges depends on how the range has been violated. The following applies here:

- If, at the point in time when the robot moves into a non-permissible range, the monitoring of this range is active, the robot will be stopped with a category 0 stop (STOP 0).
- If, at the point in time when monitoring is activated, the robot is already within a non-permissible range, the robot will be stopped with a category 1 stop (STOP 1).



1 STOP 0 Activated axis range has been violated
2 STOP 1 Violated axis range has been activated

Fig. 4 Axis ranges 2 to 7

The axis ranges 2 ... 7 can be configured as working ranges or safety ranges. This is done using the configuration program (see Section 5.3).

For each range the value can be set as:

- **FALSE** working range
- **TRUE** safety range

Axis ranges 8 to 10 (safe outputs)

For axis ranges 8 to 10, the safe outputs 1 to 3 signal whether the robot is in the respective permissible range. If the robot moves outside its permissible range the respective output goes to the LOW condition. This monitoring is always active.

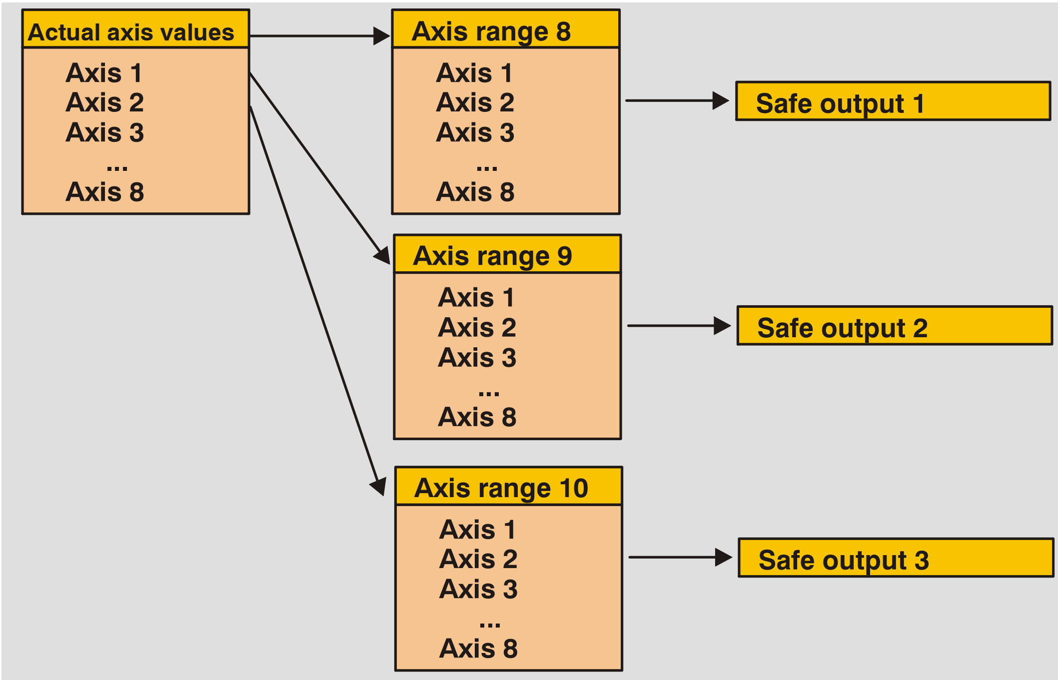


Fig. 5 Axis ranges 8 to 10

The axis ranges 8 ... 10 can be configured as working ranges or safety ranges. This is done using the configuration program (see Section 5.3).

For each range the value can be set as:

- **FALSE** working range
- **TRUE** safety range

The assignment of each axis range to the respective output is fixed. The monitoring of these axis ranges does not trigger a stop.

3.2.8 Safe operational stop

The function "Safe operational stop" initiates monitoring of all robot axes; the drives remain under control and the brakes are not applied. This function is activated by a safe input to the Safe RDC.

If these are not within a defined tolerance, the drive enable flag is withdrawn by means of a safe output and the robot is stopped (STOP 0).

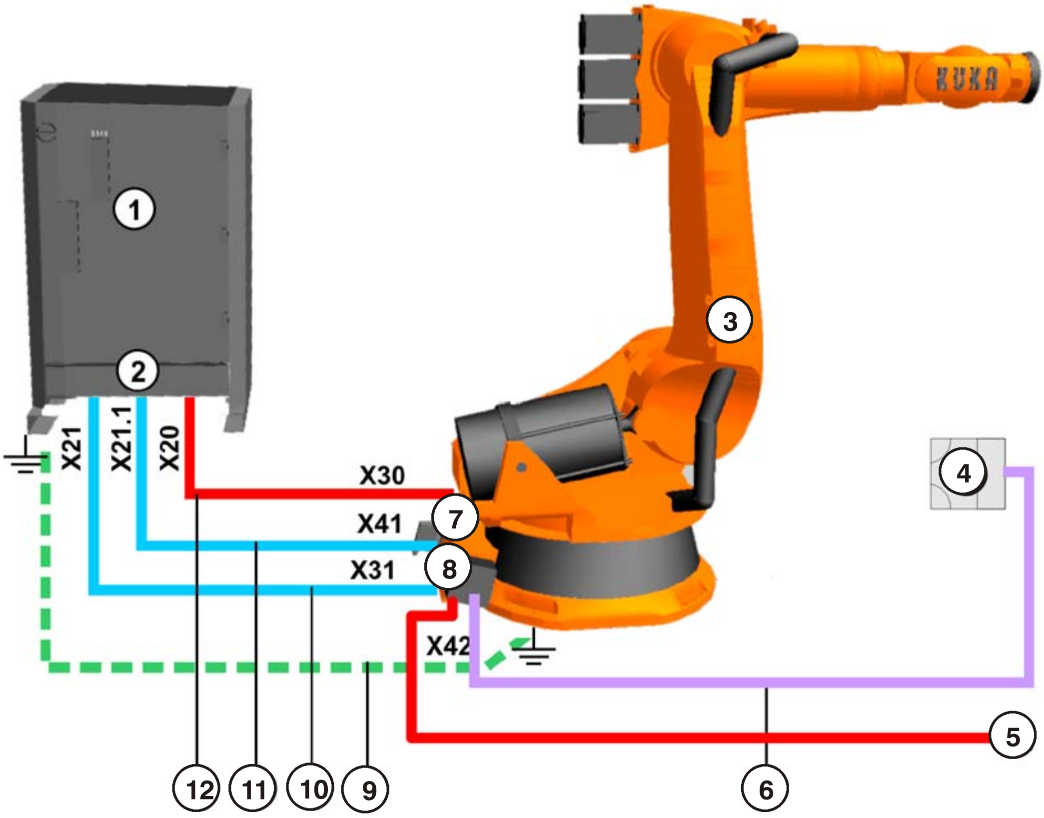
3.3 Configuration program

A configuration program is available for configuring and parameterizing the safe parameters.

The installation of this program is described in Section 5.2, and its operation is described in Section 5.3.

4 Layout, interfaces

4.1 Layout of robot and control cabinet



1	Control cabinet KR C2 edition2005	7	Junction box X01
2	SafeRobot interface	8	Safe RDC junction box
3	Robot	9	Ground conductor 16 mm^2 *)
4	Reference switch	10	Data cable X21 - X31
5	Periphery (safety PLC)	11	Data cable X21.1 - X41
6	Connecting cable X42 - XS Ref	12	Motor cable X20 - X30

*) Ground conductor necessary only for cable lengths > 25 m

Fig. 6 Layout of control cabinet, robot, SafeRobot

For detailed information regarding all connections, see circuit diagrams and cable listings supplied.

4.1.1 Junction boxes on the robot

The plug-in connections on the robot are located on the junction boxes on the base frame: on junction box X01 for the motor cable, on X02 for the data cable. The arrangement of the junction boxes and the associated connectors on the robot are as shown in the example in Fig. 7.

If connecting cables with a length > 25 m are used, a ground bolt must be provided on the base frame for the ground conductor (Fig. 25).

> The connectors for the motor cable X20 – X30 and data cables X21 – X31 and X21.1 – X41 are coded to avoid crossing over.

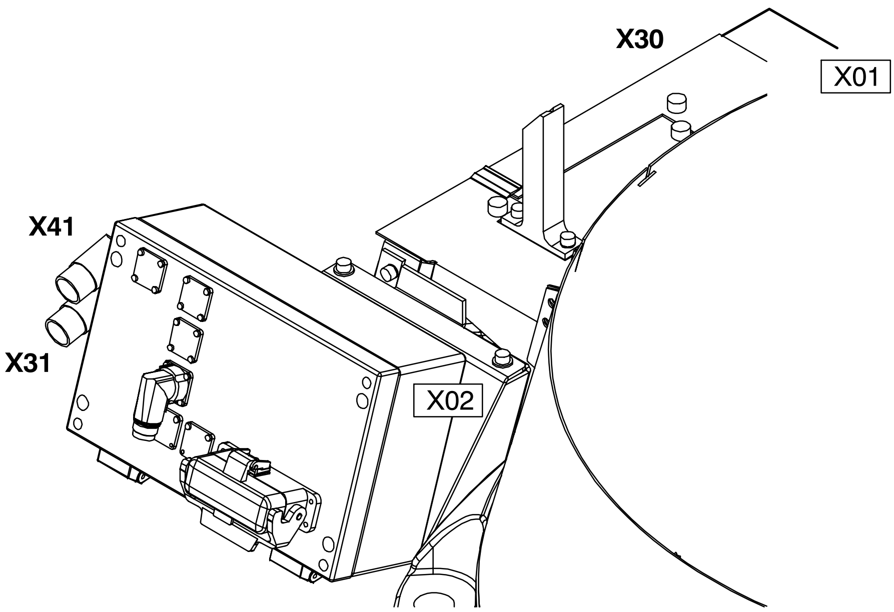
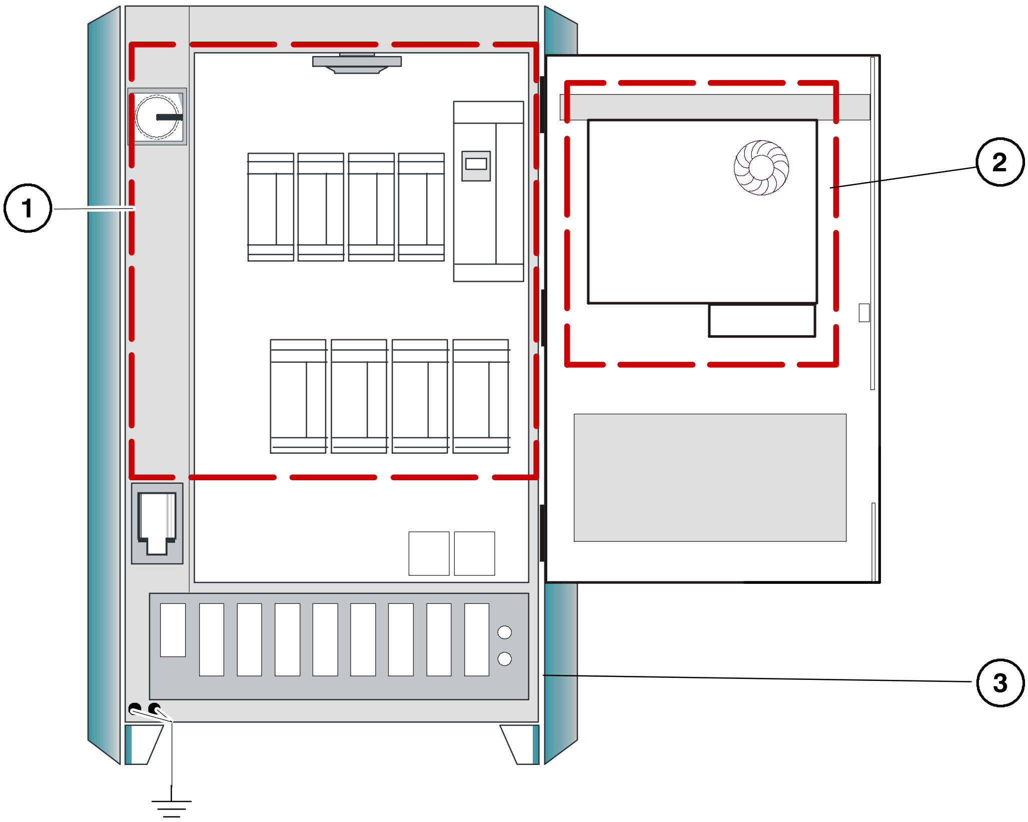


Fig. 7 Junction boxes

4.1.2 Control cabinet KR C2 edition2005

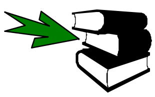
The control cabinet KR C2 edition2005 (Fig. 8) has been suitably modified for the KUKA.SafeRobot option. The connection panel is accessed by opening the door to the cabinet.

The connected cables are routed under the control cabinet to the rear.



1 Power unit
2 Computer unit (KUKA PC2004)
3 Connection panel

Fig. 8 Control cabinet KR C2 edition2005 (for SafeRobot)

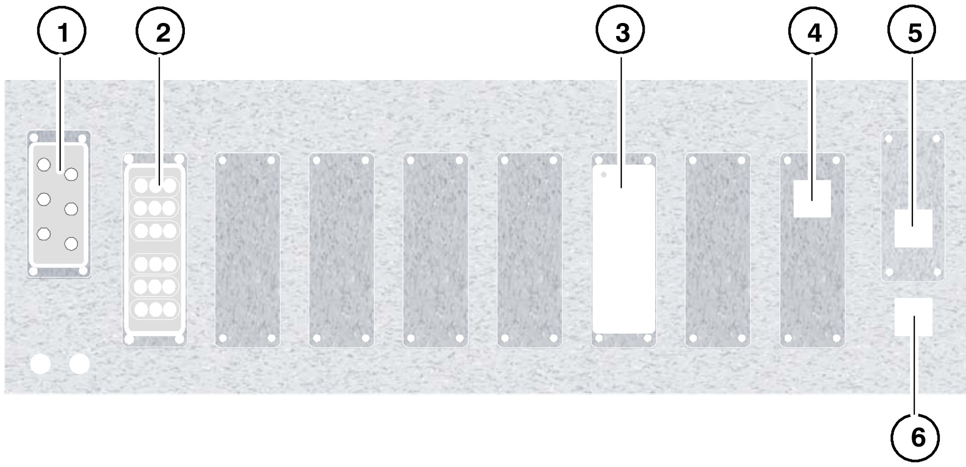


Detailed information regarding the KR C2 control cabinet and the modules shown here can be found in the [KR C2 edition2005 Operating Handbook].

4.1.3 Connection panel on the control cabinet (standard)

The connection panel (Fig. 9) is accessed by opening the door to the cabinet.

The connected cables are routed under the control cabinet to the rear.



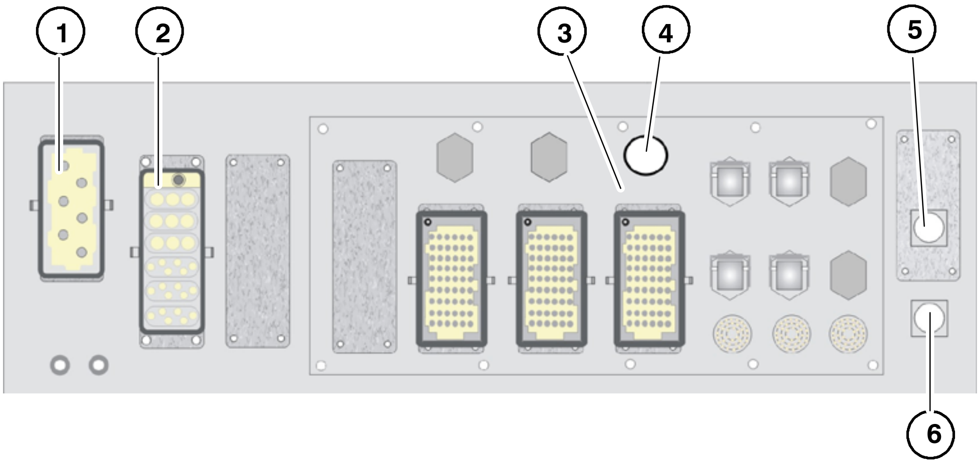
1	X1	Power supply connection	4	X21.1 Data cable, ESC – Safe RDC
2	X20	Motor connector, axes 1 to 6	5	X19 KCP connection
3	X11	Customer interface	6	X21 Data cable, DSE – Safe RDC

Fig. 9 Connection panel on the control cabinet (standard)

> Depending on the motor package and cabinet option, the assignment of the connectors and the motor connector design may differ from those shown.
>
> The connection panel for the DaimlerChrysler variant is described in Section 4.1.4.

4.1.4 Connection panel on the control cabinet (DaimlerChrysler)

Fig. 10 shows the connection panel for the DaimlerChrysler variant.



1	X1	Power supply connection	4	X21.1 Data cable, ESC – Safe RDC
2	X20	Motor connector, axes 1 to 6	5	X19 KCP connection
3	X11	Customer interface	6	X21 Data cable, DSE – Safe RDC

Fig. 10 Connection panel on the control cabinet (DaimlerChrysler)

4.2 SafeRobot control cabinet components

4.2.1 Multi-function card MFC 3 Tech

The multi-function card MFC 3 in the PCI-BUS version contains the inputs and outputs for the system.

This card has the following properties:

- RTAcc chip for VxWinRT (real-time function)
- DeviceNet/CAN bus connection
- Interface with the DSE

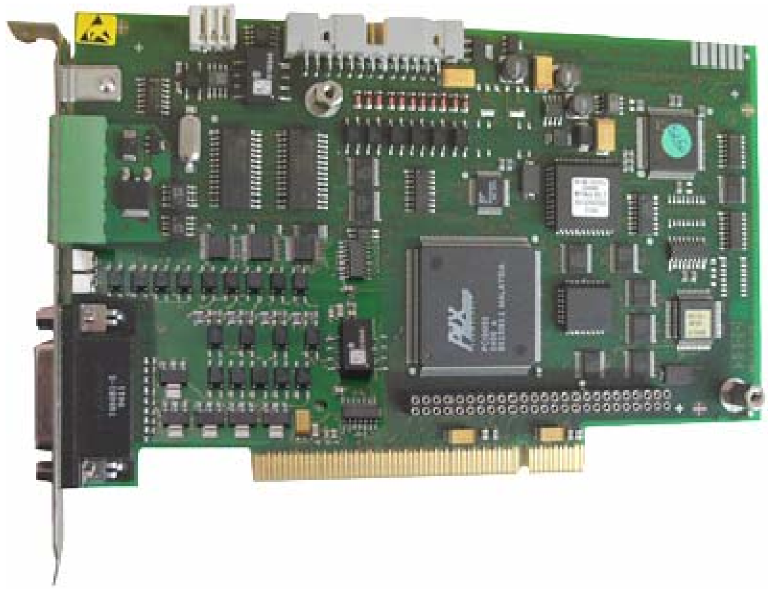
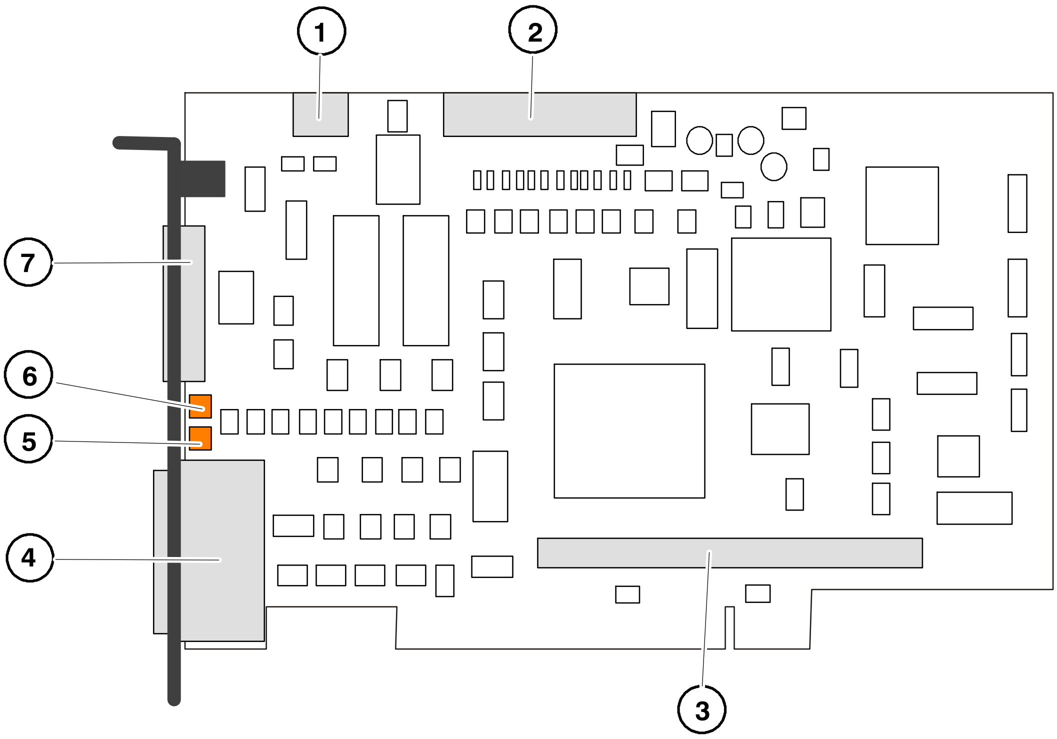


Fig. 11 Multi-function card MFC3 Tech



1	X3:	PC fan monitoring	(3-pin Wago)
2	X6:	ESC, KCP-CAN, COM, user I/O	(26-pin male connector)
3	X8101:	DSE	(50-pin socket connector)
4	X2:	Interface to ESC-CI3 board	(26-pin Sub-D connector)
5	LED2	DeviceNet CAN bus	(two-color data bit indication)
6	LED1	DeviceNet CAN bus	(two-color data bit indication)
7	X801:	CAN bus	(5-pin Combicom socket connector)

Fig. 12 Components on the MFC 3 Tech

Digital servo-electronics (DSE-IBS)

The DSE-IBS module (Fig. 13) plugged into the multi-function card undertakes the control of up to eight axes and also the processing of the error and status information read from the servo-modules. The DSE-IBS module is equipped with its own Interbus interface.

Fig. 13 DSE-IBS module

4.2.2 Safety logic – CI 3 technology

CI 3 technology is a microcontroller-based safety bus. This dual-channel system permanently monitors all connected safety-relevant components.

If the robot moves outside the set permissible working ranges, the drives are disconnected via the ESC safety logic.

“KUKA.SafeRobot” uses the CI 3-Tech board for the ESC safety circuit. The ESC is connected to the Safe RDC using the additional interface X21.1 in the control cabinet.

The following signals are available:

- QE (category 0 STOP)
- ENA (external EMERGENCY STOP, category 1 STOP)
- KGD (**K**UKA **G**uiding **D**evice)

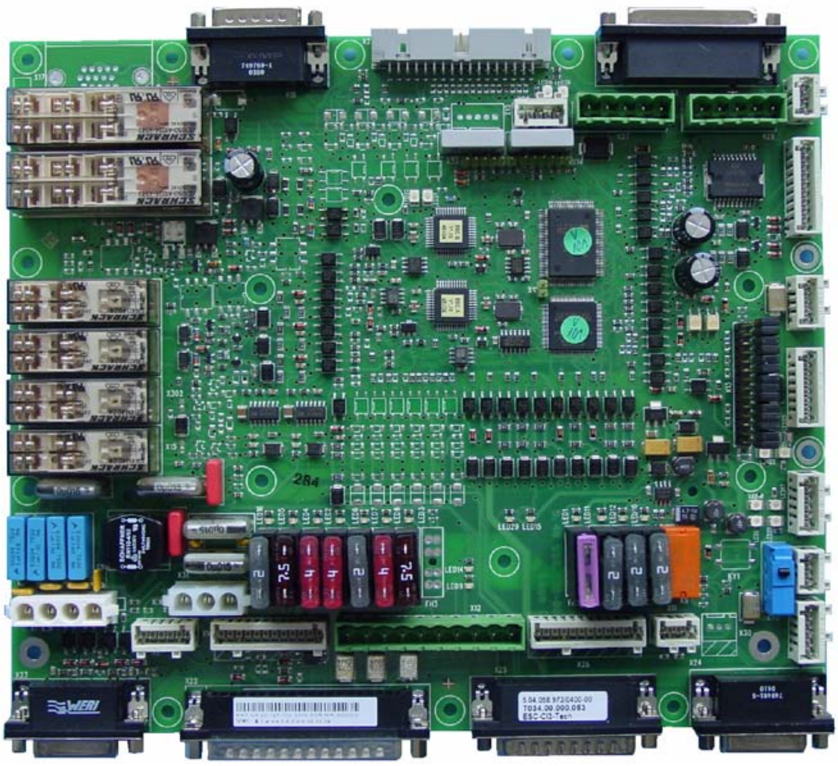


Fig. 14 CI 3-Tech board

CI 3-Tech board components and connections

Connector designation	Function
X1	Internal 24 V power supply
X2	KPS connection
X3	MFC connection
X4	External mode selector switch connection (optional)
X5	KCP connection
X6	Connector for internal/external power supply and ESC circuit
X7	CAN connection, I/O board (optional)
X8	Connection of external controllers, EMERGENCY-STOP button on cabinet
X10	Spare
X11	Safe input E7 (SafeRobot option)
X12	Periphery interface outputs >500 mA
X13	SafetyBUS Gateway interface (optional)
X16	Cobra Control (CC) interface, Common Control Cabinet (CCC) (optional)
X18	Interface to MFC3 (CR safety signals) (optional)
X19	Interface to CR lamp (optional)
X20	Interface to selector switch in Shared Pendant (optional)
X21	KCP power supply and KCP CAN
X22	Periphery interface inputs and outputs
X23	Safe RDC interface (optional)
X24	CR OUT interface (optional)
X25	CR IN interface (optional)
X26	KUKA Guiding Device (KGD) interface (optional)
X27	Multi-power tap (DeviceNet on MFC) (optional)
X28	Multi-power tap (OUT1) (optional)
X29	Multi-power tap (OUT2) (optional)
X30	Spare
X31	Internal cabinet fan connection

Fuses

The fuses are rated for voltages of up to 35 V. By every fuse on the board is a red LED which lights up if the fuse is defective.

Fuse designation	Fuse rating	Function
F2	2 A	Fan monitoring in cabinet
F10	3 A	ESC supply voltage
F13	4 A	Periphery
F21	2 A	CR lamp
F23	2 A	RDC supply
F24	2 A	Multi-power tap supply

Relays

Relay designation	Function
K1	Message: Drives ON
K2	Message: Drives ON
K3	Message: Local EMERGENCY STOP
K4	Message: Local EMERGENCY STOP
K7	Message: TEST mode
K8	Message: AUTOMATIC mode

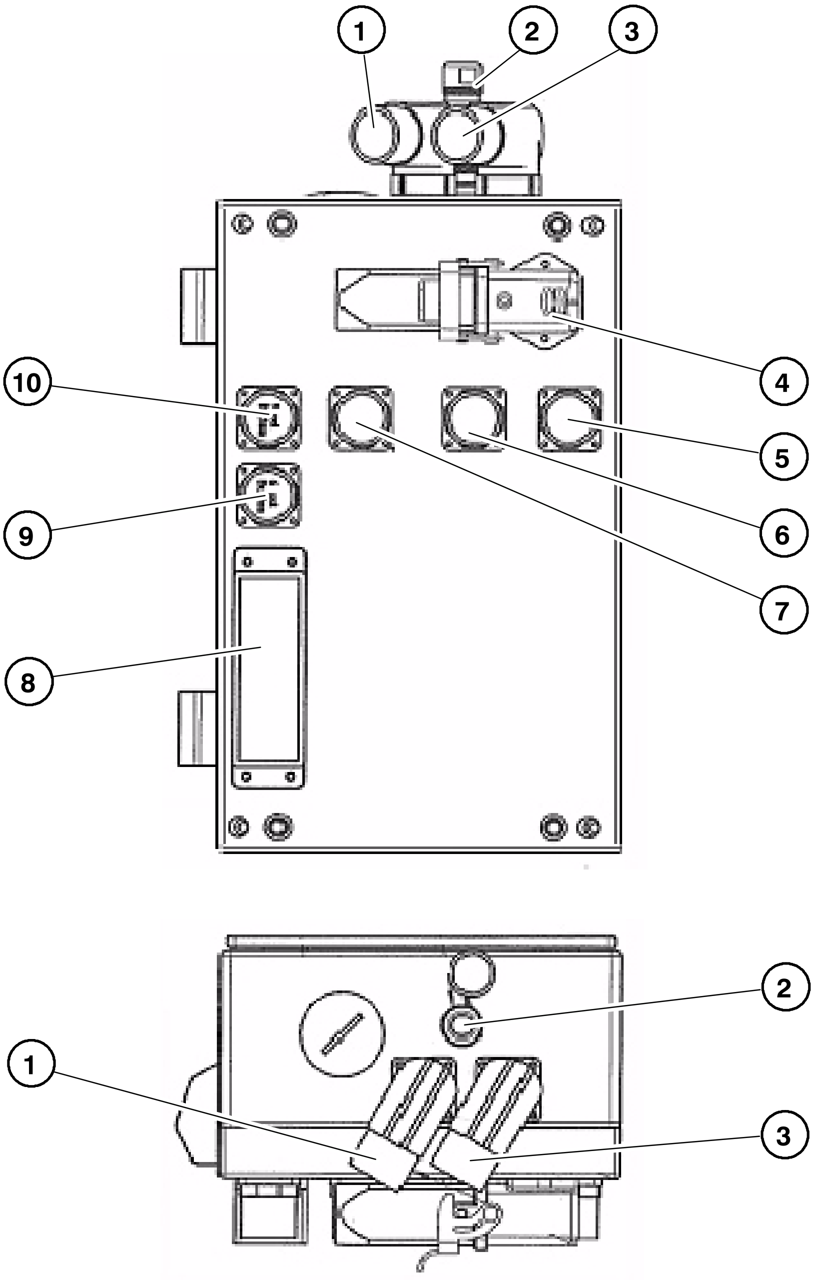
4.2.3 Safe RDC

Safe RDC box

The Safe RDC box is fitted to the robot base. This box contains the Safe RDC board and the connections to the control cabinet, robot and safety PLC.

Fig. 15 Safe RDC box

Connections to the Safe RDC box



1	X41 ESC (X2 signals)	6	X45 DSE (optional)
2	X32 EMT	7	X44 KGD (optional)
3	X31 DSE output	8	X40 Safe inputs / outputs
4	X33 Fast Measurement (optional)	9	X42 Reference switch
5	X46 Spare	10	X43 Spare

Fig. 16 Connections to the Safe RDC box

Safe RDC board

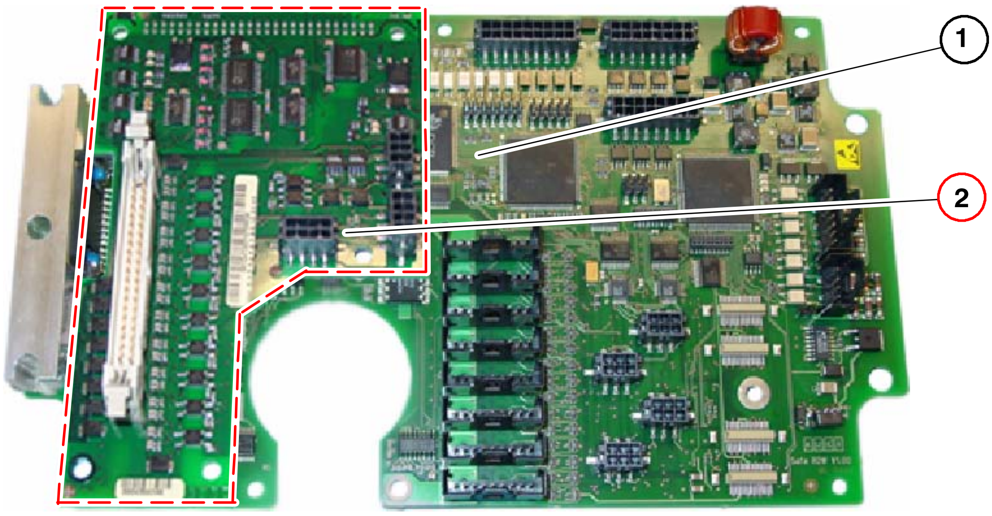
The Safe RDC board (Fig. 17) is installed in the Safe RDC box on the robot base.

The board comprises the basic board and the I/O Print piggyback board.

The basic board is of dual-channel design. Each channel is equipped with its own DSP (Digital Signal Processor) which converts the incoming analog signals to digital signals.

On the I/O Print board, the safe inputs and outputs of the Safe RDC are provided for linking to a safety PLC.

> If the inputs are led to switching equipment with contacts, a resistive circuit must be provided to ensure that the necessary minimum current flows through the contacts: Inputs 24 V: ~3 mA; outputs 24 V: 100 mA.



1 Basic board
2 Piggyback board for inputs and outputs (I/O Print)

Fig. 17 Safe RDC board

The Safe RDC performs the following functions:

- Generation of all necessary operating voltages from the supply voltage
- Evaluating the resolvers for 8 axes
- A/D conversion of up to 8 axes
- A/D conversion of 8 temperature sensors
- Evaluation of an EMT
- Open-circuit monitoring of the resolvers
- Motor temperature monitoring
- Communication with the DSE-IBS via an RS422 serial interface
- Fast Measurement
- Sensing circuit board temperature

The following safety-relevant monitoring features are available:

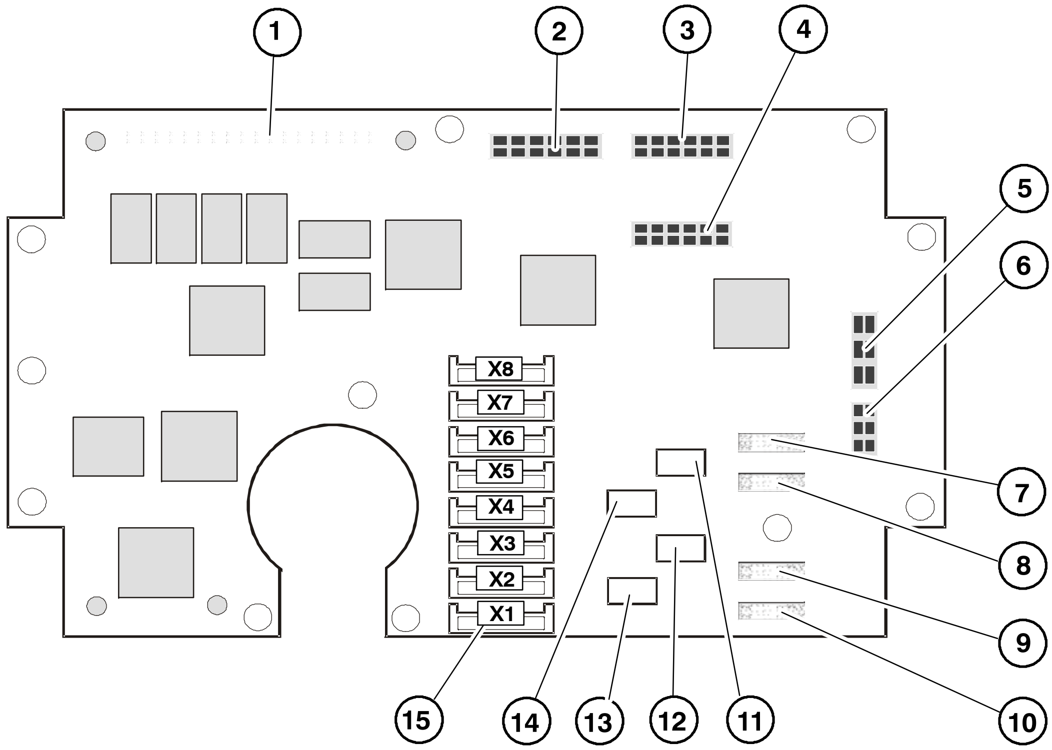
- Safe reduced velocity/acceleration (axis-specific)
- Safe reduced velocity (Cartesian) at the flange
- Safe position sensing system
- Safe axis range monitoring
- Safe operational stop
- Safe stop (ESC function)
- Monitoring of robot mastering
- Brake test
- Safe disconnection of drives in accordance with Stop 0 or Stop 1

Safe inputs and outputs

The following safe inputs are provided on the basic board: Corob_En and E_T1 and also the safe outputs: QE_A/B and ENA A/B.

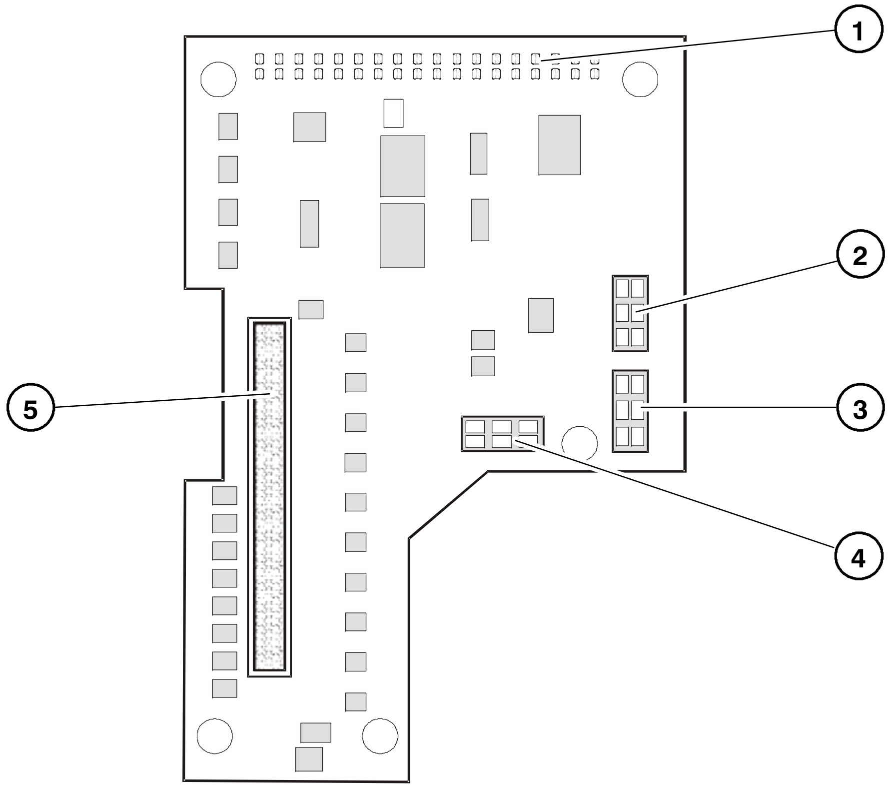
The safe inputs: E0 - E5 (axis ranges 1 - 6), reference switch, safe retraction, safe stop, reduced velocity and KGD and also the safe outputs: A0 - A2 (axis ranges), status and spare output are on the I/O Print board.

Connections to the Safe RDC board



1	X2000 Connection to I/O Print board	9	X1207 Sensor module slot
2	X901 ESC signals	10	X1208 Sensor module slot
3	X900 Connection to DSE (channel A)	11	X1200 Sensor connector
4	X1000 Connection to DSE (channel B)	12	X1202 Sensor connector
5	X1301 "Fast Measurement" connection	13	X1203 Sensor connector
6	X1300 EMT connection	14	X1201 Sensor connector
7	X1204 Sensor module slot	15	X1-X8 Resolver connector
8	X1205 Sensor module slot		

Fig. 18 Connections to the basic board

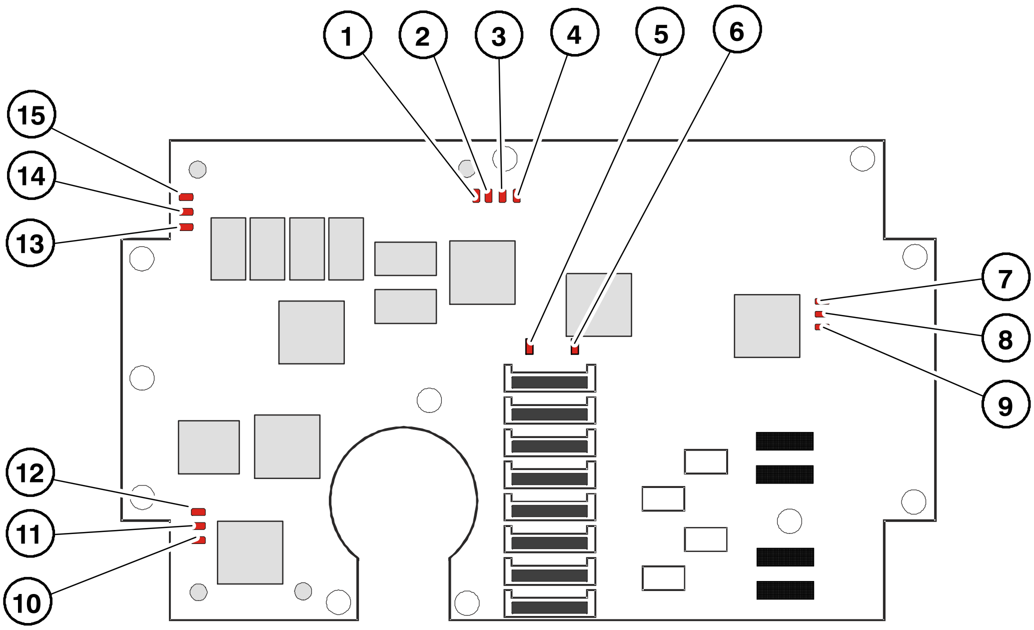


1 X901 Connection to Safe RDC
2 X904 Input for reference switch
3 X905 Input for KGD
4 X903 Spare output
5 X902 Connection for safe I/Os

Fig. 19 Connections to the piggyback board for inputs and outputs (I/O Print board)

Indicators

On the Safe RDC basic board there are LEDs to indicate the operating status. The positions are shown in Fig. 20.



1	H2103 Safe output ENA (B)		9	H1402 Microcontroller A Busy
2	H2102 Safe output QE (B)		10	H1500 Microcontroller B Operational
3	H2101 Safe output ENA (A)		11	H1501 Microcontroller B Status
4	H2100 Safe output QE (A)		12	H1502 Microcontroller B Busy
5	H1801 DSP A		13	H1702 Not used
6	H1800 DSP A		14	H1701 DSP B
7	H1400 Microcontroller A Operational		15	H1700 DSP B
8	H1401 Microcontroller A Status			

Fig. 20 LEDs on the basic board

Meaning of the LEDs for the safe outputs

The statuses of the safe outputs are shown by the LEDs H2100 to 2103 (see Fig. 20). The assignment of LEDs to outputs and the meaning of the indications is described in the following table.

LED	Safe output	Meaning
H2100 (green)	QE (A)	STOP 0 A channel On: Output has HIGH signal
H2101 (green)	ENA (A)	STOP 1 A channel On: Output has HIGH signal
H2102 (green)	QE (B)	STOP 0 B channel On: Output has HIGH signal
H2103 (green)	ENA (B)	STOP 1 B channel On: Output has HIGH signal

If all four LEDs (H2100 ... 2103) are lit, no safety stop (STOP 0 or STOP 1) is active. Assuming that no other stop condition is prevailing (such as EMERGENCY STOP at the KCP) the robot can move.

Description of the LEDs for the microcontrollers

The current operating mode and status for microcontrollers A and B is indicated by the LEDs H1400 ... H1403 and H1500 ... 1503 (see Fig. 20). The meaning of the indications at boot-up and during normal operation is described in the following table.

LED	Boot-up	Normal operation
H1400 MC **A** (green) **H1500** MC **B** (green)	**Operation** **Off:** Cannot operate, serious error **On:** Boot loader running **Flashing:** Firmware defective	**Operation** **Off:** Cannot operate, serious error **Flashing:** Normal operation
H1401 MC **A** (green) **H1501** MC **B** (green)	**State** **Off:** Initialization error **On:** Initialization ended	**State** **Off:** Normal operation **On:** DPRAM for DSP frozen **Flashing:** Waiting for synchro-nization signal
H1402 MC **A** (red) **H1502** MC **B** (red)	**Busy** **Off:** Waiting for command **On:** Command being executed	**Busy** **Off:** Waiting for command **On:** Command being executed

Description of the LEDs for the DSP

The current status of the DSP is indicated by the LEDs H1700, H1701, H1800 and H1801. The meaning of the indications at boot-up and during normal operation is described in the following table.

LED	Boot-up	Normal operation
H1800 DSP **A** (green) **H1700** DSP **B** (green)	**Operation** **Off:** Cannot operate, serious error **On:** Boot loader running	**Operation** **Off:** Cannot operate, serious error **Flashing:** Normal operation
H1800 DSP **A** (red) **H1700** DSP **B** (red)	**State** **On:** Error during DSP test **Lights up briefly:** Data transmission running	**State** Not connected

4.2.4 Interfaces to the Safe RDC

DSE signals, Safe RDC - connection X31

X31 Pin	Signal name	Description
01	+24V_CR	24V supply to the CR lamp on the robot
02	GND_P	Reference potential for the 24V supply to the Safe RDC from the control cabinet
03	+24V	24V supply to the Safe RDC from the control cabinet
04	/A_CLKR1	SSI interface to DSE channel A
05	A_CLKR1	SSI interface to DSE channel A
06	A_FSX1	SSI interface to DSE channel A
07	/A_FSX1	SSI interface to DSE channel A
08	A_DX1	SSI interface to DSE channel A
09	/A_DX1	SSI interface to DSE channel A
10	/A_FSR1	SSI interface to DSE channel A
11	A_FSR1	SSI interface to DSE channel A
12	/A_DR1	SSI interface to DSE channel A
13	A_DR1	SSI interface to DSE channel A
14	/A_CLKX1	SSI interface to DSE channel A
15	A_CLKX1	SSI interface to DSE channel A
17	GND-CR	Reference potential for the 24V supply to the CR lamp on the robot

EMT signals, Safe RDC - connection X32

X32 Pin	Name	Description
01	GND-P	Reference potential for the 24V supply
02	24V-P	24 V supply
05	EMT2	EMT input 2
06	EMT1	EMT input 1

Safe inputs and outputs, Safe RDC – connection X40

X40 Pin	Signal name	Description
01	E0_A_24V	Input 0 channel A for axis range 1
02	E0_B_24V	Input 0 channel B for axis range 1
03	/E1_A_24V	Input 1 channel A for axis range 2
04	/E1_B_24V	Input 1 channel B for axis range 2
05	E2_A_24V	Input 2 channel A for axis range 3
06	E2_B_24V	Input 2 channel B for axis range 3
07	/E3_A_24V	Input 3 channel A for axis range 4
08	/E3_B_24V	Input 3 channel B for axis range 4
09	E4_A_24V	Input 4 channel A for axis range 5
10	E4_B_24V	Input 4 channel B for axis range 5
11	/E5_A_24V	Input 5 channel A for axis range 6
12	/E5_B_24V	Input 5 channel B for axis range 6
13	/E_FREI_A_24V	Input for safe retraction channel A
14	/E_FREI_B_24V	Input for safe retraction channel B
15	E_HALT_A_24V	Input for safe stop channel A
16	E_HALT_B_24V	Input for safe stop channel B
17	/E_DV_A_24V	Input for reduced velocity channel A
18	/E_DV_B_24V	Input for reduced velocity channel B
20	OUT_A0_A	Output 0 channel A for axis range 1
21	OUT_A0_B	Output 0 channel B for axis range 1
22	OUT_A1_A	Output 1 channel A for axis range 2
23	OUT_A1_B	Output 1 channel B for axis range 2
24	OUT_A2_A	Output 2 channel A for axis range 3
25	OUT_A2_B	Output 2 channel B for axis range 3
26	OUT_STATUS_A	Output STATUS channel A
27	OUT_STATUS_B	Output STATUS channel B
28	/TA24V_A	Pulsed voltage channel A for input test
29	/TA24V_B	Pulsed voltage channel B for input test
30	GND-E	Reference potential for safe inputs with external power supply

X40 Pin	Signal name	Description
31	GND-P	If no safety PLC is connected, this pin is jumpered to pin 30 (GND_E).
32	+24V_AUSG1	+24V for external independent power supply to the safe outputs.
33	GND-A1	Reference potential for +24V-AUSG1 If no safety PLC is connected, this pin is jumpered to pin 35 (GND-P).
34	+24V-P	If no safety PLC is connected, this pin is jumpered to pin 32 (+24V_AUSG1).
35	GND-P	Reference potential for TA24V_X
36	GND-P	Reference potential for /TA24V_X If internal power supply is available, can be jumpered to pin 22 GND_E.

ESC signals, Safe RDC – connection X41

X41 Pin	Signal name	Description
01	TA 24V (A) –ESC	Pulsed voltage coming from ESC–CI3, power supply to outputs QE_A and ENA_A
02	GND ESC	Reference potential for TA 24V (A and B) ESC
03	TA 24V (B) –ESC	Pulsed voltage coming from ESC–CI3, power supply to outputs QE_B and ENA_B
04	ENA_A_24V	Safe output, ENA channel A (Stop 1) to ESC–CI3 board
05	ENA_B_24V	Safe output, ENA channel B (Stop 1) to ESC–CI3 board
06	QE_A_24V	Safe output, QE channel A (Stop 0) to ESC–CI3 board
07	QE_B_24V	Safe output, QE channel B (Stop 0) to ESC–CI3 board
08	TA 24V (B)	Pulsed voltage for channel B input test
09	TA 24V (A)	Pulsed voltage for channel A input test
10	E_T1_A_24V	Safe input, test 1 channel A
11	E_T1_B_24V	Safe input, test 1 channel B
12	COROB_ EN_A_24V	Safe input, for activating the KGD function channel A
13	COROB_ EN_B_24V	Safe input, for activating the KGD function channel B
14	GND–E	Reference potential for safe inputs with external power supply
15	GND–P	If internal power supply is available, is jumpered to pin 30 GND_E
16	Reserved	Coding pin
17	N.C.	Not connected

Input for reference switch, Safe RDC – connection X42

X42 Pin	Signal name	Description
01	E_REF_A_24V	Input for reference switch channel A
02	E_REF_B_24V	Input for reference switch channel B
03	/TA24V_A	Pulsed voltage channel A for input test
04	/TA24V_B	Pulsed voltage channel B for input test
05	GND–P	Reference potential for /TA24V_A and /TA24V_B
06	N.C.	Not connected

Connection KCP X19 (control cabinet KR C2 edition2005) to connector X20 (ESC CI3 board)

X19 Pin	Name	Description	X20 Pin
A	DISPLAY+		
B	DISPLAY-		
C	SW_Selection(A)	Switch setting “Selection” to SSB	3
D	SW_Release(B)	Switch setting “Release” to SSB	4
1	+24 V KCP voltage		
2	GND		
3	+24 V ESC voltage		
4	GND		
5	ESC In (B)		
6	ESC In (A)		
7	ESC Out (B)		
8	ESC Out (A)		
9	CAN +		
10	CAN -		
11	CR_TA(A)	24V test output A from CR logic	1
12	T1-A	Safe input, operating mode T1 channel A	5
13	CR_TA(B)	24V test output B from CR logic	2
14	T2-B	Safe input, operating mode T1 channel B	6

DSE signals

Connection X31 (Safe RDC box) to connection X21 (control cabinet KR C2)

X31 Pin	Name	Description	X21 Pin
01	+24V CR	24V supply to the CR lamp on the robot	1
02	GND-P	Reference potential for the 24V supply to the Safe RDC from the control cabinet	2
03	+24V	24V supply to Safe RDC from control cabinet	3
04	/A_CLKR1	SSI interface to DSE channel A	4
05	A_CLKR1	SSI interface to DSE channel A	5
06	/A_FSX1	SSI interface to DSE channel A	6
07	A_FSX1	SSI interface to DSE channel A	7
08	A_DX1	SSI interface to DSE channel A	8
09	/A_DX1	SSI interface to DSE channel A	9
10	/A_FSR1	SSI interface to DSE channel A	10
11	A_FSR1	SSI interface to DSE channel A	11
12	/A_DR1	SSI interface to DSE channel A	12
13	A_DR1	SSI interface to DSE channel A	13
14	/A_CLKX1	SSI interface to DSE channel A	14
15	A_CLKX1	SSI interface to DSE channel A	15
17	GND-CR	Reference potential for the 24V supply to the CR lamp on the robot	17

ESC signals (QE, ENA, T1)

Connection X41 (Safe RDC box) to connection X21.1 (control cabinet KR C2)

X41 Pin	Signal name	Description	X21.1 Pin
1	TA 24V (A) -ESC	Pulsed voltage coming from ESC-CI3, power supply to outputs QE_A and ENA_A	2
2	GND ESC	Reference potential for TA 24V (A and B) ESC	1
3	TA 24V (B) -ESC	Pulsed voltage coming from ESC-CI3, power supply to outputs QE_B and ENA_B	3
4	ENA_A_24V	Safe output, ENA channel A (Stop 1) to ESC-CI3 board	8
5	ENA_B_24V	Safe output, ENA channel B (Stop 1) to ESC-CI3 board	9
6	QE_A_24V	Safe output, QE channel A (Stop 0) to ESC-CI3 board	6
7	QE_B_24V	Safe output, QE channel B (Stop 0) to ESC-CI3 board	7
8	TA 24V (B)	Pulsed voltage for channel B input test	4
9	TA 24V (A)	Pulsed voltage for channel A input test	5
10	E_T1_A_24V	Safe input, test 1 channel A	10
11	E_T1_B_24V	Safe input, test 1 channel B	11
12	COROB_ EN_A_24V	Safe input, for activating the KGD function channel A	12
13	COROB_ EN_B_24V	Safe input, for activating the KGD function channel B	13
14	GND_E	Reference potential for safe inputs with external power supply	14
15	GND-P	If internal power supply is available, is jumpered to pin 30 GND_E	15
16	Reserved	Coding pin	16
17	N.C.	Not connected	17

Reference switch

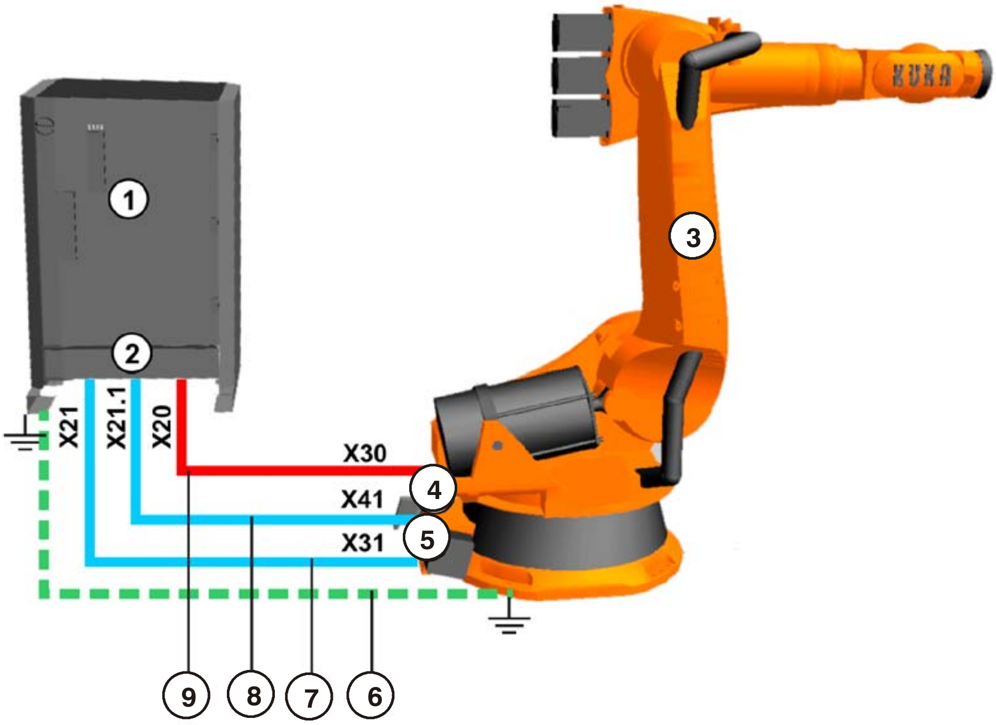
Connection X42 (Safe RDC box) to connection XS Ref (reference switch)

See also Section 4.4.1.

X42 Pin	Signal name	Description	XS Ref Pin
01	E_REF_A_24V	Input for reference switch channel A	2
02	E_REF_B_24V	Input for reference switch channel B	5
03	/TA24V_A	Pulsed voltage channel A for input test	1
04	/TA24V_B	Pulsed voltage channel B for input test	4
05	GND-P	Reference potential for /TA24V_A and /TA24V_B	3
06	N.C.	Not connected	6

4.3 Connecting cables between robot and control cabinet

4.3.1 Connecting cables diagram



1	Control cabinet KR C2 edition2005	6	Ground conductor 16 mm^2 *)
2	SafeRobot interface	7	Data cable X21 - X31
3	Robot	8	Data cable X21.1 - X41
4	Junction box X01	9	Motor cable X20 - X30
5	Safe RDC junction box		

*) Ground conductor necessary only for cable lengths > 25 m

Fig. 21 Connecting cables between control cabinet and robot, Safe RDC

4.3.2 Connecting cables

Connecting cables are all the cables running between the robot and the control cabinet (Fig. 21). They have plug-in connections at both ends. In order to avoid the connectors being mixed up, the ends of each cable are provided with a designation label, which must match the designation of the socket on the robot or on the control cabinet. In addition the connectors are coded.

The connectors must be plugged in carefully so as not to bend the contact pins.

For connecting cables of length > 25 m an additional ground conductor is required to provide a low-resistance connection in accordance with DIN EN 60204.
The ground conductors are fastened with cable lugs to threaded bolts.

Routing of cables

The following points must be observed when routing the cables:

- The minimum bending radius of the cables (150 mm for fixed installation) must be observed.
- Protect cables against exposure to mechanical stress.
- Route the cables without tension (no tensile forces on the connectors).
- Cables are only to be installed indoors.
- Observe permissible temperature range (fixed installation) 263 K (-10 °C) to 343 K (+70 °C).
- Route power cables separately from the control cables (such as data cables, bus cables).

4.3.3 Configuration of the connecting cables

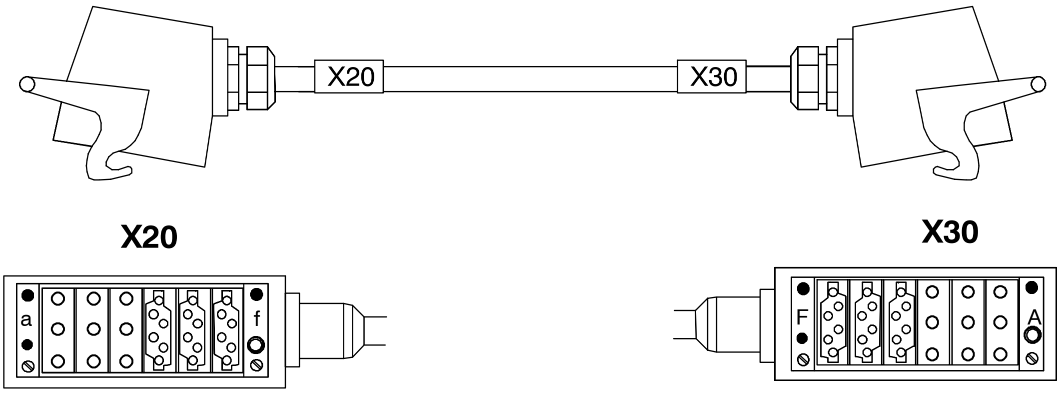
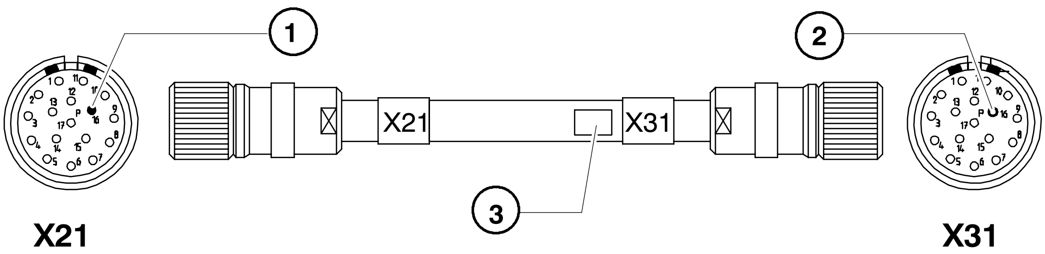
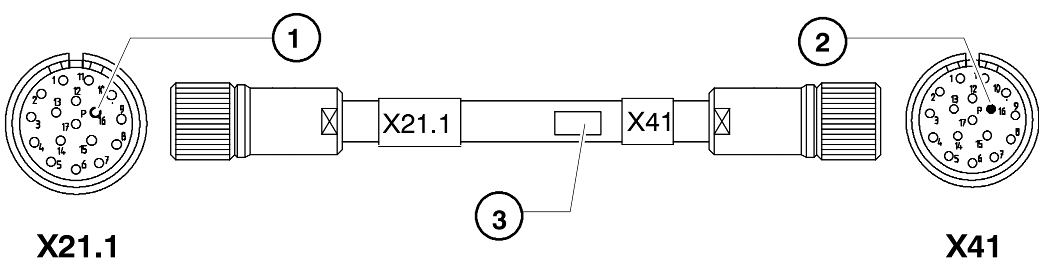


Fig. 22 Motor cable, X20 – X30



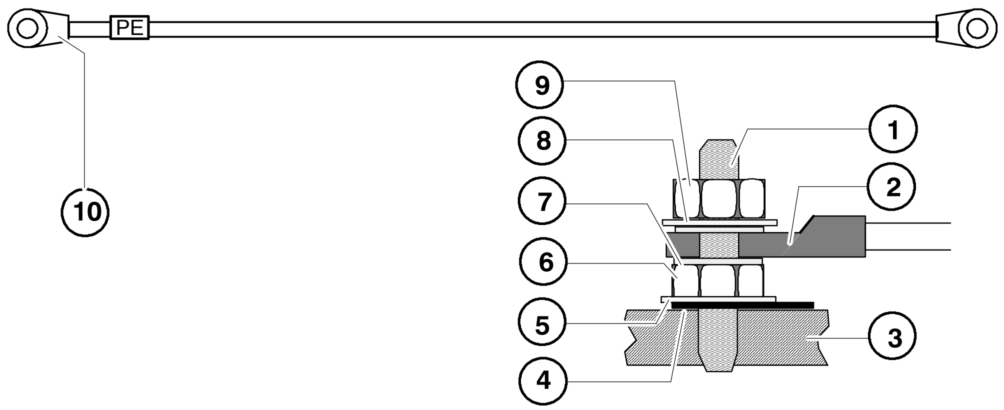
1	Coding pin	3	Barcode plate
2	Coding hole		

Fig. 23 Data cable X21 – X31



1	Coding hole	3	Barcode plate
2	Coding pin		

Fig. 24 Data cable X21.1 – X41



1	PE bolt: M8x30 stud bolt mech. galv. DIN 913	6	M8 nut
2	Cable lug	7	Washer 8.4
3	Robot	8	VS8 washer
4	Ground plate	9	M8 nut
5	Washer VS8	10	Ring cable lug, hole 8.4 mm

Fig. 25 Ground conductor connection

4.3.4 Interface assignments

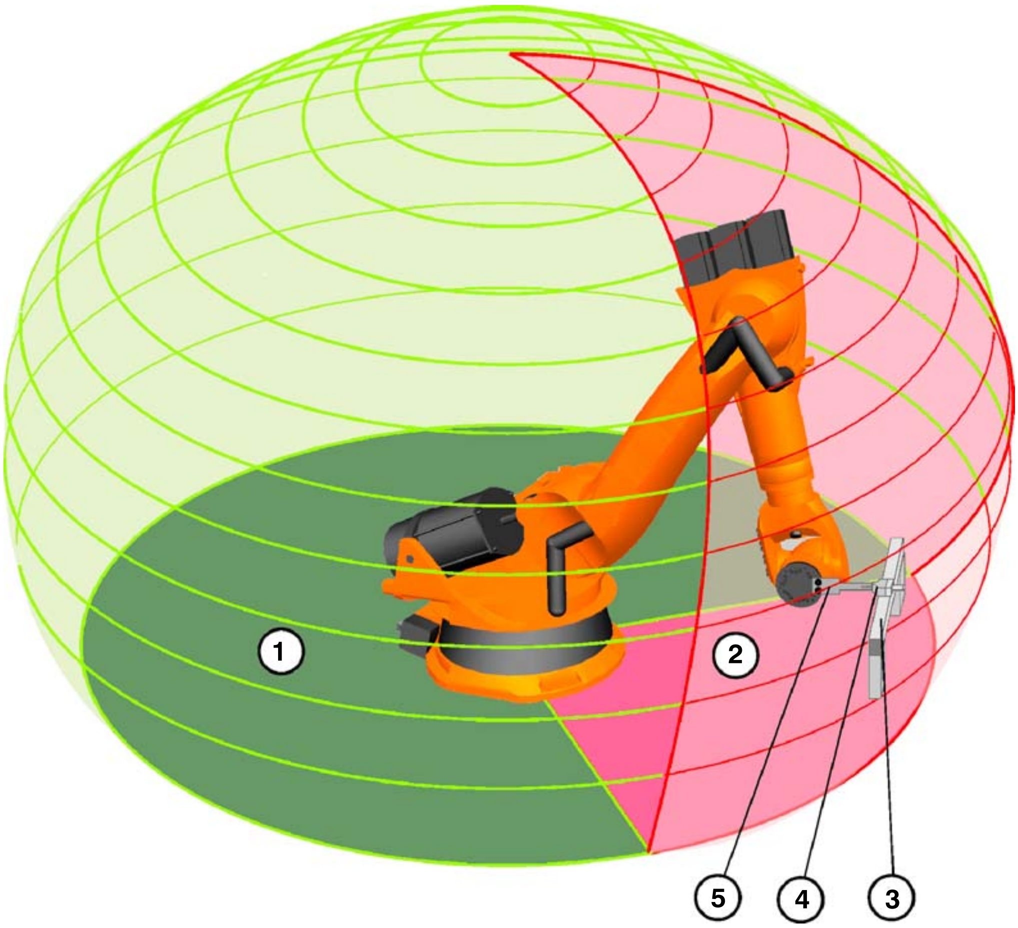
The pin assignments for the connecting cables and their signal designations are described in Section 4.2.3.

4.4 Reference switch

For safe operation, a reference run must be performed every time the robot controller is booted up, and also at specified intervals during continuous operation (see Section 5.4.2).

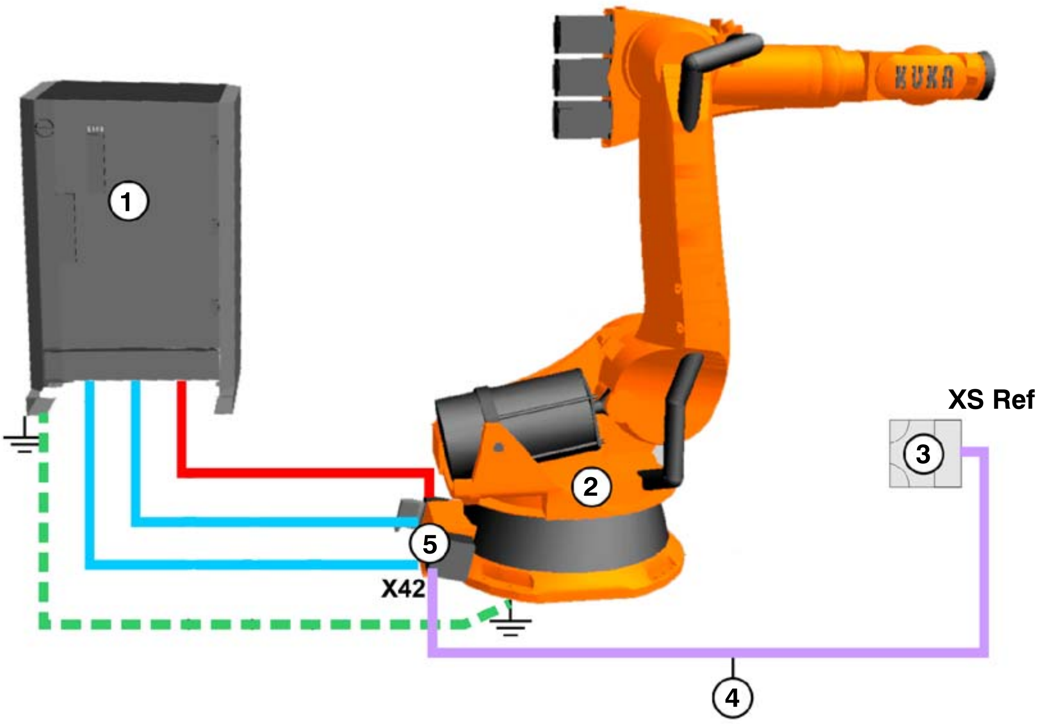
For this purpose a reference switch must be installed within the possible working range of the robot. This reference switch should be installed outside the process range of the robot and must not be at the mastering position of the robot or at a singularity position.

The function of the reference run is described in Section 5.4.2 of this documentation, and a program example is shown in Section 7.1.



1	Process range within the working range	4	Reference switch
2	Range outside the process range	5	Reference switch actuating plate
3	Construction for mounting the reference switch		

Fig. 26 Reference switch: working range, process range



1	Control cabinet KR C2 edition2005	4	Connecting cable X42 – XS Ref
2	Robot	5	Safe RDC junction box
3	Reference switch		

Fig. 27 Interface, SafeRobot – reference switch

4.4.1 Components for reference switch

The following components are necessary:

- **Reference switch** (KUKA)
  installed in the working range of the robot
- **Reference switch actuating plate** (KUKA)
  installed on the robot wrist, projecting beyond the flange
- **Connecting cable for reference switch, 15 m** (KUKA)
  to interface X42 on the Safe RDC

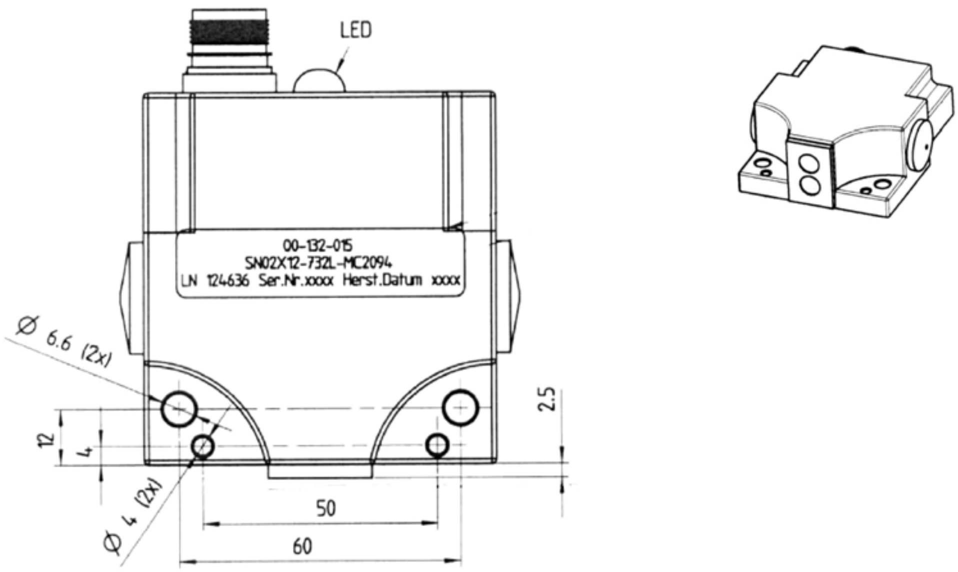


Fig. 28 Reference switch with position of fastening holes

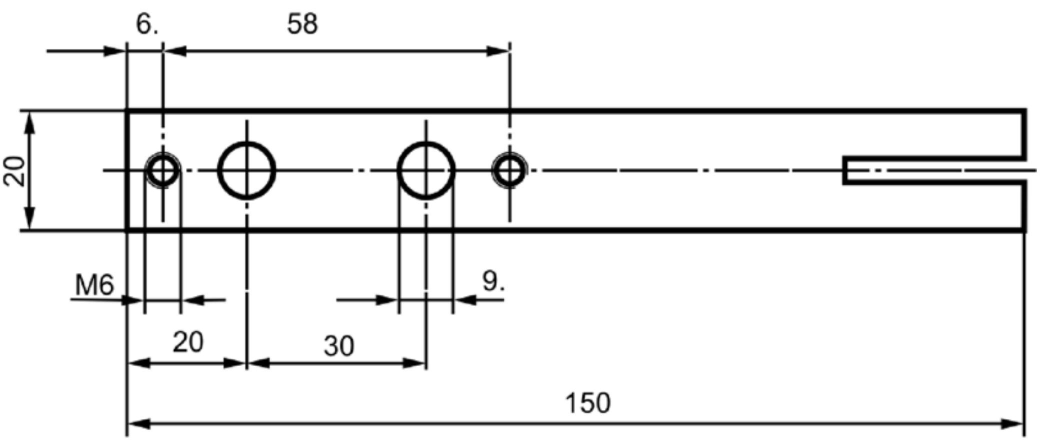


Fig. 29 Reference switch actuating plate with position of fastening holes

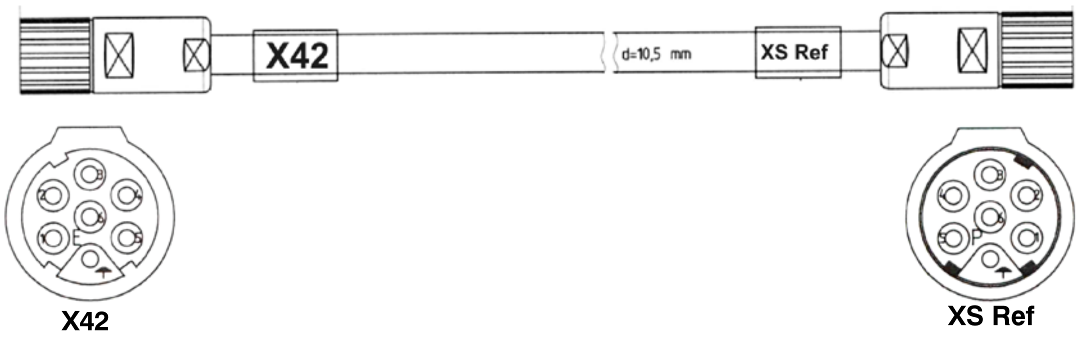
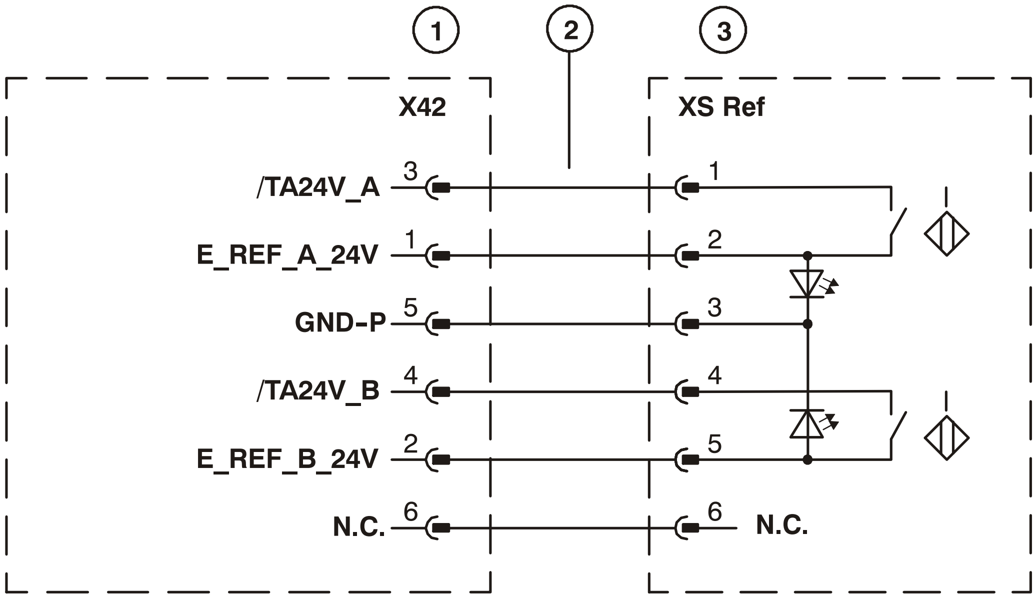


Fig. 30 Connecting cable X42 – XS Ref (length: 15 m)



1 Safe RDC
2 Connecting cable X42 – XS Ref
3 Reference switch

Fig. 31 Pin assignment for connector X42, reference switch

4.4.2 Installing the reference switch

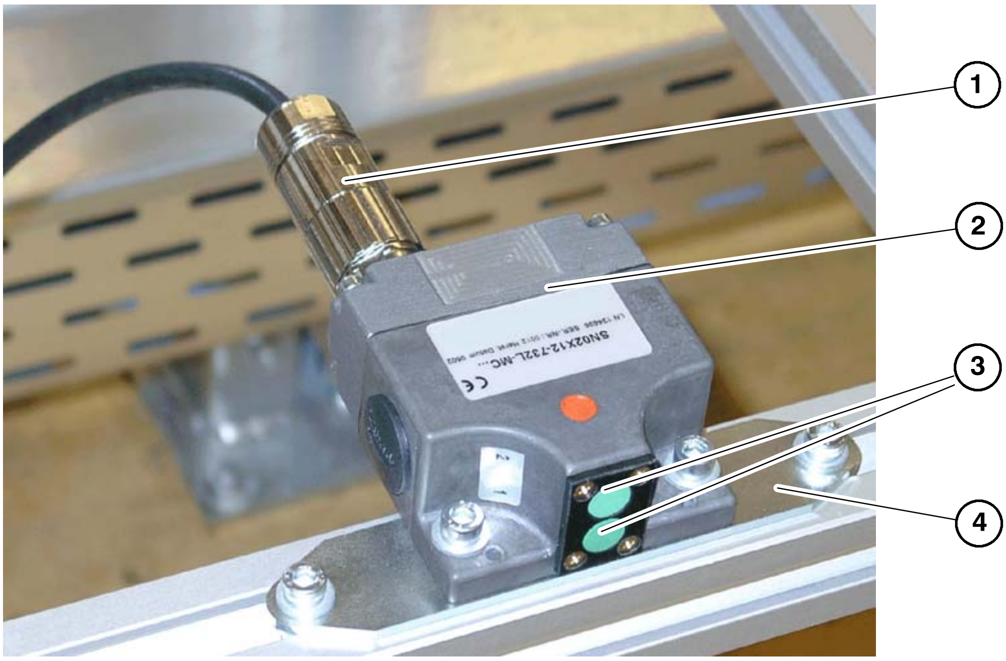
The reference switch is installed within the working range of the robot. The installation position should be chosen so that the switch does not interfere with the normal working process of the robot (see Fig. 26), i.e. outside the normal process range of the robot.

C A U T I O N !

The reference switch must not be installed in a position which would bring the robot into the mastering position or a singularity position while performing a reference run (actuation of the reference switch). Were this to happen it would mean the reference run could not be successfully completed.

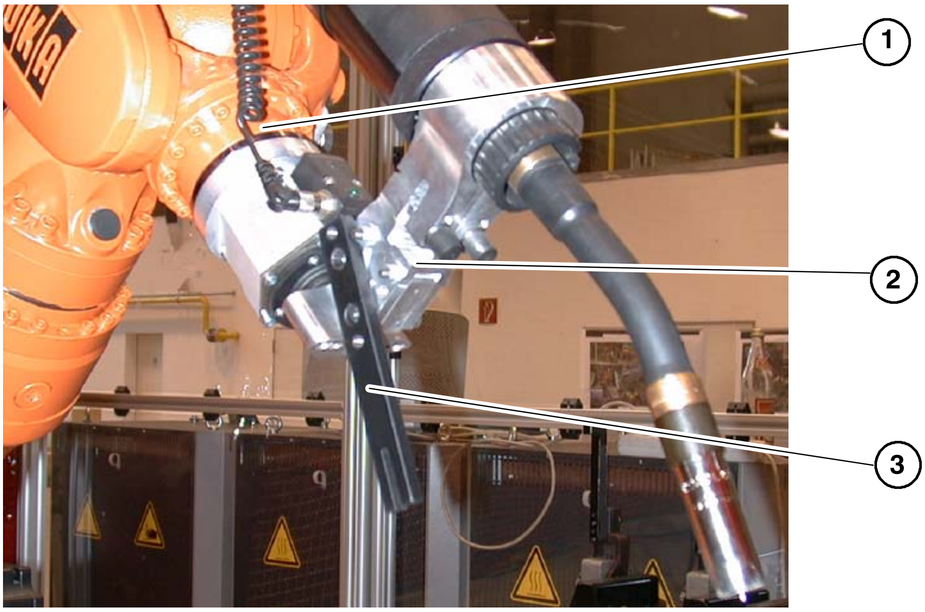
A singularity of the robot is a position that satisfies any of the following conditions:

- Axes A4 and A6 are in line
- Axes A1 and A4 are in line
- Axes A1 and A6 are in line



1 Connecting cable X42 - XS Ref
2 Reference switch
3 Sensors on the reference switch
4 Fastening plate

Fig. 32 Installing the reference switch



1 Robot flange
2 Tool
3 Reference switch actuating plate

Fig. 33 Actuating plate for reference switch

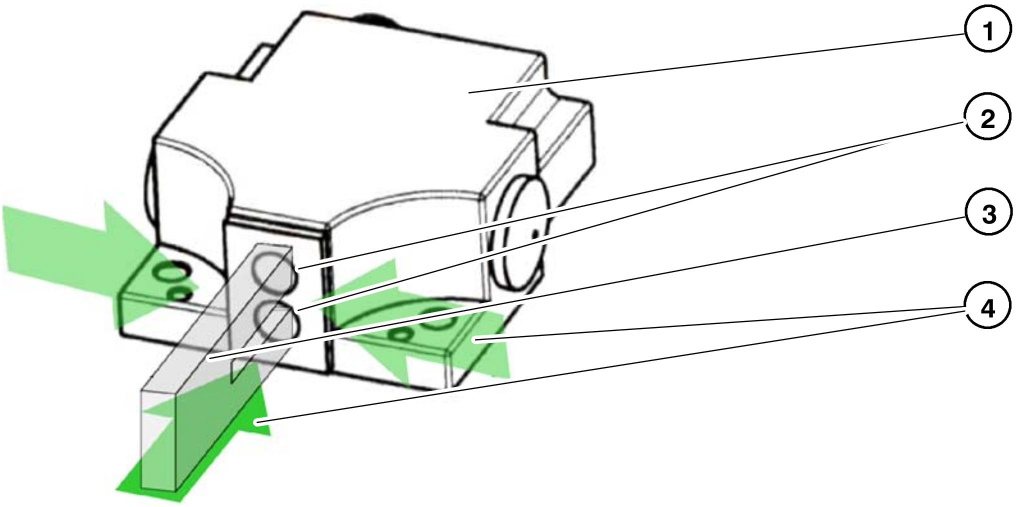
Installation

- At a suitable position, set up a sufficiently stable mechanical mounting to carry the reference switch. An example is shown in Fig. 32.
- Secure the reference switch to it using the holes provided for the purpose (see Fig. 28 and Fig. 32).
- Connect the reference switch to the X42 interface on the Safe RDC using the connecting cable (see Fig. 30 and Fig. 32).
- Fit the actuating plate (see Fig. 29 and Fig. 33) to the robot wrist, so that this projects beyond the flange.

It must be ensured that the reference switch and actuating plate are installed in such a way that the switching sensors (see Fig. 32) integrated in the reference switch can be correctly approached with the forked actuating plate.

The sensors can be approached forwards or sideways, as shown in Fig. 34, but always so that the actuating plate points with the fork towards the two sensor markings on the reference switch.

The operation of the reference switch can be checked using the LED indicator on the rear of the reference switch (see Fig. 28).



1	Reference switch	3	Actuating plate for the reference switch
2	Sensors on the reference switch	4	Possible approach directions to the reference switch

Fig. 34 Reference switch, actuating plate – possible approach directions

4.5 Keyswitch for "safe retraction" mode

"Safe retraction" mode can be activated for moving the robot free under manual control. This is done by setting the safe input "Safe retraction".

For this purpose a keyswitch can be installed at a suitable point, with which the input "Safe retraction channel A" or "Safe retraction channel B" (see Section 4.2.3, Safe inputs and outputs, Safe RDC – connection X40) can be set to the HIGH signal.

4.6 Periphery

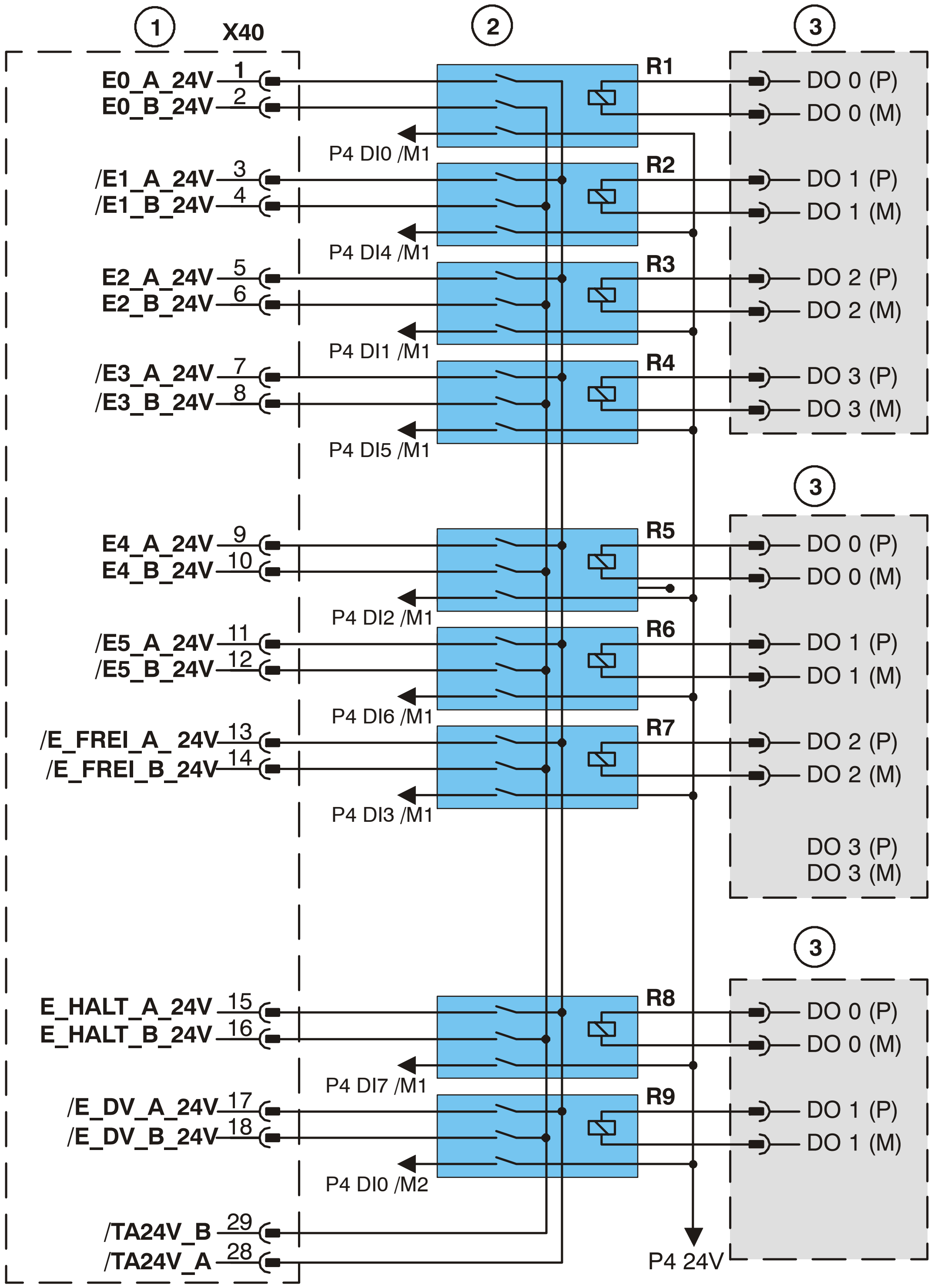
"KUKA.SafeRobot" allows connection of a safety PLC.

NOTE
If the robot is operated without a PLC, the Safe RDC interface X40 must be connected as described in Section 4.7.

4.6.1 Example of connection to a safety PLC (Siemens ET200S)

An example of connection of the safe outputs of a safety PLC to the safe inputs of the Safe RDC is shown in Fig. 35. This is a solution using relays.

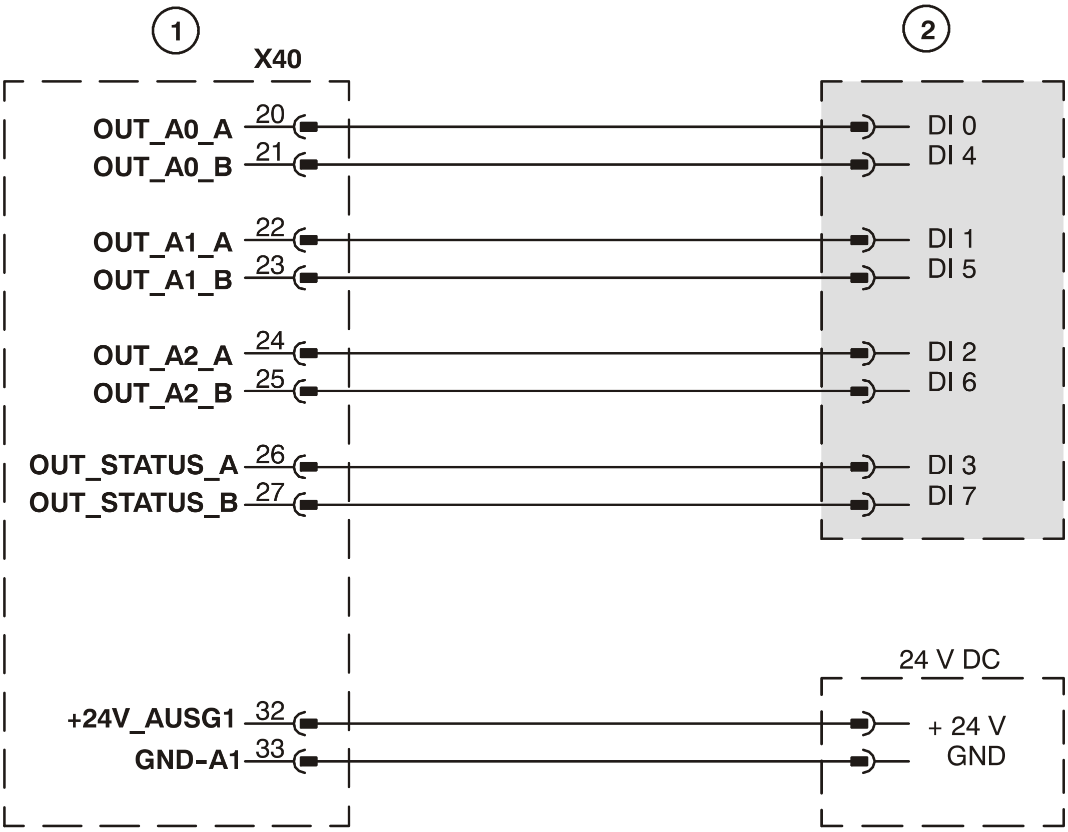
The relays used must be positively driven.



1	Safe RDC	R1 ... R9	Positively driven relay DO x
2	Relay (positively driven) R1 ... R9	DO x	Outputs, Siemens ET200S
3	Module, Siemens Profi Safe 4F-DO 24V/2A		

Fig. 35 Connection of safe outputs from Siemens ET200S to inputs of Safe RDC using relays (example)

An example of connection of the safe inputs of a Siemens PLC ET200S to the safe inputs of the Safe RDC is shown in Fig. 36.



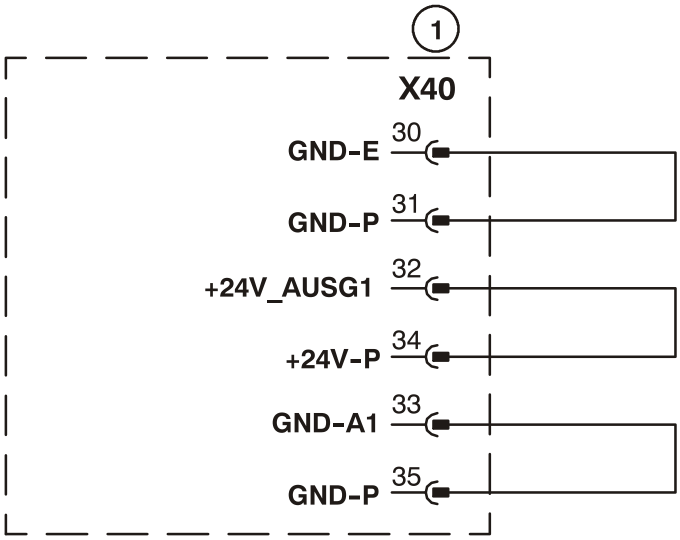
1 Safe RDC
2 Module, Siemens Profi Safe 4/8F-DI 24V/

DI x Outputs, Siemens ET200S

Fig. 36 Connection of safe inputs of Siemens ET200S to safe outputs from Safe RDC (example)

4.7 Assignment of X40 for operation without a PLC

When the “KUKA.SafeRDC” is operated without a safety PLC, the interface X40 of the Safe RDC must be connected as shown in Fig. 37.



1 Safe RDC

Fig. 37 Pin assignment for X40 Safe RDC for operation without a PLC

4.8 Functional examples

In this section two examples are described, which make clear the function of "KUKA.SafeRobot".

The inputs and outputs of the Safe RDC should be configured as shown in the following tables.

Inputs to the Safe RDC

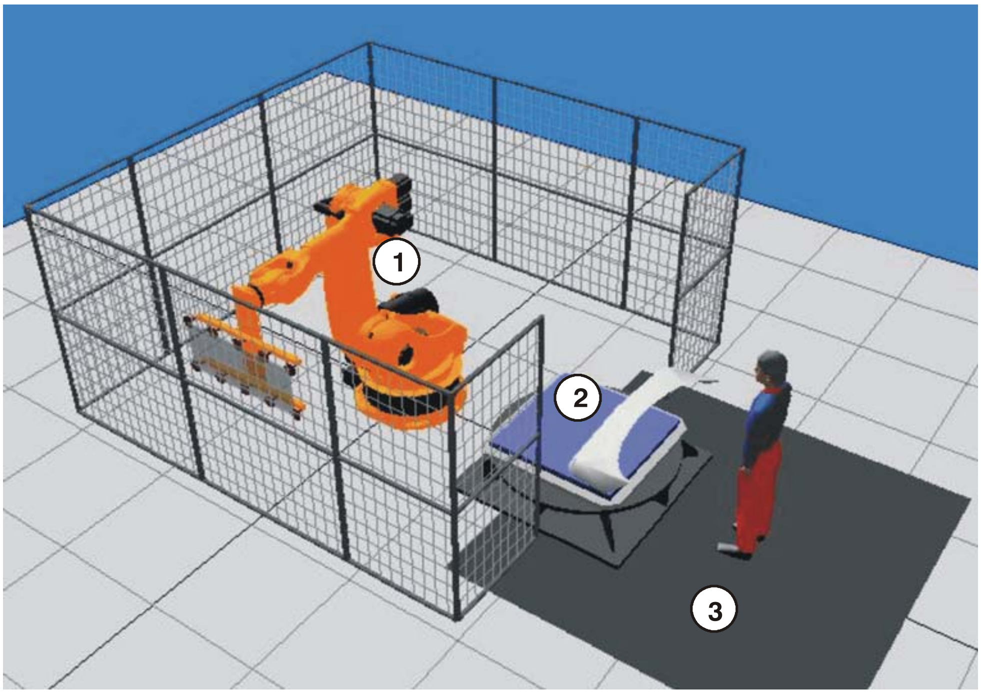
Input	Description
E0	Input for activating axis range 0 (safety range on LOW signal)
E1	Input for activating axis range 1 (safety range on LOW signal)
E2	Input for activating axis range 2 (safety range on LOW signal)
E3	Input for activating axis range 3 (safety range on LOW signal)
E4	Input for activating axis range 4 (safety range on LOW signal)
E5	Input for activating axis range 5 (safety range on LOW signal)
E_dV	Input for monitoring the reduced velocity (on LOW signal)
E_Halt	Input for monitoring the robot at standstill (on LOW signal)

Outputs from the Safe RDC

Output	Description
A0	Output to indicate when axis range 0 has been left (LOW signal)
A1	Output to indicate when axis range 1 has been left (LOW signal)
A2	Output to indicate when axis range 2 has been left (LOW signal)

4.8.1 Example of a loading station at a turntable

Fig. 38 shows a loading station at a turntable.



1 Robot
2 Turntable
3 Safeguard (e.g. safety mat)

Fig. 38 Loading station at a turntable

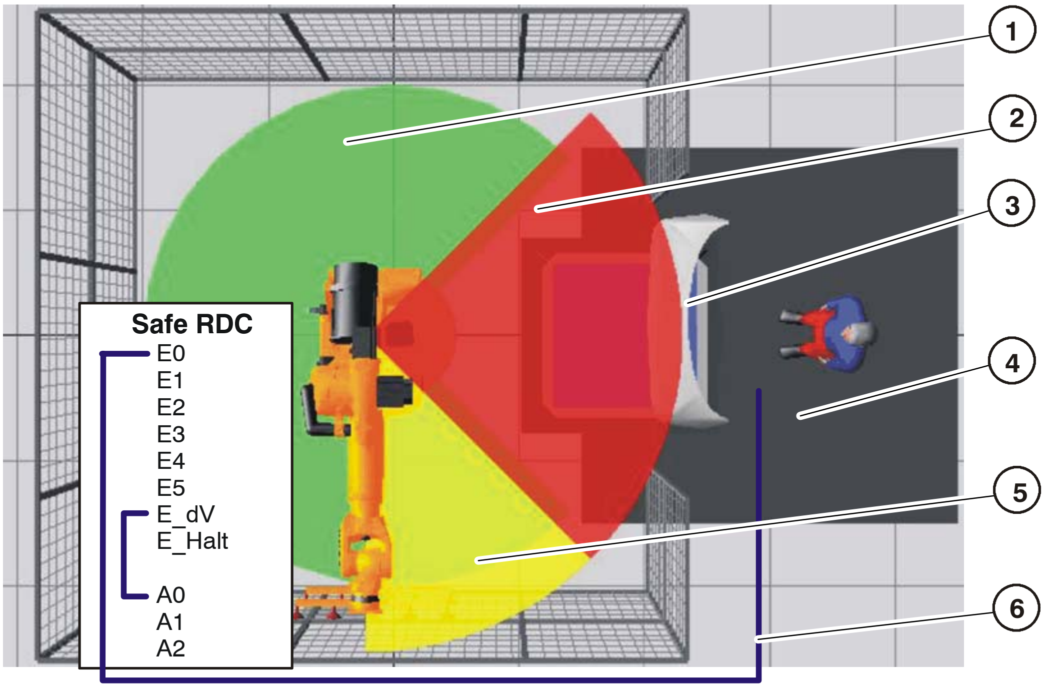
It must be ensured that the robot cannot move into the safety range or carry out motion within it when the safeguard is triggered (e.g. when a person is standing on the safety mat). This is monitored in this example by input E0, which in the example shown is linked to the safety mat (LOW signal).

Fig. 39 shows the individual ranges:

- Working range
- Range with reduced velocity
- Safety range

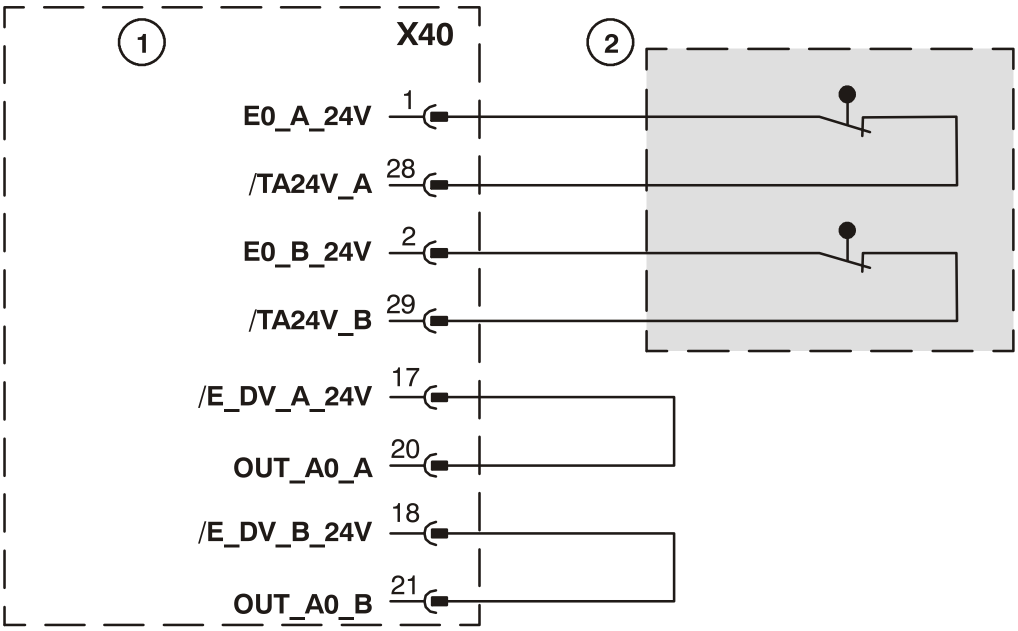
Fig. 40 shows the connection of the safeguard (e.g. safety mat) to the interface X40 of the Safe RDC and other necessary jumpers.

The range with reduced velocity is also monitored, so that the safety clearances can be reduced. This is done by connecting output A0 to the input for activating the reduced velocity (E_dV).



1	Working range	4	Safeguard (e.g. safety mat)
2	Safety range	5	Range with reduced velocity
3	Turntable	6	Dual channel connection

Fig. 39 Loading station at a turntable - ranges, inputs, outputs

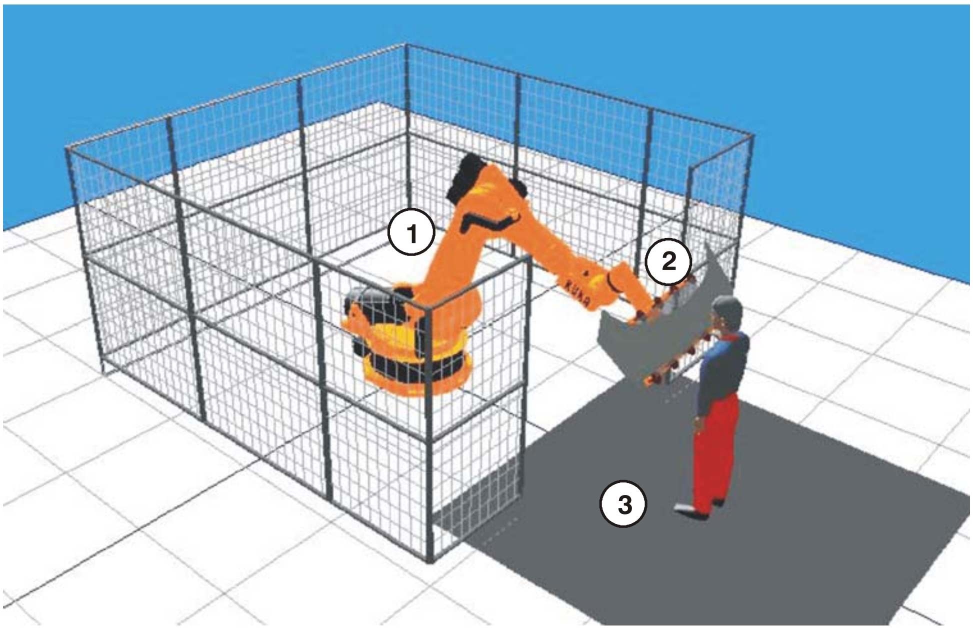


1	Safe RDC
2	Safeguard (e.g. safety mat)

Fig. 40 Safe RDC, X40 - connection to safeguard and jumpering

4.8.2 Example of a loading station at a robot gripper

Fig. 41 shows a loading station at which the component is placed manually directly into the robot gripper.



1 Robot
2 Robot gripper
3 Safeguard (e.g. safety mat)

Fig. 41 Loading station at a robot gripper

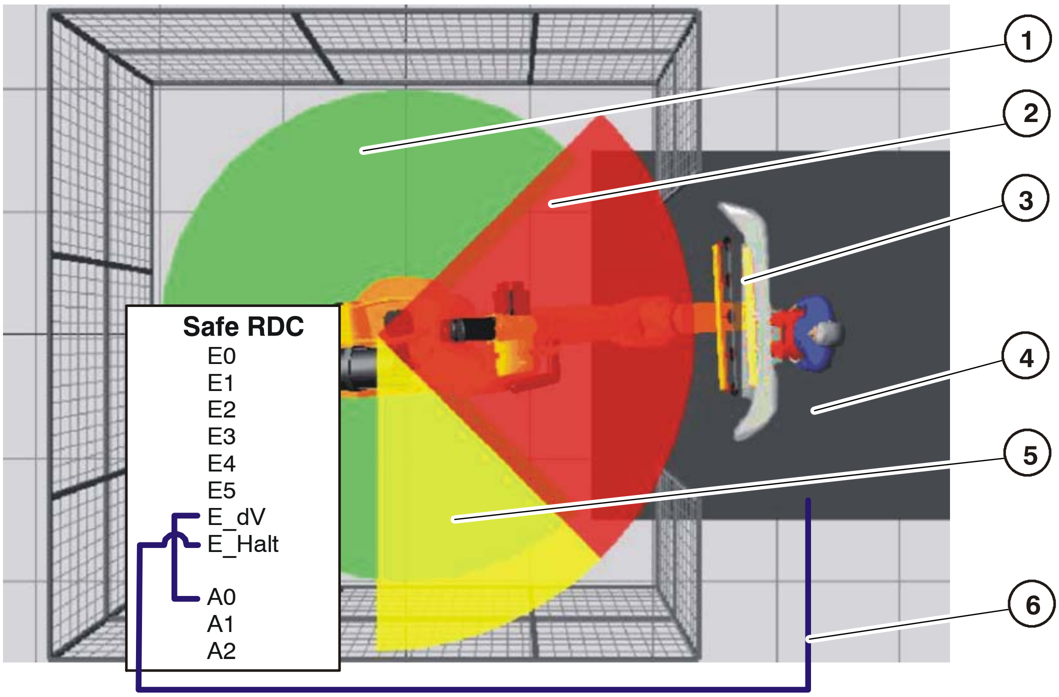
Fig. 42 shows the individual ranges:

- Working range
- Range with reduced velocity
- Safety range

Fig. 43 shows the connection of the safeguard (e.g. safety mat) to the interface X40 of the Safe RDC and other necessary jumpers.

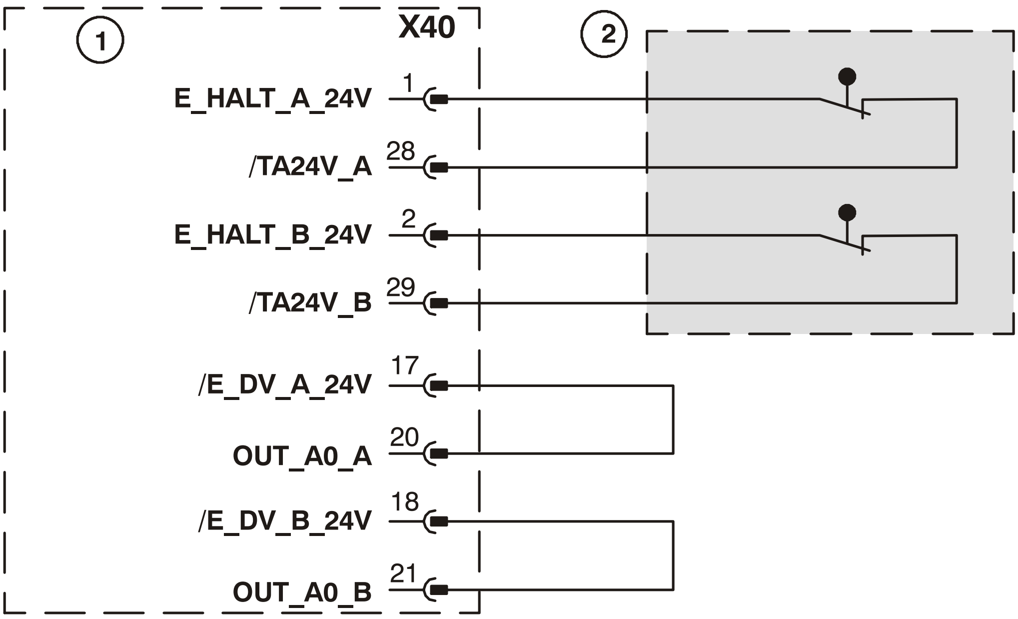
It must be ensured that if the robot is in the safety range it does not move after the safeguard has been triggered (e.g. after the safety mat has been stepped on). This is monitored in this example by input E_Halt, which is linked to the safety mat (LOW signal).

The range with reduced velocity is also monitored, so that the safety clearances can be reduced. This is done by connecting output A0 to the input for activating the reduced velocity (E_dV).



1 Working range
2 Safety range
3 Robot gripper
4 Safeguard (e.g. safety mat)
5 Range with reduced velocity
6 Dual channel connection

Fig. 42 Loading station at a robot gripper – ranges, inputs, outputs



1 Safe RDC
2 Safeguard (e.g. safety mat)

Fig. 43 Safe RDC, X40 – connection to safeguard and jumpering

5 Commissioning

5.1 Prerequisites

5.1.1 Requirements regarding the operating personnel

The following instructions and information must be observed in order to ensure the safety of the operating personnel, third parties and the overall installation.

In case of doubt regarding the order in which to carry out different procedures, human safety is to be the overriding consideration that determines the sequence followed.

- Operating personnel must be thoroughly instructed in the handling and operation of the equipment, either by the user or by a person entrusted with this task by the user.
- Set-up, installation, configuration, operation, programming, exchange and maintenance / repair must be performed only by personnel specially trained for the product described here.

5.1.2 Instruction and training of operating personnel

The basis for the instruction of the operating personnel is these operating instructions.

We recommend suitable training for the operating personnel.

Information on training courses is available from the addresses listed in Section 1.1.

5.1.3 Training for administrators and safety maintenance personnel

For persons with access to the user groups “Administrators” and “Safety maintenance” appropriate training is necessary.

Information on training courses is available from the addresses listed in Section 1.1.

5.2 Installing the configuration program

The installation, uninstallation, reinstallation and update of technology packages are described in detail in the documentation **[Installation/Uninstallation/Update of Tech Packages]**.

5.3 Using the configuration program

5.3.1 User group

For configuration and parameterization a dedicated configuration program is available. To use this program it is necessary to have the appropriate user rights.

This requires

- **Logging into** the appropriate **user group** by means of the menu function “Configuration” → “User group”.
  In the window which opens, select the option “Safety maintenance” under “Choose a user:” and enter the password in the corresponding box. See also information and instructions on the HMI screen.
- Setting the **operating mode** “T1” or “T2”

It is essential that users of the robot controller cannot log into the user group “Safety maintenance” and also do not have administrator rights, because otherwise the safety aspects of user administration in the robot controller would be compromised!

If the login is not to the user group “Safety maintenance” the parameters can still be viewed, but not changed.

5.3.2 Starting the configuration program

The configuration program is started from the HMI menu “Setup”.

Two start options are available:

- **Setup → Service → Safe Robot → Examination**
  The configuration program is started and the data are checked, but the configuration window to change the parameters is not displayed.
- **Setup → Service → Safe Robot → Configuration**
  The configuration program is started, the data are checked, and the configuration window to change the parameters is displayed.

Displaying the configuration program

The screen display of the program appears in the form of a table (Fig. 44).

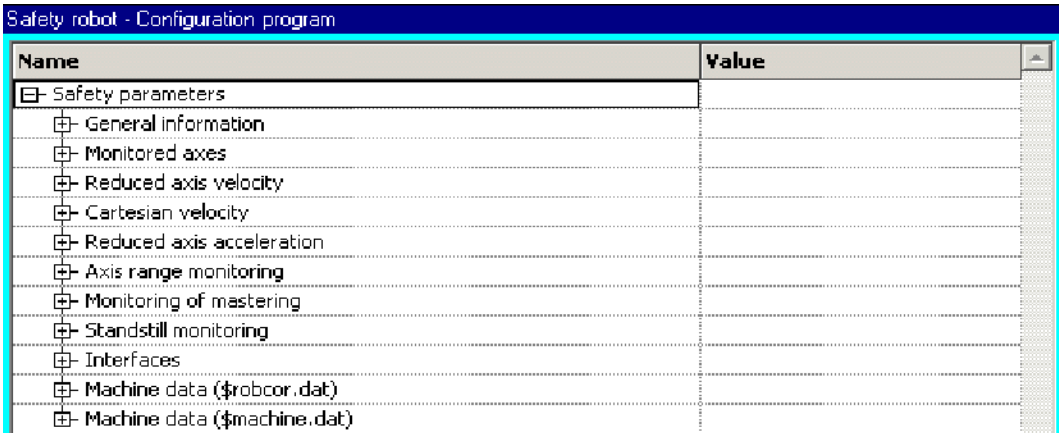


Fig. 44 Screen display of parameter groups

> The configuration program window is not fully covered by other windows, even when those windows are active.
>
> This means, for instance, that the navigator is not available in full-screen mode if the configuration program is running at the same time.

Navigation is performed using the cursor keys (↑↓), and opening / closing of the individual sections is performed using the cursor keys (⇆). The “Enter” key is used to apply the changes that are made; the ESC key to discard them.

After the program has been started the necessary data records are read in. This is indicated by a message on the screen.

The RDC data are read in only if the data saved on the hard disk are identical with those saved in the RDC.

The format version of the data is compatible with the RDC software and has a fixed link to it.

NOTE
Loading and saving procedures should not be interrupted.

If an error occurs, the procedure will be aborted.
This is indicated by an error message.

5.3.3 Checking the data

When the robot controller is booted up a check is made to discover whether the software on the Safe RDC is the current version. If the software version on the Safe RDC is an older version than that in the controller, the current version will be loaded to the Safe RDC.

After reading in the data, the data saved on the hard disk are compared with the data in the RDC. If they are identical, the data are loaded into the configuration table.

If the data are different, the user must decide which data records to use.

If the RDC data are invalid or incompatible, only the data on the hard disk can be loaded.

When data are loaded from the hard disk or from the RDC, **all** of the respective parameters are loaded into the configuration table.
When machine data are loaded, only the data from the machine data file are loaded.

If an error occurs, the execution of the program is aborted; this is indicated by an error message.

NOTE
Runtime variables are only stored internally (volatile memory) and not on the hard disk or in the RDC table.

5.3.4 Changing parameter values

Parameter values are changed using the respective box in the “Value” column. After a change, the respective parameter (“Name” column) and the changed value are shown in red.

> If a value in shown in gray, that value is write-protected and cannot be changed.
>
> If a value outside the permissible value range is input, an appropriate error message is shown.
>
> A list of default values can be found in Section 5.3.6.

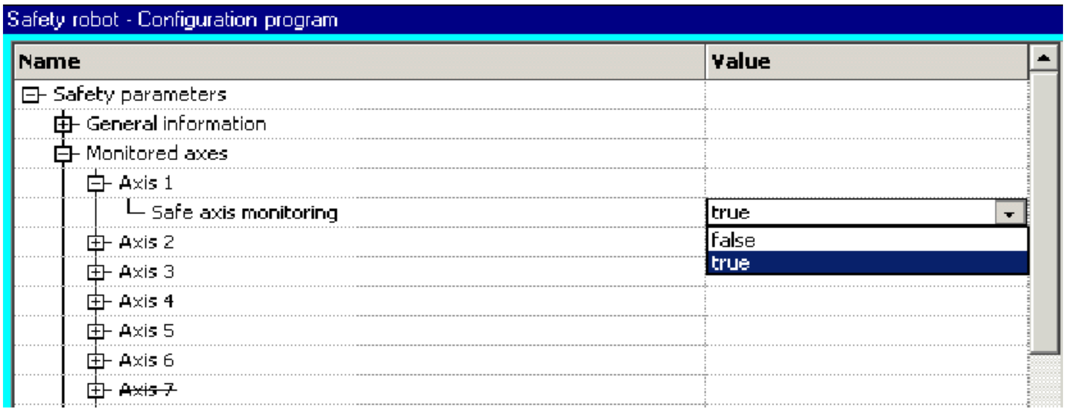


Fig. 45 Changing parameters

The values in the selection boxes (see example in Fig. 45) can be changed by keyboard input (in the example “false” as a change from “true” to “false”) or by pressing the key combination <ALT> + cursor key ↑ or <ALT> + cursor key ↓.

To quit the configuration program, press the softkey “Close”. If changes have been made, you will be asked whether these changes should be saved. Press the softkey “Yes” to save the changes and close the configuration program. Press the softkey “No” to close the program without saving the changed values. Press the softkey “Cancel” to return to the configuration program.

5.3.5 Configuration of safety-relevant parameters

The configuration program allows safety parameters to be configured.

Safety-relevant parameters are:

- Axis velocity [°/s]
- Axis acceleration [°/s^2]
- Safe reduced velocity [mm/s]
- Reference point (position of all axes) [°]
- Axis range limits [°] (radial axes)
- Axis range limits [mm] (linear axes)
- Activation/deactivation of the test pulses for the inputs

There follows a description of the safety-relevant parameters in the order that they appear in the configuration program.

General information

The section “General information” (Fig. 46) shows the content of the time stamp and the version. These values cannot be edited.

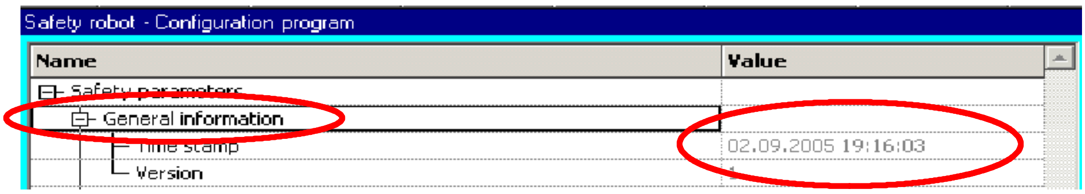


Fig. 46 General information

Monitored axes

In the section “Monitored axes” (Fig. 47) the monitored axes (A 1 ... A 8) are entered.

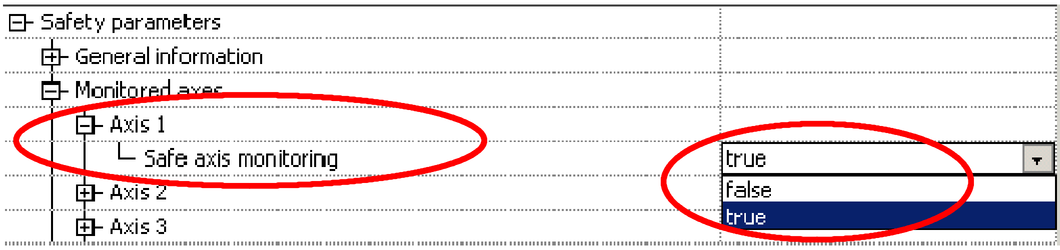


Fig. 47 Monitored axes

Axes to be monitored are set to the value “true”, axes not to be monitored are set to the value “false”.

The names of axes that are not to be monitored are shown crossed out in the “Name” column.

Reduced axis velocity

In the section “Reduced axis velocity” (Fig. 48) an axis velocity differing from the default value (see Section 5.3.6) can be entered.

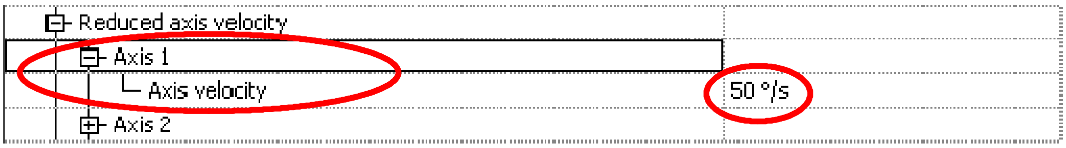


Fig. 48 Reduced axis velocity

Cartesian velocity

In the section “Cartesian velocity” (Fig. 49) the Cartesian axis velocity (flange center point) can be changed.

Fig. 49 Cartesian velocity

Reduced axis acceleration

In the section “Reduced axis acceleration” (Fig. 50) an axis acceleration differing from the default value (see Section 5.3.6) can be entered.

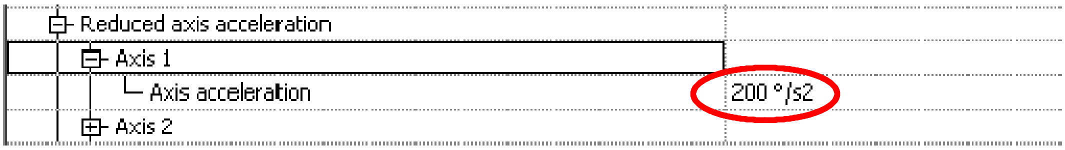


Fig. 50 Reduced axis acceleration

Axis range monitoring

In the section “Axis range monitoring” (Fig. 52) the upper and lower axis angles can be entered.

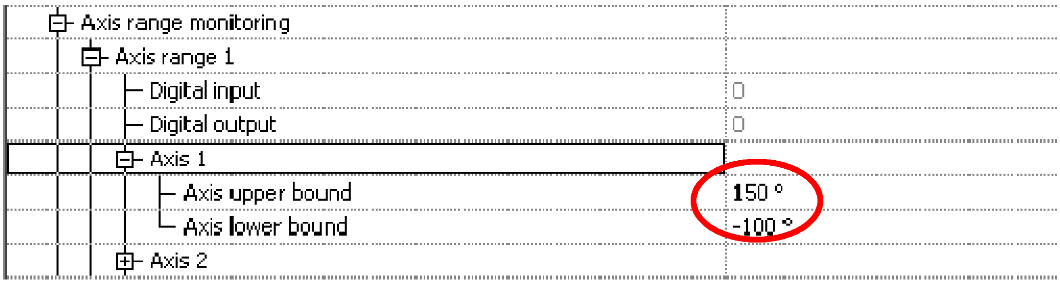


Fig. 51 Axis range monitoring

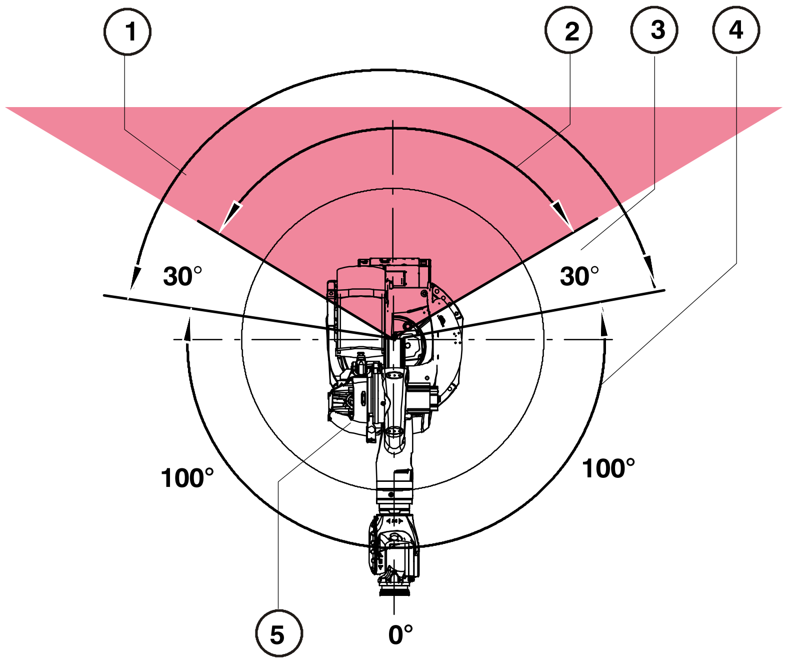
The axis angles are always entered reckoning from axis position 0° (see also Fig. 52).

C A U T I O N !

The robot stopping distance (braking distance) must always be taken into account here; in the example in Fig. 52 this is taken to be 30°.

The exact value for each individual case must be determined by a stopping distance measurement.

After every change to the axis parameters a check must be carried out.



1	Safety range without stopping distances	4	Actual working range
2	Actual safety range	5	Robot
3	Braking distance (max. stopping distance)		

Fig. 52 Example: axis range axis 1 – axis angles

Monitoring of mastering

In the section “Monitoring of mastering” (Fig. 53) the reference mastering positions of the individual axes (as were determined at commissioning) are entered (see Section 5.4.2 of this documentation).

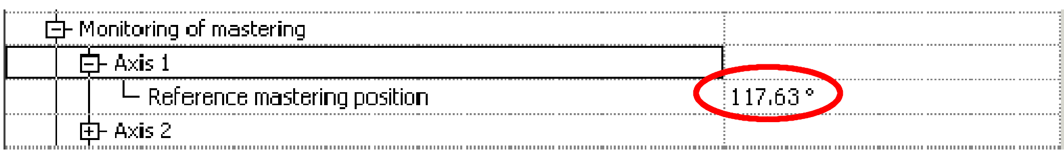


Fig. 53 Monitoring of mastering

These are the axis-specific values which are given on triggering the reference switch (menu function “Monitor” → “Rob. position” → “Axis-specific”).

Standstill monitoring – Axis angle tolerance

In the section “Standstill monitoring” (Fig. 54) an axis angle tolerance differing from the default value (see Section 5.3.6) can be entered for the respective axis.

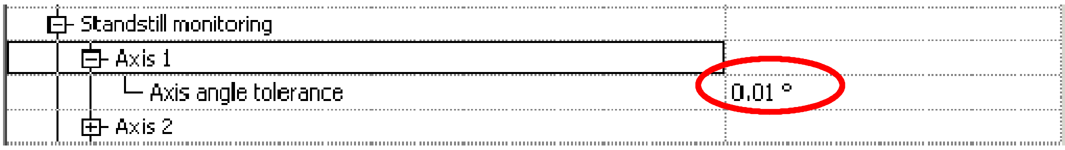


Fig. 54 Standstill monitoring – Axis angle tolerance

Interfaces – Input check pulsing

In the section “Interfaces” (Fig. 55) the value for “Input check pulsing” can be set to “true” or “false”.

Fig. 55 Interfaces – Input check pulsing

Machine data

In the section “Machine data” (Fig. 56) the machine data from “$robcor.dat” and “$machine.dat” can be viewed but not changed.

Name	Value
Machine data ($robcor.dat)	
Machine data ($machine.dat)	
$RAT_MOT_ENC	
Axis 1	
Numerator - Motor:Resolver ratio	1
Denumerator - Motor:Resolver ratio	4
Axis 2	
Axis 3	
Axis 4	
Axis 5	
Axis 6	
~~Axis 7~~	
~~Axis 8~~	
$RAT_MOT_AX	

Fig. 56 Machine data

5.3.6 Parameter default values

Monitored axes

Name	Value
Axis 1 ... 8 **Safe axis monitoring**	**false**

Reduced axis velocity

Name	Value
Axis 1 ... 8 **Axis velocity**	**100 °/s**

Cartesian velocity

Name	Value
Cartesian velocity **Flange center point velocity**	**250 mm/s**

Reduced axis acceleration

Name	Value
Axis 1 ... 8 **Axis acceleration**	**200 mm/s**

Axis range monitoring

For all axis ranges and all axes:

Name	Value
Upper axis angle	**180°**
Lower axis angle	**-180°**
Range inversion	**false**

Monitoring of mastering

Name	Value
Axis 1 ... 8 **Reference mastering position**	**0 °/s**

Standstill monitoring – Axis angle tolerance

Name	Value
Axis 1 ... 8 **Axis angle tolerance**	**0.01°**

Interfaces – Input check pulsing

Name	Value
Interfaces **Input check pulsing**	**true**

5.4 Brake test and reference run

W A R N I N G !
While the drives are being disconnected, no person should be within the robot range, because it is not impossible the robot may sag!

5.4.1 Brake test

For assurance of the braking function of the robot axes, after **every boot-up** of the robot controller and **at intervals of every eight hours when the robot is operating** a **brake test** must be performed.

NOTE
The brake test cannot be performed in "T1" mode.

If the test is not performed in time or is unsuccessful a message appears to this effect in the KCP message window.

W A R N I N G !
The robot can continue to operate and execute its program after a brake test has been omitted or failed, but it is no longer in a safe condition and this can pose a hazard to persons and property!

The brake test is activated by calling a function in a KRL program. This is done by creating a KRL sub-function, which is integrated into a KRL program. A program example is included in Section 7.1 of this documentation.

The brake test is performed on each axis successively. The robot moves at a defined velocity and the brakes are applied. During this process the respective motor current is monitored. A message is displayed based on the measured value of the current.

After successful completion of the test on all axes, the message "Ackn. brake test required" is displayed in the message window of the KCP.

C A U T I O N !
In the event of a brake failure the robot should be brought into a gravity-neutral position, to reduce the risk of uncontrolled movements resulting from the absence of braking.
Please contact your KUKA Service Center to initiate repairs.

5.4.2 Reference run

To check the robot mastering, after **every boot-up** of the robot controller and **at intervals of every eight hours when the robot is operating** a **reference run** must be performed.

For this purpose the robot is moved to a defined reference position where it actuates the reference switch. At this reference position the actual values of the axes must correspond to the reference setpoint values. To move to the reference position, a movement to an exact positioning point is programmed, so that the robot moves to precisely the desired position.

If the test is not performed in time or is unsuccessful a message appears to this effect in the KCP message window.

W A R N I N G !

The robot can continue to operate and execute its program after a reference run has been omitted or failed, but it is no longer in a safe condition and this can pose a hazard to persons and property!

For information about the reference switch and its installation, see Section 4.4 of this documentation. A program example is included in Section 7.1 of this documentation.

The following actions should be performed at commissioning or if it is necessary to determine the reference values:

- Move the actuating plate mounted on the robot wrist towards the sensors on the reference switch (identified by the two green dots on the face of the reference switch). The distance between the reference switch and actuating plate must be between 2 and 3 mm.
- When the actuating plate is correctly positioned over the reference switch, the two LEDs on the underside of the reference switch light up.
- Teach this position and name the point “RefSwitch”.
- Using the menu function “Monitor” → “Rob. position” → “Axis-specific” open the status window and make a note of the axis-specific values.
- Move the robot to the home position.
- Start the configuration program using the menu function
  Setup → Service → Safe Robot → Configuration (see Section 5.3.2).
- Under “Monitoring of mastering” enter the values previously noted, and save them.
- The next time the robot moves to the reference switch, the values determined for the current robot position are compared with the saved reference values. If the values agree, the message “Ackn. mastering test required” is displayed.

5.5 Acceptance test for KUKA.SafeRobot – Checklist

It is a pre-requirement for commissioning that an acceptance test shall have been performed for the system in accordance with the checklist shown in Section 10.2.

6 Operation

6.1 Safe robot retraction

“Safe retraction” mode is activated by setting the safe input “Safe retraction” using the keyswitch. See Section 4.5. When safe retraction is activated a corresponding message is displayed.

In “safe retraction” mode the Cartesian velocity monitoring, the axis-specific velocity monitoring and the axis-specific acceleration monitoring are all activated. All other monitoring is deactivated, so that the robot can be moved free out of an interlocked range.

C A U T I O N !

In this operating mode the robot cannot be monitored in safe mode.

Because safe retraction compromises the safety of the robot, this must be performed only by authorized personnel using a safe input.

7 Programming

7.1 Brake test and reference run

Brake tests and reference runs must be performed every time the robot controller is booted up, and also at specified intervals during continuous operation. See Section 5.4.

Program examples for extending the “SPS.SUB” program and the KRL program (*.src) can be found in Sections 7.1.1 and 7.1.2.

As well as these extensions, some additional user-defined variables must be declared in the file “$CONFIG.DAT” (directory “C:\KRC\ROBOTER\KRC\steu”), in the section “User-defined Variables”:

```
;====================================
; Userdefined Variables
;====================================
BOOL boRef=FALSE
BOOL boRefDone=FALSE
BOOL boBrakeTest=FALSE
BOOL boBrakeTestDone=FALSE
BOOL boReboot=FALSE
;====================================
```

7.1.1 Example of extension to “SPS.SUB”

In the file “SPS.SUB” (directory “C:\KRC\ROBOTER\KRC\R1\System” the extensions described below are necessary.

LOOP

```
LOOP
if $POWER_FAIL then
     boReboot=true
endif
```

The FOLD “**INIT_SAVEROB**” must be added.

```
;FOLD INIT_SAVEROB
;perform reference run and brake test on restart
IF (boReboot OR $TIMER_FLAG[20]) THEN
     boRef=TRUE
ENDIF
IF (boReboot OR $TIMER_FLAG[19]) THEN
     boBrakeTest=TRUE
     boReboot=FALSE
ENDIF
IF (boRef AND boRefDone) THEN
     $TIMER[20]=-28800000
     $TIMER_STOP[20]=FALSE
     boRef=FALSE
     boRefDone=FALSE
ENDIF
IF (boBrakeTest AND boBrakeTestDone) THEN
     $TIMER[19]=-28800000
     $TIMER_STOP[19]=FALSE
     boBrakeTest=FALSE
     boBrakeTestDone=FALSE
ENDIF

;ENDFOLD (INIT_SAVEROB)
```

7.1.2 Example of extension to a KRL program

To perform brake tests and reference runs automatically at the required intervals of time, an appropriate command sequence must be inserted into the KRL program.

```
if boRef then
     Refschalter( )
     boRefDone=true
endif

if boBrakeTest then
     brakeTest(0 )
     boBrakeTestDone=true
endif
```

Program example for reference run

```
; Movement to within approx. 10 cm of the reference switch
PTP P1 Vel= 100 % PDAT1 Tool[1] Base[0]

; Precise movement to the reference switch
LIN REFSCHALTER Vel= 0.5 m/s CPDAT1 Tool[1] Base[0]

; Movement away from the reference switch
LIN P1 VEL= 0.5 m/s CPDAT2 Tool[1] Base[0]
```

NOTE:
When programming the reference run, note that the movement to the reference switch and the movement back from it are **not** executed as PTP motions.

8 Diagnostics, fault analysis

8.1 Error messages for KUKA.SafeRobot

"KUKA.SafeRobot" generates a range of error messages which are described below.

Message text	Type of message	Reaction
Safe reduced axis-specific acceleration: **"Maximum acceleration of** [axis] **exceeded"**	Status and acknowledgement message	STOP 0
Safe reduced axis-specific velocity: **"Maximum speed of** [axis number] **exceeded"**	Status and acknowledgement message	STOP 0
Safe reduced Cartesian velocity: **"Maximum Cartesian speed exceeded"**	Status and acknowledgement message	STOP 0
Axis-specific workspace monitoring: **"Workspace no.** [axis range number] **exceeded"**	Status and acknowledgement message	STOP 0 or STOP 1, depending on the type of axis range violation.
Brake test: **"Brake test failed** [axis number]"	Status and acknowledgement message	None
"Brake test required"	Status and acknowledgement message	None
Reference run for mastering: **"Mastering test failed"**	Status and acknowledgement message	None
"Mastering test required"	Status and acknowledgement message	None
System error for extraordinary malfunctions on the Safe RDC: **"Safe RDC system error** [system error number]"	Status and acknowledgement message	STOP 0
Preconditions for safe monitoring: **"Safety parameters incorrect** [parameter index]"	Status and acknowledgement message	STOP 0
"Safe input/output incorrect"	Status and acknowledgement message	STOP 0
"Safe operational stop violated"	Status and acknowledgement message	STOP 0

Message text	Type of message	Reaction
“Error while starting the Safe RDC”	Status message	STOP 1
“EMERGENCY STOP safety controller”	Status message	STOP 0
“Safety mode not possible”	Status message	STOP 0
“Safe retraction activated”	Status message	Monitoring of the safe reduced velocity/acceleration active; further monitoring bypassed

Two types of STOP are defined as reactions to errors:

- **STOP 0**:
  To trigger the STOP 0 the ESC signal QE is set to LOW via a safe output of the Safe RDC.
  This leads to direct disconnection of the drive contactor.
- **STOP 1**:
  To trigger the STOP 1 the ESC signal ENA is set to LOW via a safe output of the Safe RDC.
  This leads to delayed disconnection of the drive contactor.

9 Repair

The specified service life of the hardware used for “KUKA.SafeRobot” is 40,000 operating hours.

“KUKA.SafeRobot” components should be exchanged no later than at the expiry of this period of time (as shown on the operating hours counter).

9.1 Preparation

W A R N I N G !

All pertinent safety regulations as well as the chapter [Safety, General] must be observed when performing any of the work described below.

Before the start of work the main switch on the control cabinet must be switched off and locked with a suitable lock to prevent it being switched back on! The incoming power cable must be deenergized and measures must be taken to prevent it from being inadvertently energized again.

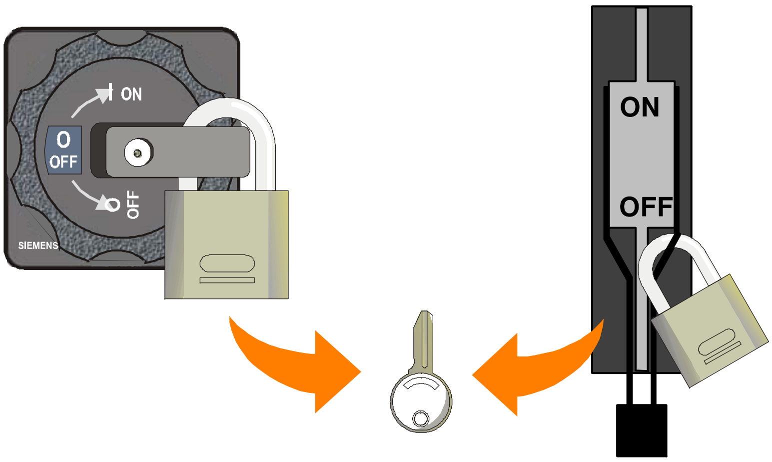


Fig. 57 Main switch in the “OFF” position and locked

C A U T I O N !

The RDC data cable may not be disconnected while energized!
It is essential to wait until completion of the battery backup operation.

9.2 Removing the Safe RDC

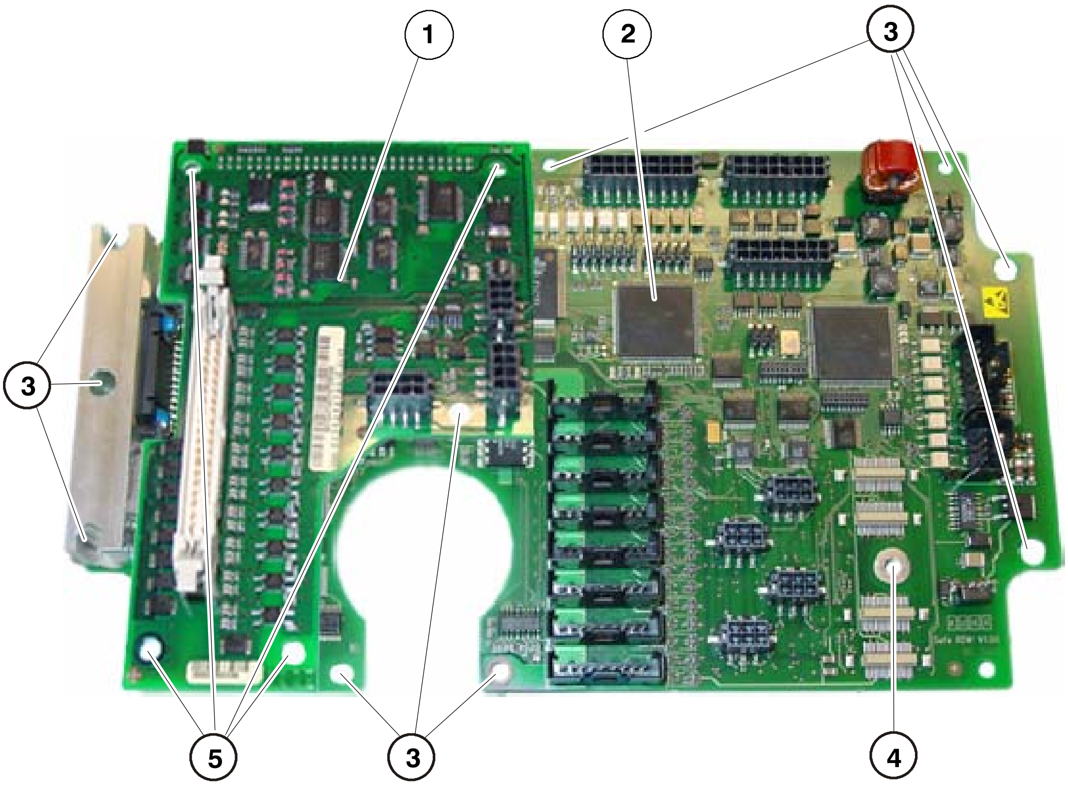
(1) Switch off the system and wait until the battery–backed shutdown storage procedure has been completed.

(2) Undo the screws on the cover of the RDC box and swing the cover open.

(3) Carefully disconnect all connections to the Safe RDC and bend them to one side so that they are out of the way.

(4) Release the fastenings of the basic board (Fig. 58 [**3**]) and carefully remove the circuit board with the I/O Print board from the box.

(5) If necessary, release the fastenings of the I/O Print board (Fig. 58 [**4**]) and pull it off the basic board without tilting it.



1 I/O Print board
2 Basic board
3 Fastening points for basic board
4 Mounting for spacer pins of the sensor modules
5 Fastening points for I/O Print board

Fig. 58 Fastening points of the Safe RDC

9.3 Installing the Safe RDC

(1) Plug the I/O Print board on to the new basic board and tighten the fastening screws (Fig. 58 [**4**]).

(2) Install the Safe RDC and fasten it into place (Fig. 58 [**3**]).

(3) Reconnect all connections.

> The cables are labeled.
> If there are no external axes, connectors X7 and X8 (Fig. 18) are not used.

10 Appendix

10.1 Technical data

In this chapter, only the data specific to the “Safe Robot” system are described. Information regarding the technical data of the control cabinet can be found in the chapter **[Technical Data]** of the KR C2 Operating Handbook.

The following standards were taken into account for “KUKA.SafeRobot”:

- EN 292-1 and 2
- EN 60204-1
- EN 775
- EN 418
- EN 614-1
- EN 954-1
- EN 55011
- EN 61508
- EN 61000-4-2
- EN 61000-4-3
- EN 61000-4-4
- EN 61000-4-5
- EN 61000-4-6
- EN 61000-4-11

“KUKA.SafeRobot” satisfies Safety Category 3 (SIL 2).

Safe RDC

Environmental conditions for the Safe RDC within the box:

Name	Technical data
Temperature range	during transport: -25° C to +70° C during storage: -25° C to +60° C during operation: components up to +85° C circuit boards up to + 75° C
Relative atmospheric humidity	Class 3K3 to EN 50178 (non-condensing)
Shock	Duration 5 ms 20g
Vibration	Amplitude 1 mm up to 13.2 Hz Acceleration 0.7g from 13.2 Hz to 100 Hz (German Lloyd, General Conditions)
Supply voltage	18 to 33 V DC
EMC	Immunity from interference with mains filter to EN 61800-3
Degree of fouling	Degree of fouling 2 (internal) to VDE 0110 part 2
Permissible altitude of installation	1000 m above MSL with no reduction in power
Protection rating of circuit boards	IP 00
Protection rating of box housing	IP 65

Safe inputs

Voltage: 24 V DC

Input current: 3 mA

with special external circuit: max: 10 mA

Safe outputs

Voltage: 24 V DC

Load rating: 100 mA per channel

10.2 Acceptance test for KUKA.SafeRobot - Checklists

Before the robot is put into operation, the continuity of the ground conductor connection between the control cabinet and the robot must be tested with a ground conductor measurement to DIN EN 60204-20.2.

After reinstallation, maintenance work and after every change to the system, the system must be subjected to an acceptance test in accordance with the checklists:

- Robot system check

- Working range monitoring configuration check

The forms filled in during the checks are to be retained in a secure place as evidence!

NOTE

The system may be put into operation only after successful completion of all checks.

The forms filled in during the checks are to be retained as evidence.

The preconditions for the acceptance test of KUKA.SafeRobot are the complete mechanical and electrical installation of the robot, the controller and the necessary accessories, together with the correct installation of the software

- KUKA System Software (KSS) Release 5.4
- KUKA.SafeRobot V1.0

Checklist for robot system check

The checks were performed on robot serial number ....

No.	Check	OK
1	The robot and tool were checked for correct mechanical condition and installation.	❐
2	The control cabinet and all its connections were visually checked.	❐
3	All electrical cables were checked for good condition and correct connection.	❐
4	A check was made to determine whether the entire system (robot, controller, accessories, etc.) satisfied the environmental conditions set out in the respective specifications.	❐
5	All safeguards (protective fence, light barriers, etc.) were checked for good condition and correct operation.	❐
6	The machine data selected were checked and were suitable for the type of robot that was connected.	❐
7	A check was made that the actual payload of the robot did not exceed the permissible payload capacity set out in the specification for the robot.	❐
8	Robot mastering was performed.	❐
9	The reference switch was not in a position which would bring the robot into the mastering position or a singularity position (see section 4.4.2) while performing a reference run (actuation of the reference switch)	❐
10	The external activation of the safe inputs and outputs for the working ranges was checked for correct operation.	❐
11	The configuration program was opened; if different or incompatible data were reported, the data were transferred to the Safe RDC.	❐
12	The position of the reference switch was entered in the configuration program in axis-specific form.	❐
13	Necessary further configurations were performed in the configuration program and transferred to the Safe RDC.	❐
14	The correct configuration of the working ranges were successfully checked by moving to them. For each working range that was used, the form “Checklist for working range monitoring configuration check” was used and the respective check successfully performed.	❐
15	Correct configuration of the Cartesian velocity was checked	❐
16	Correct configuration of the axis-specific velocity was checked	❐
17	Correct configuration of the axis-specific acceleration was checked	❐
18	Brake test was performed successfully	❐
19	Reference run was performed successfully	❐
20	Message “Ackn. safety mode not possible” (this message appears when points 11, 13, 18 and 19 have been completed successfully)	❐

21	The correct configuration of the axis-specific velocity was checked	
	Axis 1 .... °/s	❐
	Axis 2 .... °/s	❐
	Axis 3 .... °/s	❐
	Axis 4 .... °/s	❐
	Axis 5 .... °/s	❐
	Axis 6 .... °/s	❐
	Axis 7 .... °/s	❐
	Axis 8 .... °/s	❐

22	The correct configuration of the axis-specific acceleration was checked	
	Axis 1 .... °/s	❐
	Axis 2 .... °/s	❐
	Axis 3 .... °/s	❐
	Axis 4 .... °/s	❐
	Axis 5 .... °/s	❐
	Axis 6 .... °/s	❐
	Axis 7 .... °/s	❐
	Axis 8 .... °/s	❐

Performed by (Date, signature): ....

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

Checklist for working range monitoring configuration check

Designation of system: ....

Working range number ....

Axis	Check	OK
1	Lower limit value: .... was checked for correctness	❐
	Upper limit value: .... was checked for correctness	❐
2	Lower limit value: .... was checked for correctness	❐
	Upper limit value: .... was checked for correctness	❐
3	Lower limit value: .... was checked for correctness	❐
	Upper limit value: .... was checked for correctness	❐
4	Lower limit value: .... was checked for correctness	❐
	Upper limit value: .... was checked for correctness	❐
5	Lower limit value: .... was checked for correctness	❐
	Upper limit value: .... was checked for correctness	❐
6	Lower limit value: .... was checked for correctness	❐
	Upper limit value: .... was checked for correctness	❐
7	Lower limit value: .... was checked for correctness	❐
	Upper limit value: .... was checked for correctness	❐
8	Lower limit value: .... was checked for correctness	❐
	Upper limit value: .... was checked for correctness	❐
	In the configuration of the working ranges, due allowance was made for the maximum stopping distance of the robot.	❐

Performed by (Date, signature): ....

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

A

B

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