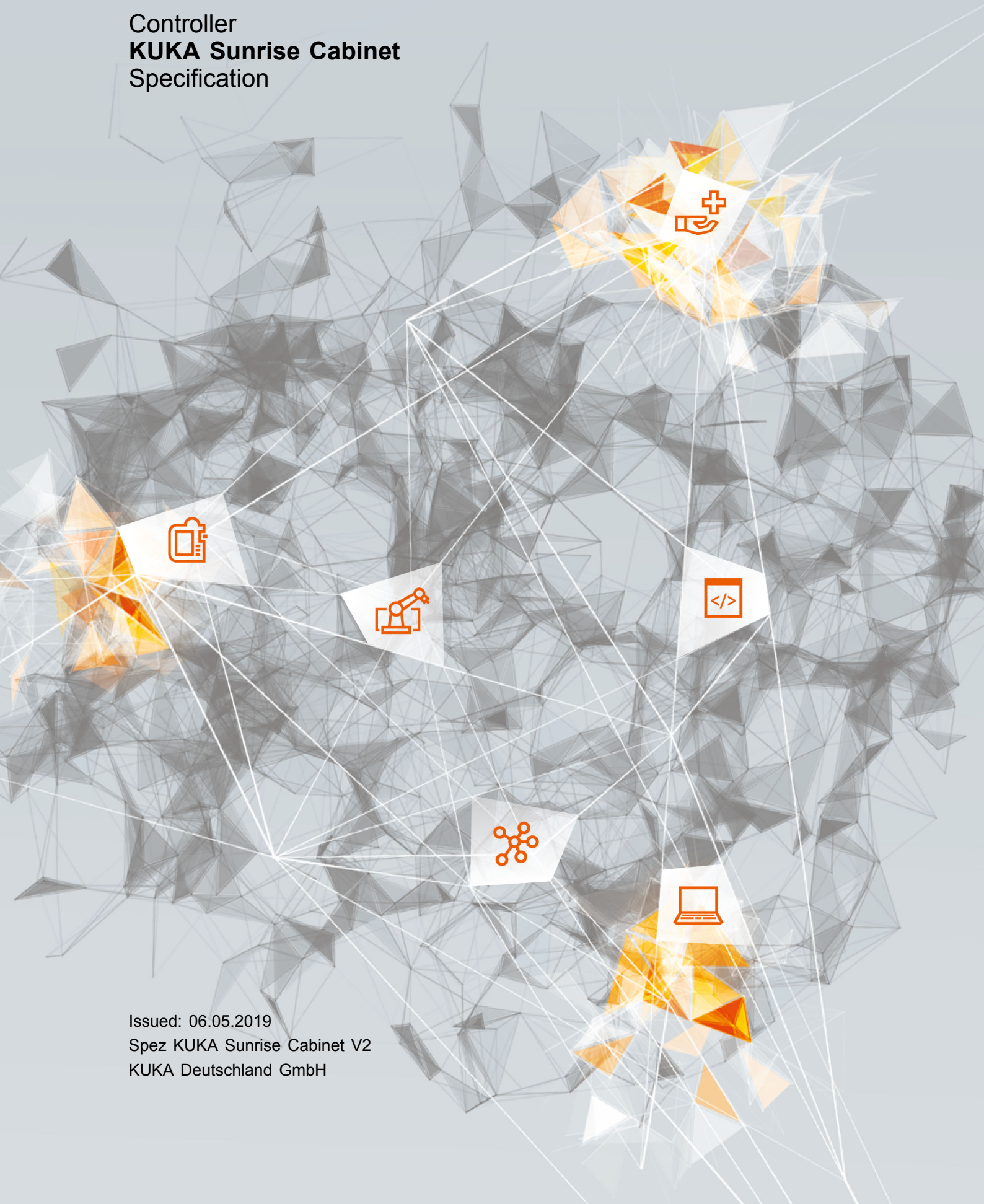
KUKA

Controller
KUKA Sunrise Cabinet
Specification



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Spez KUKA Sunrise Cabinet V2
KUKA Deutschland GmbH

KUKA Deutschland GmbH
Zugspitzstraße 140
D-86165 Augsburg
Germany

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.

KIM-PS5-DOC

Translation of the original documentation

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Book structure:	Spez KUKA Sunrise Cabinet V2.1 BS10024
Version:	Spez KUKA Sunrise Cabinet V2

Contents

1 Introduction

1.1 Industrial robot documentation

The industrial robot documentation consists of the following parts:

- Documentation for the robot arm
- Documentation for the robot controller
- Documentation for the smartPAD-2
- Operating and programming instructions for the System Software
- Instructions for options and accessories
- Spare parts in KUKA.Xpert

Each of these sets of instructions is a separate document.

1.2 Representation of warnings and notes

Safety

These warnings are provided for safety purposes and **must** be observed.

DANGER

These warnings mean that it is certain or highly probable that death or severe injuries **will** occur, if no precautions are taken.

WARNING

These warnings mean that death or severe injuries **may** occur, if no precautions are taken.

CAUTION

These warnings mean that minor injuries **may** occur, if no precautions are taken.

NOTICE

These warnings mean that damage to property **may** occur, if no precautions are taken.

These warnings contain references to safety-relevant information or general safety measures.
These warnings do not refer to individual hazards or individual precautionary measures.

This warning draws attention to procedures which serve to prevent or remedy emergencies or malfunctions:

SAFETY INSTRUCTION

The following procedure must be followed exactly!

Procedures marked with this warning **must** be followed exactly.

Notices

These notices serve to make your work easier or contain references to further information.

Tip to make your work easier or reference to further information.

1.3 Trademarks

- **Windows** is a trademark of Microsoft Corporation.
- **EtherCAT®** is a registered trademark and patented technology, licensed by Beckhoff Automation GmbH, Germany.

1.4 Terms used

Term	Description
CCU_SR	**C**abinet **C**ontrol **U**nit **S**mall **R**obot
CIB_SR	**C**abinet **I**nterface **B**oard **S**mall **R**obot
Dual NIC card	Dual network card
EDS	**E**lectronic **D**ata **S**torage (memory card)
EMC	Electromagnetic compatibility
KCB	**K**UKA **C**ontroller **B**us
KEB	**K**UKA **E**xtension **B**us
KEI	**K**UKA **E**xtension **I**nterface
KLI	**K**UKA **L**ine **I**nterface. Connection to higher-level control infrastructure (PLC, archiving)
KOI	**K**UKA **O**ption **I**nterface
KONI	**K**UKA **O**ption **N**etwork **I**nterface
KPC	Control PC
KSB	**K**UKA **S**ystem **B**us. Internal KUKA bus for internal networking of the controllers with each other
KSI	**K**UKA **S**ervice **I**nterface
KSP_SR	**K**UKA **S**ervo **P**ack Small Robot
KSS	**K**UKA **S**ystem **S**oftware
Manipulator	The robot arm and the associated electrical installations
PMB_SR	**P**ower **M**anagement **B**oard **S**mall **R**obot
SATA connections	Data bus for exchanging data between the processor and the hard drive
SSD	**S**olid-**S**tate **D**rive (electronic storage medium)
USB	**U**niversal **S**erial **B**us. Bus system for connecting additional devices to a computer
EA	External axis (linear unit, Posiflex)

2 Purpose

2.1 Target group

This documentation is aimed at users with the following knowledge and skills:

- Advanced knowledge of electrical and electronic systems
- Advanced knowledge of the robot controller
- Advanced knowledge of the Windows operating system

For optimal use of our products, we recommend that our customers take part in a course of training at KUKA College. Information about the training program can be found at www.kuka.com or can be obtained directly from our subsidiaries.

2.2 Intended use

Use

The KUKA Sunrise Cabinet robot controller is intended solely for operating KUKA axes in industrial applications. KUKA axes include, for example, industrial robots and mobile platforms.

Misuse

Any use or application deviating from the intended use is deemed to be misuse and is not allowed. KUKA Deutschland GmbH is not liable for any damage resulting from such misuse. The risk lies entirely with the user.

Examples of such misuse include:

- Operating axes that are not KUKA axes
- Use for non-industrial applications for which specific product requirements/standards exist (e.g. medical applications)
- Use outside the permissible operating parameters
- Operation in potentially explosive environments
- Outdoor operation

Purpose

3 Product description

3.1 Overview of the robot system

A robot system (>>> *Fig. 3-1*) comprises all the assemblies of an industrial robot, including the manipulator (mechanical system and electrical installations), controller, connecting cables, end effector (tool) and other equipment.

The industrial robot consists of the following components:

- Manipulator
- KUKA Sunrise Cabinet robot controller
- KUKA smartPAD control panel
- Connecting cables
- Software
- Options, accessories

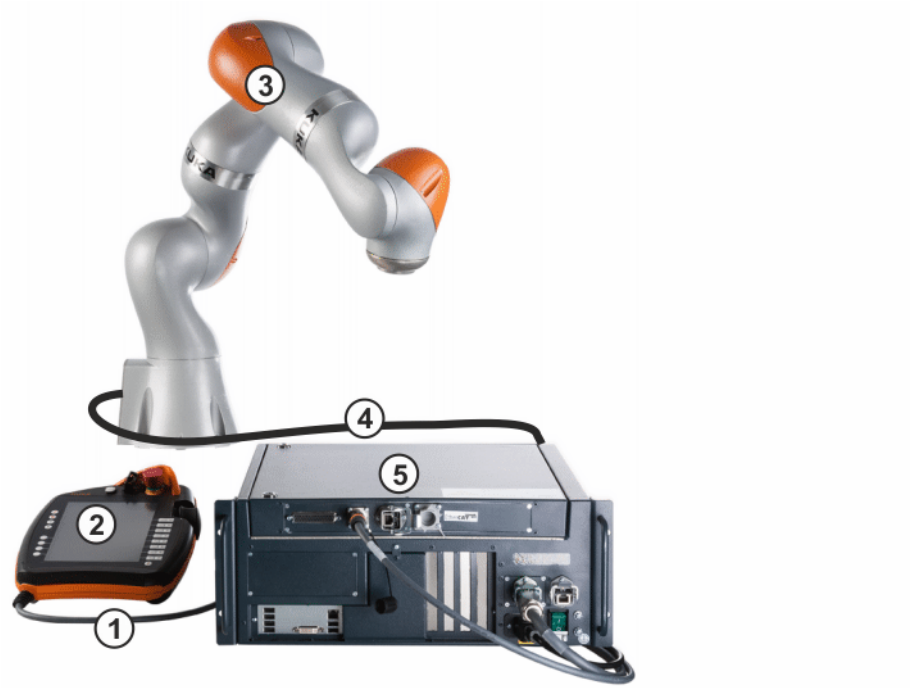


Fig. 3-1: Overview of robot system

1 Connecting cable to the smartPAD
2 KUKA smartPAD control panel
3 Manipulator
4 Connecting cable to KUKA Sunrise Cabinet robot controller
5 KUKA Sunrise Cabinet robot controller

3.2 KUKA Sunrise Cabinet

Overview

The KUKA Sunrise Cabinet robot controller consists of the following components:

- Control PC
- smartPAD control panel

- Connection panel

The robot controller can be installed in a 19" rack.

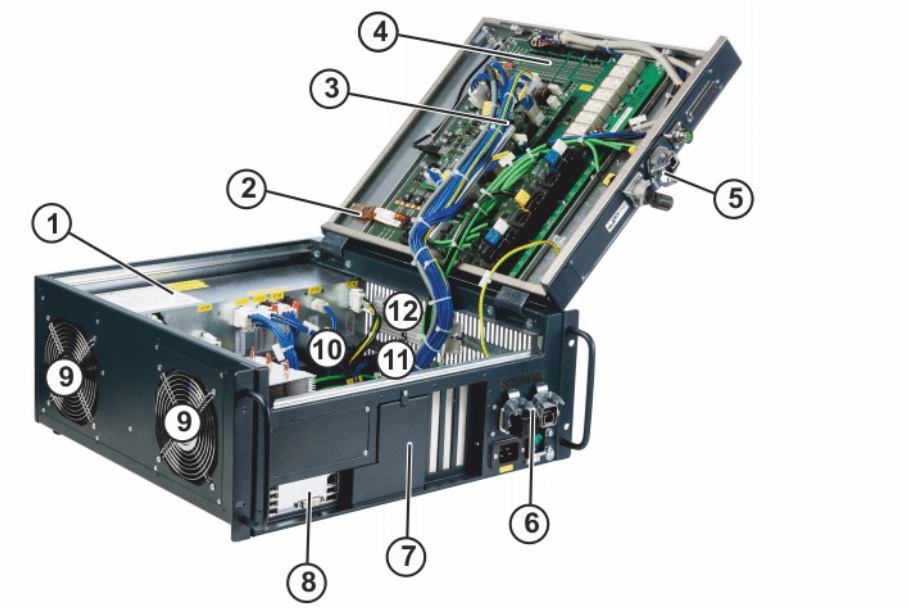


Fig. 3-2: Control unit overview

1	Low-voltage power supply unit
2	Memory card (EDS)
3	Power Management Board, Small Robot (PMB_SR)
4	Cabinet Interface Board, Small Robot (CIB_SR)
5	Interfaces
6	Main switch, interfaces
7	Network connections cover
8	PC interfaces
9	Fans
10	Batteries
11	Options
12	Brake resistor

3.3 Control PC

Components

The control PC (KPC) includes the following components:

- Motherboard
- Processor
- Heat sink
- Memory modules
- Hard drive
- LAN Dual NIC network card (not present on all motherboard variants)

3.4 Cabinet Control Unit, Small Robot

Description

The Cabinet Control Unit, Small Robot (CCU_SR) is the central power distributor and communication interface for all components of the robot controller. The CCU_SR consists of the Cabinet Interface Board, Small Robot (CIB_SR) and the Power Management Board, Small Robot (PMB_SR). All data are transferred via this internal communication interface to the controller for further processing. If the mains voltage fails, the control components continue to be powered by batteries until the position data are saved and the controller has shut down. The charge and quality of the batteries are checked by means of a load test.

The CCU_SR also incorporates sensing, control and switching functions. The output signals are provided as electrically isolated outputs.

Functions

- Communication interface for the components of the robot controller
- Safe inputs and outputs
  - Contactor activation
  - 3 floating outputs
  - 7 safe inputs
  - Teach pendant plugged in
- Fan power supply monitoring
- Control box internal temperature
- The following components are connected to the KPC via the KUKA Controller Bus:
  - Power Drive System
- The following operator panels and service devices are connected to the control PC via the KUKA System Bus:
  - KUKA Operator Panel Interface
- Diagnostic LEDs
- Electronic Data Storage interface

Power supply with battery backup

- KUKA smartPAD
- Control PC quad-core processor
- Power Drive System

Power supply without battery backup

- Motor brakes
- Customer interface

3.5 Low-voltage power supply unit

Description

The low-voltage power supply unit provides power to the components of the robot controller and supplies the manipulator drives with 48 V DC.

Two green LEDs indicate the operating state of the low-voltage power supply unit.

3.6 Batteries

In the event of a power failure, or if the power is switched off, the batteries enable the robot controller to be shut down in a controlled manner. The batteries are charged via the CCU_SR and the charge is checked and indicated.

3.7 Mains filter

Description

The mains filter (interference suppressor filter) suppresses interference voltages on the power cable.

3.8 Description of interfaces

Overview

The connection panel of the KUKA Sunrise Cabinet robot controller consists as standard of connections for the following cables:

- Device connection cable
- Manipulator cable
- smartPAD cable
- Peripheral cables

The configuration of the connection panel varies according to the customer-specific version and the options required.

Connection panel

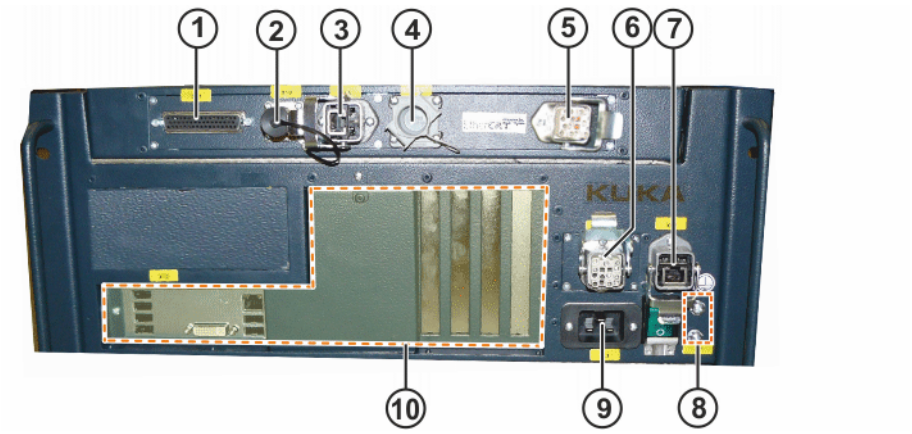


Fig. 3-3: KUKA Sunrise Cabinet interfaces

Item	Interface	Item	Interface
1	X11 interface	6	X21 Manipulator interface
2	X19 smartPAD interface	7	X66 KUKA Line Interface
3	X65 Extension interface	8	PE connections
4	X69 Service interface	9	K1 Power supply connection
5	X650 Interface for media flange	10	Control PC interfaces

All contactor, relay and valve coils that are connected to the robot controller by the user must be equipped with suitable suppressor diodes. RC elements and VCR resistors are not suitable.

3.8.1 Control PC interfaces

Motherboards

The following motherboard variants can be installed in the control PC:

- D3076-K
- D3236-K
- D3445-K

3.8.1.1 Motherboard D3076-K PC interfaces

Overview

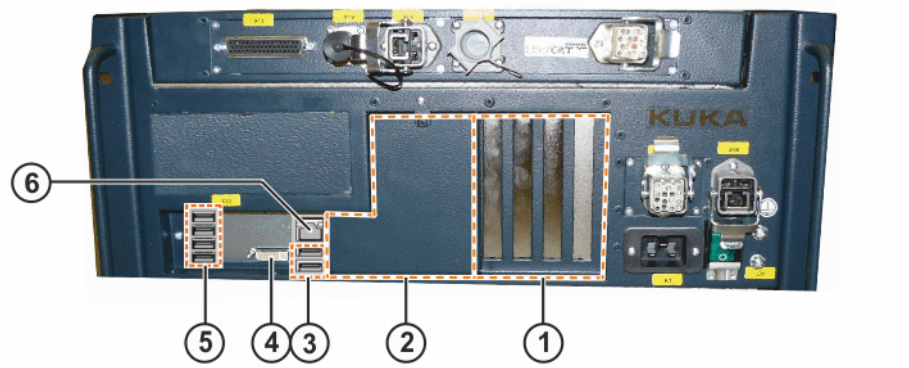


Fig. 3-4: Motherboard D3076-K interfaces

1 Field bus cards, slots 1 to 4
2 Cover, field bus cards
3 2 USB 2.0 ports
4 DVI-I
5 4 USB 2.0 ports
6 LAN Onboard – KUKA Option Network Interface

KUKA Deutschland GmbH has assembled, tested and supplied the motherboard with an optimum configuration. No liability will be accepted for modifications to the configuration that have not been carried out by KUKA Deutschland GmbH.

Slot assignment

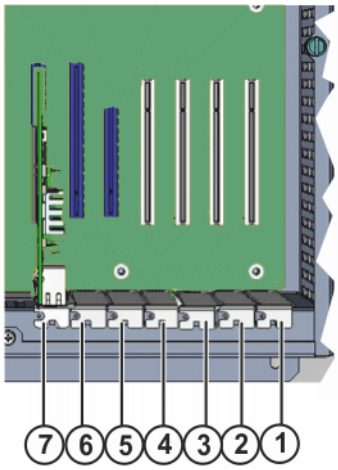


Fig. 3-5: Motherboard slot assignment

The PC slots can be fitted with the following plug-in cards:

Slot	Type	Plug-in card
1	PCI	Field bus
2	PCI	Field bus
3	PCI	Field bus
4	PCI	Field bus
5	PCIe	not available
6	PCIe	not available
7	PCIe	LAN Dual NIC network card

3.8.1.2 Motherboard D3236-K PC interfaces

Overview

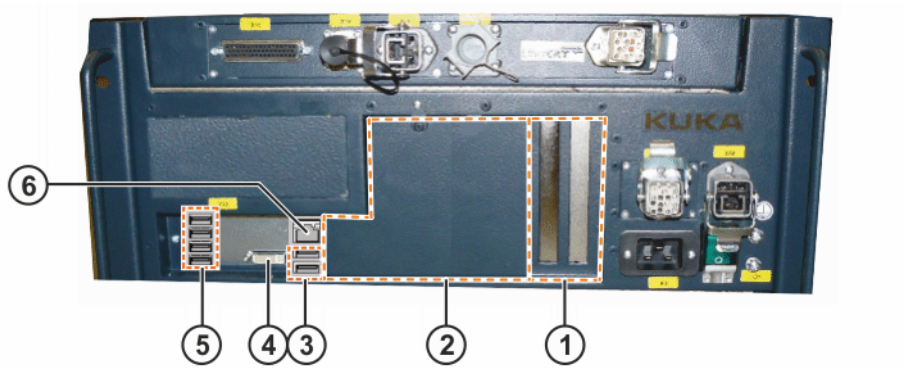


Fig. 3-6: Motherboard D3236-K interfaces

1 Field bus cards, slots 1 to 2
2 Cover
3 2 USB 3.0 ports
4 DVI-I
5 4 USB 2.0 ports
6 LAN Onboard – KUKA Option Network Interface

KUKA Deutschland GmbH has assembled, tested and supplied the motherboard with an optimum configuration. No liability will be accepted for modifications to the configuration that have not been carried out by KUKA Deutschland GmbH.

Slot assignment

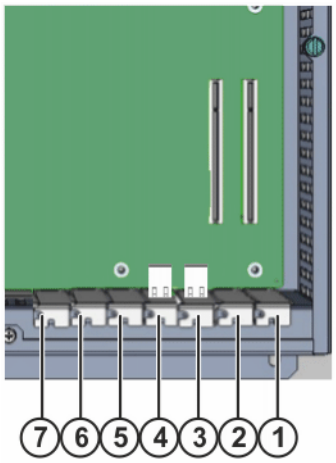


Fig. 3-7: Motherboard slot assignment

The PC slots can be fitted with the following plug-in cards:

Slot	Type	Plug-in card
1	PCI	Field bus
2	PCI	Field bus
3	-	Not available
4	-	Not available
5	-	Not available
6	-	Not available
7	-	Not available

3.8.1.3 Motherboard D3445-K PC interfaces

Overview

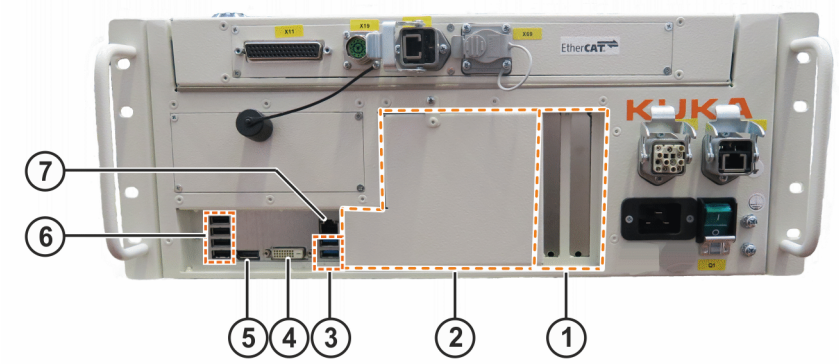


Fig. 3-8: Motherboard D3445-K interfaces

1 Field bus cards, slots 1 to 2
2 Cover
3 2 USB 2.0 ports
4 DVI-D

5 Display port
6 4 USB 2.0 ports
7 LAN Onboard – KUKA Line Interface

VGA support is possible via DP on VGA adapter. The user interface of the controller can only be displayed on an external monitor if no active operator control device (smartPAD, VRP) is connected to the controller.

KUKA Deutschland GmbH has assembled, tested and supplied the motherboard with an optimum configuration. No liability will be accepted for modifications to the configuration that have not been carried out by KUKA Deutschland GmbH.

Slot assignment

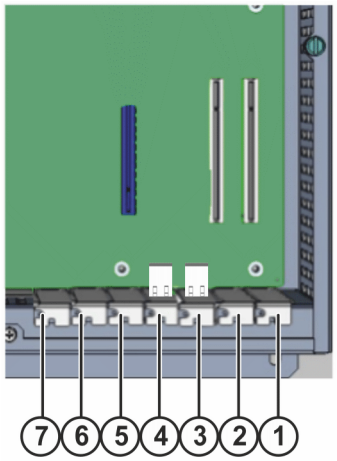


Fig. 3-9: Slot assignment, motherboard D3445-K

Slot	Type	Plug-in card
1	PCI	Field bus
2	PCI	Field bus
3	-	not available
4	-	not available
5	PCIe	not available
6	-	not available
7	-	not available

3.9 Cooling

Description

The components of the control and power electronics are cooled with ambient air by 2 fans.

NOTICE

Upstream installation of filter mats at the ventilation slits causes an increase in temperature, leading to a reduction in the service life of the installed devices!

Cooling circuit, control box

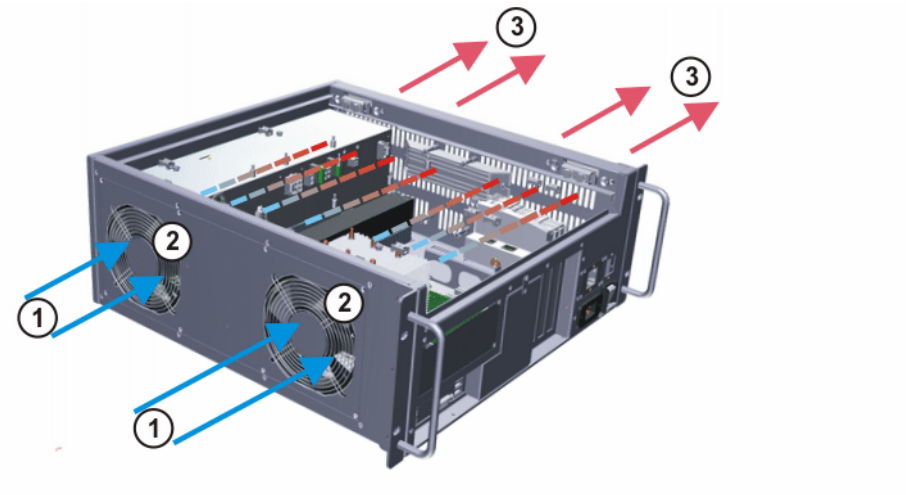


Fig. 3-10: Cooling circuit, control box

1 Air inlet
2 Fan
3 Air outlet

4 Technical data

Basic data

Cabinet type	KUKA Sunrise Cabinet (19" housing)
Color	RAL 7016
Weight	23 kg
Protection rating	IP 20
Sound level according to DIN 45635-1	average: 54 dB (A)

Power supply connection

The robot controller may only be connected to grounded-neutral power supply systems.

Rated supply voltage	110 V/230 V AC, single-phase
Permissible tolerance of rated supply voltage	Rated supply voltage ±10%
Mains frequency	50 Hz ± 1 Hz or 60 Hz ± 1 Hz
Rated power input	1 kVA, see rating plate
Thermal power dissipation	370 W
Mains-side fusing	2x 15 A slow-blowing (1x phase; 1x neutral conductor (optional))
Equipotential bonding	The common neutral point for the equipotential bonding conductors and all protective ground conductors is the reference bus of the power unit.

Environmental conditions

Humidity class (EN 60204)	-
Classification of environmental conditions (EN 60721-3-3)	3K3
Temperature change	1.1 K/min
Ambient temperature	
During operation	5 °C to 45 °C (278 K to 318 K)
During storage/transportation	-25 °C to 40 °C (248 K to 313 K)
During operation with cooling unit	-
During storage/transportation without battery	-25 °C to 70 °C (248 K to 343 K)
Altitude	
Without derating	max. 1000 m above mean sea level

With derating	max. 3000 m above mean sea level (derating 5%/1000 m)

NOTICE

To prevent exhaustive discharge and thus destruction of the batteries, the batteries must be recharged at regular intervals according to the storage temperature.
If the storage temperature is +20 °C or lower, the batteries must be recharged every 9 months.
If the storage temperature is between +20 °C and +30 °C, the batteries must be recharged every 6 months.
If the storage temperature is between +30 °C and +40 °C, the batteries must be recharged every 3 months.

Vibration resistance

r.m.s. acceleration (sustained oscillation)	
During operation	0.1 g
During transportation	0.37 g
Frequency range (sustained oscillation)	
During operation	4...120 Hz
During transportation	4...120 Hz
Acceleration (shock in X/Y/Z direction)	
During operation	2.5 g
During transportation	10 g
Waveform/duration (shock in X/Y/Z direction)	
During operation	Half-sine/11 ms
During transportation	Half-sine/11 ms

If more severe mechanical stress is expected, the controller must be installed on anti-vibration components.

Control unit

Supply voltage	DC 27.1 V ± 0.1 V

Main processor	Quad-core
DIMM memory modules	See shipping version (min. 2 GB)
Hard drive	SSD

KUKA smartPAD

Supply voltage	20 … 27.1 V DC
Dimensions (WxHxD)	approx. 33x26x8 cm
Display	Touch-sensitive color display 600x800 pixels
Display size	8.4"
Interfaces	USB
Weight	1.1 kg

Cable lengths

For cable designations, standard lengths and optional lengths, please refer to the operating instructions or assembly instructions of the manipulator.

When using smartPAD cable extensions, only two extensions may be used. An overall cable length of 50 m must not be exceeded.

4.1 Cabinet Interface Board, Small Robot

The power contacts must only be fed from a safely isolated PELV power supply unit. (>>> *4.2 "External 24 V power supply" Page 24*)

CIB_SR outputs

Operating voltage, power contacts	≤ 30 V
Current via power contact	min. 10 mA < 750 mA
Cable lengths (connection of actuators)	< 50 m cable lengths < 100 m wire length (outgoing and incoming lines)
Cable cross-section (connection of actuators)	≥ 1 mm^2
Switching cycles CIB_SR	Service life: 20 years < 100,000 (corresponds to 13 switching cycles per day)

The module must be exchanged when the number of switching cycles is exceeded.

CIB_SR inputs

Switching level of the inputs	The state for the inputs is not defined for the voltage range from 5 V to 11 V (transition range). Either the ON state or the OFF state is set. OFF state for the voltage range from -3 V to 5 V (OFF range). ON state for the voltage range from 11 V to 30 V (ON range).
Load current with 24 V supply voltage	> 10 mA
Load current with 18 V supply voltage	> 6.5 mA
Max. load current	< 15 mA
Cable length, terminal - sensor	< 50 m, or < 100 m wire length (outgoing and incoming lines)
Cable cross-section, test output - input connection	> 0.5 mm^2
Capacitive load for the test outputs per channel	< 200 nF

Resistive load for the test outputs per channel	< 33 Ω

Test outputs A and B are sustained short-circuit proof.
The specified currents flow via the contact element connected to the input. This must be rated for the maximum current of 15 mA.

4.2 External 24 V power supply

PELV external power supply

External voltage	PELV power supply unit acc. to EN 60950 with rated voltage 27 V (18 V ... 30 V), safely isolated
Continuous current	> 8 A
Cable cross-section of power supply cable	≥ 1 mm^2
Cable length of power supply cable	< 50 m, or < 100 m wire length (outgoing and incoming lines)

The cables of the power supply unit must not be routed together with power-carrying cables.

The minus connection of the external voltage must be grounded by the customer.

Parallel connection of a basic-insulated device is not permitted.

4.3 Dimensions

The dimensions of the robot controller are indicated in the diagram (>>> *Fig. 4-1*).

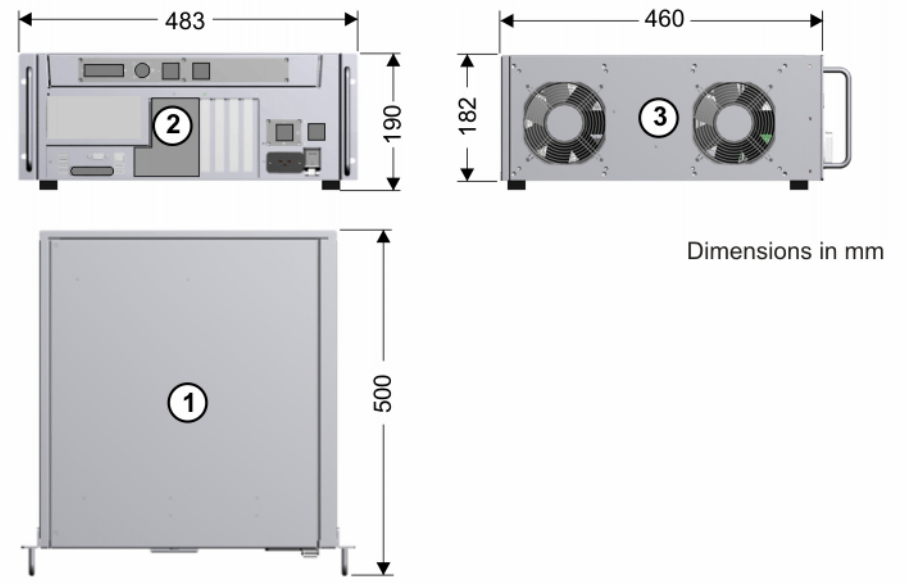


Fig. 4-1: Dimensions

1 Top view
2 Front view
3 Side view

4.4 Dimensions of the smartPAD holder (optional)

The diagram shows the dimensions and drilling locations for mounting on the safety fence.

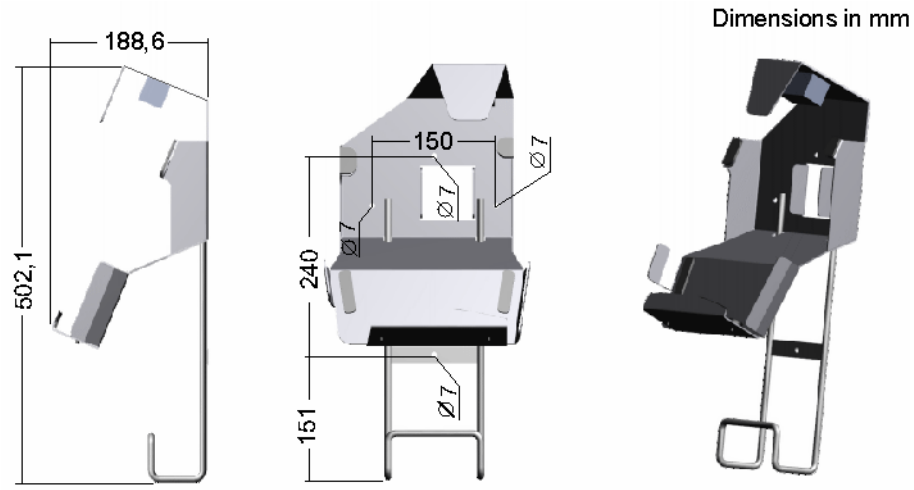


Fig. 4-2: Dimensions and drilling locations for smartPAD holder

4.5 Dimensions of handle brackets

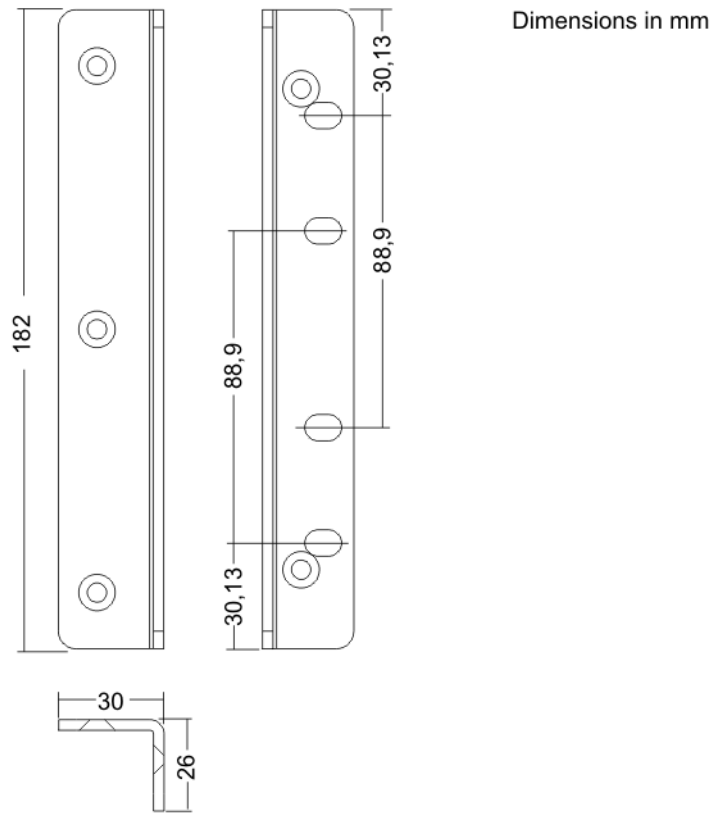


Fig. 4-3: Dimensions of handle brackets

4.6 Plates and labels

Designations

The following plates and labels are attached to the robot controller. They must not be removed or rendered illegible. Illegible plates and labels must be replaced.

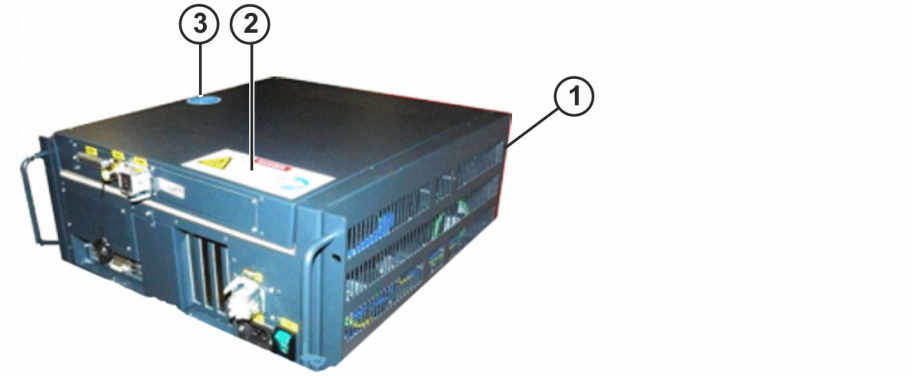
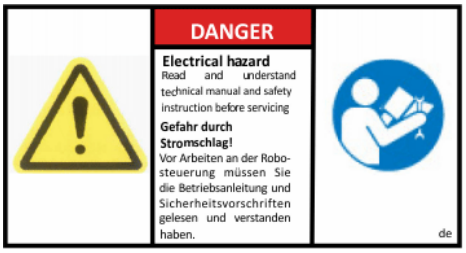


Fig. 4-4: Plates and labels

Item	Description
1	 **Robot controller rating plate**
2	 **Electric shock hazard** The operating instructions and safety regulations must be read and understood before work is carried out on the robot controller.
3	 **Remove mains connector** Unplug mains connector before opening the housing.

The plates may vary slightly from the examples illustrated above depending on the specific cabinet type or as a result of updates.

5 Safety

5.1 Legal framework

5.1.1 Liability

The device described in this document is either an industrial robot or a component thereof.

Components of the industrial robot:

- Manipulator
- Robot controller
- Hand-held control panel
- Connecting cables
- Software
- Options, accessories

The industrial robot is built using state-of-the-art technology and in accordance with the recognized safety rules. Nevertheless, misuse of the industrial robot may constitute a risk to life and limb or cause damage to the industrial robot and to other material property.

The industrial robot may only be used in perfect technical condition in accordance with its designated use and only by safety-conscious persons who are fully aware of the risks involved in its operation. Use of the industrial robot is subject to compliance with this document and with the declaration of incorporation supplied together with the industrial robot. Any functional disorders affecting safety must be rectified immediately.

Safety information

Information about safety may not be construed against KUKA Deutschland GmbH. Even if all safety instructions are followed, this is not a guarantee that the industrial robot will not cause personal injuries or material damage.

No modifications may be carried out to the industrial robot without the authorization of KUKA Deutschland GmbH. Unauthorized modifications will result in the loss of warranty and liability claims.

Additional components (tools, software, etc.), not supplied by KUKA Deutschland GmbH, may be integrated into the industrial robot. The user is liable for any damage these components may cause to the industrial robot or to other material property.

In addition to the Safety chapter, this document contains further safety instructions. These must also be observed.

5.1.2 Intended use of the industrial robot

The industrial robot is intended exclusively for the use designated in the “Purpose” chapter of the operating instructions or assembly instructions.

Any use or application deviating from the intended use is deemed to be misuse and is not allowed. It will result in the loss of warranty and liability claims.

Operation of the industrial robot in accordance with its intended use also requires compliance with the operating and assembly instructions for the individual components, with particular reference to the maintenance specifications.

The user is responsible for carrying out a risk assessment. This indicates the additional safety equipment that is required, the installation of which is also the responsibility of the user.

Misuse

Any use or application deviating from the intended use is deemed to be misuse and is not allowed. This includes e.g.:

- Use as a climbing aid
- Operation outside the specified operating parameters
- Operation without the required safety equipment

5.1.3 EC declaration of conformity and declaration of incorporation

The industrial robot constitutes partly completed machinery as defined by the EC Machinery Directive. The industrial robot may only be put into operation if the following preconditions are met:

- The industrial robot is integrated into a complete system.

  or: The industrial robot, together with other machinery, constitutes a complete system.

  or: All safety functions and safeguards required for operation in the complete machine as defined by the EC Machinery Directive have been added to the industrial robot.
- The complete system complies with the EC Machinery Directive. This has been confirmed by means of a conformity assessment procedure.

EC declaration of conformity

The system integrator must issue an EC declaration of conformity for the complete system in accordance with the Machinery Directive. The EC declaration of conformity forms the basis for the CE mark for the system. The industrial robot must always be operated in accordance with the applicable national laws, regulations and standards.

The robot controller has a CE mark in accordance with the EMC Directive and the Low Voltage Directive.

Declaration of incorporation

The partly completed machinery is supplied with a declaration of incorporation in accordance with Annex II B of the Machinery Directive 2006/42/EC. The assembly instructions and a list of essential requirements complied with in accordance with Annex I are integral parts of this declaration of incorporation.

The declaration of incorporation declares that the start-up of the partly completed machinery is not allowed until the partly completed machinery has been incorporated into machinery, or has been assembled with other parts to form machinery, and this machinery complies with the terms of the EC Machinery Directive, and the EC declaration of conformity is present in accordance with Annex II A.

5.2 Safety functions

Safety functions are distinguished according to the safety requirements that they fulfill:

- Safety-oriented functions for the protection of personnel

  The safety-oriented functions of the industrial robot meet the following safety requirements:

  – **Category 3** and **Performance Level d** in accordance with EN ISO 13849-1
  – **SIL 2** according to EN 62061

  The requirements are only met on the following condition, however:

  – All safety-relevant mechanical and electromechanical components of the industrial robot are tested for correct functioning during start-up and at least once every 12 months, unless otherwise determined in accordance with a workplace risk assessment. These include:
    – Local EMERGENCY STOP device on the teach pendant
    – Enabling device on the teach pendant
    – Enabling device on the hand guiding device (if present)
    – External enabling devices (if present)
    – Keyswitch on the smartPAD (if used as teach pendant)
    – Safety-oriented outputs of the discrete safety interface

Details about safety parameters (e.g. PFH, SIL, Performance Level) are also available as a SISTEMA library. The library can be downloaded from the KUKA website.

- Non-safety-oriented functions for the protection of machines

  The non-safety-oriented functions of the industrial robot do not meet specific safety requirements:

DANGER

In the absence of the required operational safety functions and safeguards, the industrial robot can cause personal injury or material damage. If the required safety functions or safeguards are dismantled or deactivated, the industrial robot may not be operated.

During system planning, the safety functions of the overall system must also be planned and designed. The industrial robot must be integrated into this safety system of the overall system.

5.2.1 Terms used

Term	Description
Axis range	Range within which the axis may move The axis range must be defined for each axis.
Stopping distance	Stopping distance = reaction distance + braking distance The stopping distance is part of the danger zone.
Workspace	The manipulator is allowed to move within its workspace. The workspace is derived from the individual axis ranges.
Automatic (AUT)	Operating mode for program execution. The manipulator moves at the programmed velocity.
Operator (User)	The user of the industrial robot can be the management, employer or delegated person responsible for use of the industrial robot.

Term	Description
Danger zone	The danger zone consists of the workspace and the stopping distances.
Service life	The service life of a safety-relevant component begins at the time of delivery of the component to the customer. The service life is not affected by whether the component is used in a robot controller or elsewhere or not, as safety-relevant components are also subject to aging during storage.
CRR	**C**ontrolled **R**obot **R**etraction CRR is an operating mode which can be selected when the industrial robot is stopped by the safety controller for one of the following reasons: • Industrial robot violates an axis-specific or Cartesian monitoring space. • Orientation of a safety-oriented tool is outside the monitored range. • Industrial robot violates a force or axis torque monitoring function. • A position sensor is not mastered or referenced. • An axis torque sensor is not referenced. After changing to CRR mode, the industrial robot may once again be moved.
KUKA smartPAD	see “smartPAD”
Manipulator	The robot arm and the associated electrical installations
Safety zone	The manipulator is not allowed to move within the safety zone. The safety zone is the area outside the danger zone.
Safety stop	The safety stop is triggered by the safety controller, interrupts the work procedure and causes all robot motions to come to a standstill. The program data are retained in the case of a safety stop and the program can be resumed from the point of interruption. The safety stop can be executed as a Stop category 0, Stop category 1 or Stop category 1 (path-maintaining). **Note:** In this document, a safety stop of Stop category 0 is referred to as safety stop 0, a safety stop of Stop category 1 as safety stop 1 and a safety stop of Stop category 1 (path-maintaining) as safety stop 1 (path-maintaining).
smartPAD	The smartPAD is the hand-held control panel for the robot cell (station). It has all the operator control and display functions required for operation of the station.
Stop category 0	The drives are deactivated immediately and the brakes are applied.
Stop category 1	The manipulator is braked and does not stay on the programmed path. The manipulator is brought to a standstill with the drives. As soon as an axis is at a standstill, the drive is switched off and the brake is applied. The internal electronic drive system of the robot performs safety-oriented monitoring of the braking process. Stop category 0 is executed in the event of a fault. **Note:** Stop category 1 is currently only supported by the LBR iiwa. For other manipulators, Stop category 0 is executed.

Term	Description
Stop category 1 (path-maintaining)	The manipulator is braked and stays on the programmed path. At standstill, the drives are deactivated and the brakes are applied. If Stop category 1 (path-maintaining) is triggered by the safety controller, the safety controller monitors the braking process. The brakes are applied and the drives are switched off after 1 s at the latest. Stop category 1 is executed in the event of a fault.
System integrator (plant integrator)	System integrators are people who safely integrate the industrial robot into a complete system and commission it.
T1	Test mode, Manual Reduced Velocity (<= 250 mm/s) **Note:** With manual guidance in T1, the velocity is not reduced, but rather limited through a safety-oriented velocity monitoring in accordance with the safety configuration. **Note:** The maximum velocity of 250 mm/s does not apply to a mobile platform.
T2	Test mode, Manual High Velocity (> 250 mm/s permissible)

5.2.2 Personnel

The following persons or groups of persons are defined for the industrial robot:

- User
- Personnel

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

User

The user must observe the labor laws and regulations. This includes e.g.:

- The user must comply with his monitoring obligations.
- The user must carry out briefing at defined intervals.

Personnel

Personnel must be instructed, before any work is commenced, in the type of work involved and what exactly it entails as well as any hazards which may exist. Instruction must be carried out regularly. Instruction is also required after particular incidents or technical modifications.

Personnel includes:

- System integrator
- Operators, subdivided into:
  - Start-up, maintenance and service personnel
  - Operating personnel
  - Cleaning personnel

Installation, exchange, adjustment, operation, maintenance and repair must be performed only as specified in the operating or assembly instructions for the relevant component of the industrial robot and only by personnel specially trained for this purpose.

System integrator

The industrial robot is safely integrated into a complete system by the system integrator.

The system integrator is responsible for the following tasks:

- Installing the industrial robot
- Connecting the industrial robot
- Performing risk assessment
- Implementing the required safety functions and safeguards
- Issuing the EC declaration of conformity
- Attaching the CE mark
- Creating the operating instructions for the system

Operators

The operator must meet the following preconditions:

- The operator must be trained for the work to be carried out.
- Work on the system must only be carried out by qualified personnel. These are people who, due to their specialist training, knowledge and experience, and their familiarization with the relevant standards, are able to assess the work to be carried out and detect any potential hazards.

Work on the electrical and mechanical equipment of the manipulator may only be carried out by KUKA Deutschland GmbH.

5.2.3 Workspace, safety zone and danger zone

Working zones are to be restricted to the necessary minimum size in order to prevent danger to persons or the risk of material damage. Safely monitored axis limits that limit the motion range of an axis and are required for personnel protection are configurable.

Further information about configuring safely monitored axis limits is contained in the “Safety configuration” chapter of the operating and programming instructions of the system software for system integrators.

The danger zone consists of the workspace and the stopping distances of the manipulator. In the event of a stop, the manipulator is braked and comes to a stop within the danger zone. The safety zone is the area outside the danger zone.

The danger zone must be protected by means of physical safeguards, e.g. by light barriers, light curtains or safety fences. If there are no physical safeguards present, the requirements for collaborative operation in accordance with EN ISO 10218 must be met. There must be no shearing or crushing hazards at the loading and transfer areas.

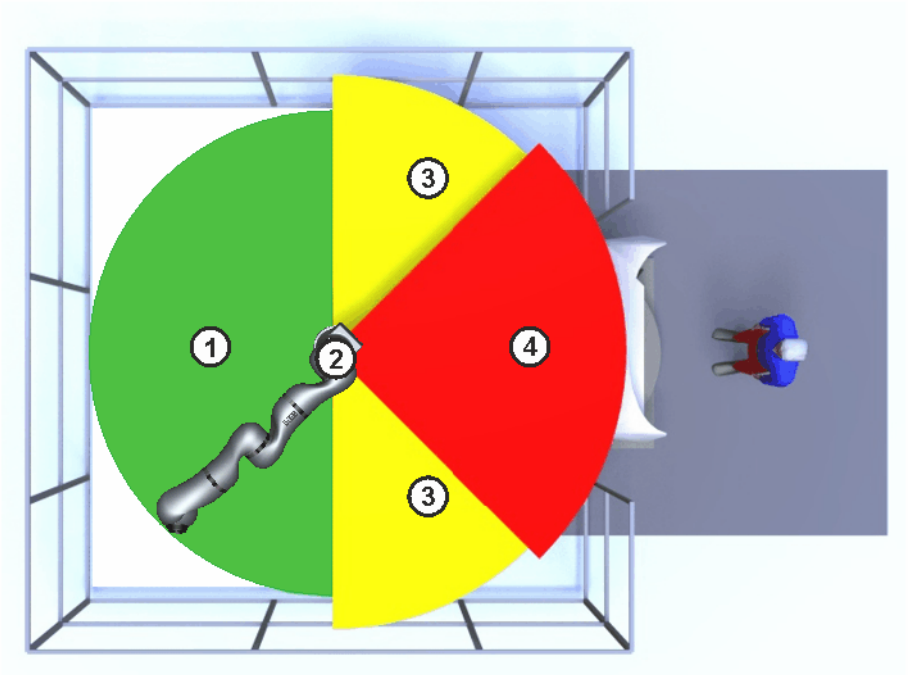


Fig. 5-1: Example: axis range A1

1	Workspace	3	Stopping distance
2	Manipulator	4	Safety zone

5.2.4 Safety-oriented functions

The following safety-oriented functions are present and permanently defined in the industrial robot:

- EMERGENCY STOP device
- Enabling device

The following safety-oriented functions are preconfigured and can be integrated into the system via the safety interface of the robot controller:

- Operator safety (= connection for the monitoring of physical safeguards)
- External EMERGENCY STOP device
- External safety stop 1 (path-maintaining)

Other safety-oriented functions can also be configured, e.g.:

- External enabling device
- External safe operational stop
- Axis-specific workspace monitoring
- Cartesian workspace monitoring
- Cartesian protected space monitoring
- Velocity monitoring
- Standstill monitoring
- Axis torque monitoring
- Collision detection

Further information about configuring the safety functions is contained in the “Safety configuration” chapter of the operating and programming instructions of the system software for system integrators.

The preconfigured safety functions are described in the following sections on safety.

5.2.4.1 EMERGENCY STOP device

As standard, the EMERGENCY STOP device of the industrial robot is the EMERGENCY STOP device on the smartPAD teach pendant. The EMERGENCY STOP device must be pressed in the event of a hazardous situation or emergency.

Reaction of the industrial robot if the EMERGENCY STOP device is pressed:

- The manipulator stops with a safety stop 1 (path-maintaining).

Before operation can be resumed, the EMERGENCY STOP device must be turned to release it.

From KUKA Sunrise.OS 2.4 onwards, the inputs for the local EMERGENCY STOP can be configured, i.e. a different EMERGENCY STOP device can be connected and used for the local EMERGENCY STOP.

WARNING

Tools and other equipment connected to the robot must be integrated into the EMERGENCY STOP circuit on the system side if they could constitute a potential hazard.
Failure to observe this precaution may result in death, severe injuries or considerable damage to property.

If a holder is used for the teach pendant and conceals the EMERGENCY STOP device on the teach pendant, an external EMERGENCY STOP device must be installed that is accessible at all times.

(>>> *5.2.4.4 "External EMERGENCY STOP device" Page 35*)

5.2.4.2 Enabling device

As standard, the enabling device of the industrial robot is the enabling device on the smartPAD teach pendant.

There are 3 enabling switches installed on the smartPAD. The enabling switches have 3 positions:

- Not pressed
- Center position
- Fully pressed (panic position)

In the test modes and in CRR, the manipulator can only be moved if one of the enabling switches is held in the central position.

- Releasing the enabling switch triggers a safety stop 1 (path-maintaining).
- Fully pressing the enabling switch triggers a safety stop 1 (path-maintaining).

From KUKA Sunrise.OS 2.4 onwards, the inputs of the enabling device for the teach pendant can be configured, i.e. a different teach pendant with enabling device can be connected and used.

If an enabling switch malfunctions (e.g. jams in the center position), the industrial robot can be stopped using one of the following methods:

- Press another enabling switch down fully.
- Actuate the EMERGENCY STOP device.

- Release the Start key.

WARNING

The enabling switches must not be held down by adhesive tape or other means or tampered with in any other way.
Death, injuries or damage to property may result.

5.2.4.3 “Operator safety” signal

The “operator safety” signal is used for monitoring physical safeguards, e.g. safety gates. In the default configuration, T2 and automatic operation are not possible without this signal. Alternatively, the requirements for collaborative operation in accordance with EN ISO 10218 must be met.

Reaction of the industrial robot in the event of a loss of signal during T2 or automatic operation (default configuration):

- The manipulator stops with a safety stop 1 (path-maintaining).

By default, operator safety is not active in the modes T1 (Manual Reduced Velocity) and CRR, i.e. the signal is not evaluated.

WARNING

Following a loss of signal, automatic operation must not be resumed merely by closing the safeguard; the signal for operator safety must first be set by an additional device, e.g. by an acknowledge button. It is the responsibility of the system integrator to ensure this. This is to prevent automatic operation from being resumed inadvertently while there are still persons in the danger zone, e.g. due to the safety gate closing accidentally.

- This additional device must be designed in such a way that an actual check of the danger zone can be carried out first. Devices that do not allow this (e.g. because they are automatically triggered by closure of the safeguard) are not permitted.
- Failure to observe this may result in death to persons, severe injuries or considerable damage to property.

5.2.4.4 External EMERGENCY STOP device

Every operator station that can initiate a robot motion or other potentially hazardous situation must be equipped with an EMERGENCY STOP device. The system integrator is responsible for ensuring this.

Reaction of the industrial robot if the external EMERGENCY STOP device is pressed (default configuration):

- The manipulator stops with a safety stop 1 (path-maintaining).

External EMERGENCY STOP devices are connected via the safety interface of the robot controller. External EMERGENCY STOP devices are not included in the scope of supply of the industrial robot.

5.2.4.5 External safety stop 1 (path-maintaining)

The external safety stop 1 (path-maintaining) can be triggered via an input on the safety interface (default configuration). The state is maintained as long as the external signal is FALSE. If the external signal is TRUE, the manipulator can be moved again. No acknowledgement is required.

5.2.4.6 External enabling device

External enabling devices are required if it is necessary for more than one person to be in the danger zone of the industrial robot.

Multiple external enabling devices can be connected via the safety interface of the robot controller. External enabling devices are not included in the scope of supply of the industrial robot.

An external enabling device can be used for manual guidance of the robot. When enabling is active, the robot may only be moved at reduced velocity.

For manual guidance, safety-oriented velocity monitoring with a maximum permissible velocity of 250 mm/s is preconfigured. The maximum permissible velocity can be adapted.

The value for the maximum permissible velocity must be determined as part of a risk assessment.

5.2.4.7 External safe operational stop

The safe operational stop is a standstill monitoring function. It does not stop the robot motion, but monitors whether the robot axes are stationary.

The safe operational stop can be triggered via an input on the safety interface. The state is maintained as long as the external signal is FALSE. If the external signal is TRUE, the manipulator can be moved again. No acknowledgement is required.

5.2.5 Triggers for safety-oriented stop reactions

Stop reactions are triggered in response to operator actions or as a reaction to monitoring functions and errors. The following tables show the different stop reactions according to the operating mode that has been set.

Overview

In KUKA Sunrise a distinction is made between the following triggers:

- Permanently defined triggers

  Permanently defined triggers for stop reactions and the associated stop category are preset by the system and cannot be changed. However, it is possible for the implemented stop reaction to be stepped up in the user-specific safety configuration.
- User-specific triggers

  In addition to the permanently defined triggers, the user can also configure other triggers for stop reactions including the associated stop category.

Further information about configuring the safety functions is contained in the “Safety configuration” chapter of the operating and programming instructions of the system software for system integrators.

Permanently defined triggers

The following triggers for stop reactions are permanently defined:

Trigger	T1, T2, CRR	AUT
Operating mode changed during operation	Safety stop 1 (path-maintaining)	
Enabling switch released	Safety stop 1 (path-maintaining)	-
Enabling switch pressed fully down (panic position)	Safety stop 1 (path-maintaining)	-
Local E-STOP pressed	Safety stop 1 (path-maintaining)	
Error in safety controller	Safety stop 1	

User-specific triggers

When creating a new Sunrise project, the system automatically generates a project-specific safety configuration. This contains the following user-specific stop reaction triggers preconfigured by KUKA (in addition to the permanently defined triggers):

Trigger	T1, CRR	T2, AUT
Safety gate opened (operator safety)	-	Safety stop 1 (path-maintaining)
External E-STOP pressed	Safety stop 1 (path-maintaining)	
External safety stop	Safety stop 1 (path-maintaining)	

This default safety configuration is valid for the system software without additionally installed option packages or catalog elements. If additional option packages or catalog elements have been installed, the default safety configuration may be modified.

Triggers for manual guidance

If an enabling device is configured for manual guidance, the following additional triggers for stop reactions are permanently defined:

Trigger	T1, CRR	T2, AUT
Manual guidance enabling switch released	Safety stop 1 (path-maintaining)	-
Manual guidance enabling switch pressed fully down (panic position)	Safety stop 1 (path-maintaining)	-
Maximum permissible velocity exceeded while manual guidance enabling signal is set	Safety stop 1 (path-maintaining)	

A maximum permissible velocity of 250 mm/s is preconfigured for manual guidance. The maximum permissible velocity can be adapted.

The value for the maximum permissible velocity must be determined as part of a risk assessment.

5.2.6 Non-safety-oriented functions

5.2.6.1 Mode selection

The industrial robot can be operated in the following modes:

- Manual Reduced Velocity (T1)

- Manual High Velocity (T2)
- Automatic (AUT)
- Controlled robot retraction (CRR)

Operating mode	Use	Velocities
T1	Programming, teaching and testing of programs.	• Program verification: Reduced programmed velocity, maximum 250 mm/s • Jog mode: Jog velocity, maximum 250 mm/s • Manual guidance: No limitation of the velocity, but safety-oriented velocity monitoring in accordance with the safety configuration **Note:** The maximum velocity of 250 mm/s does not apply to a mobile platform.
T2	Testing of programs	• Program verification: Programmed velocity • Jog mode: Not possible
AUT	Automatic execution of programs For industrial robots with and without higher-level controllers	• Program operation: Programmed velocity • Jog mode: Not possible
CRR	CRR is an operating mode which can be selected when the industrial robot is stopped by the safety controller for one of the following reasons: • Industrial robot violates an axis-specific or Cartesian monitoring space. • Orientation of a safety-oriented tool is outside the monitored range. • Industrial robot violates a force or axis torque monitoring function. • A position sensor is not mastered or referenced. • An axis torque sensor is not referenced. After changing to CRR mode, the industrial robot may once again be moved.	• Program verification: Reduced programmed velocity, maximum 250 mm/s • Jog mode: Jog velocity, maximum 250 mm/s • Manual guidance: No limitation of the velocity, but safety-oriented velocity monitoring in accordance with the safety configuration

5.2.6.2 Velocity monitoring in T1

The reduced velocity in T1 does not constitute a safety-rated reduced speed in the standard safety configuration, i.e. the maximum permissible velocity of 250 mm/s in T1 is not subjected to safety-oriented monitoring.

If the application requires safety-oriented velocity monitoring in T1, this can be added in the safety configuration. The safety option KUKA Sun-

rise.SafeOperation provides the monitoring function *Cartesian velocity monitoring* for this purpose.

Further information about configuring safety-oriented velocity monitoring for T1 is contained in the “Safety configuration” chapter of the operating and programming instructions of the system software for system integrators.

5.2.6.3 Software limit switches

The axis ranges of all manipulator axes are limited by means of non-safety-oriented software limit switches. These software limit switches only serve as machine protection and are preset in such a way that the manipulator is stopped under servo control if the axis limit is exceeded, thereby preventing damage to the mechanical equipment.

5.3 Additional protective equipment

5.3.1 Jog mode

In the operating modes T1 (Manual Reduced Velocity), T2 (Manual High Velocity) and CRR, the robot controller can only execute programs in jog mode. This means that it is necessary to hold down an enabling switch and the Start key in order to execute a program.

- Releasing the enabling switch on the smartPAD triggers a safety stop 1 (path-maintaining).
- Pressing fully down on the enabling switch on the smartPAD triggers a safety stop 1 (path-maintaining).
- Releasing the Start key triggers a stop of Stop category 1 (path-maintaining).

5.3.2 Labeling on the industrial robot

All plates, labels, symbols and marks constitute safety-relevant parts of the industrial robot. They must not be modified or removed.

Labeling on the industrial robot consists of:

- Identification plates
- Warning signs
- Safety symbols
- Designation labels
- Cable markings
- Rating plates

Further information is contained in the technical data of the operating instructions or assembly instructions of the components of the industrial robot.

5.3.3 External safeguards

The access of persons to the danger zone of the industrial robot must be prevented by means of safeguards. Alternatively, the requirements for collaborative operation in accordance with EN ISO 10218 must be met. It is the responsibility of the system integrator to ensure this.

Physical safeguards must meet the following requirements:

- They meet the requirements of EN ISO 14120.
- They prevent access of persons to the danger zone and cannot be easily circumvented.
- They are sufficiently fastened and can withstand all forces that are likely to occur in the course of operation, whether from inside or outside the enclosure.
- They do not, themselves, represent a hazard or potential hazard.
- The prescribed minimum clearance from the danger zone is maintained.

Safety gates (maintenance gates) must meet the following requirements:

- They are reduced to an absolute minimum.
- The interlocks (e.g. safety gate switches) are linked to the configured operator safety inputs of the robot controller.
- Switching devices, switches and the type of switching conform to the requirements of Performance Level d and category 3 according to EN ISO 13849-1.
- Depending on the risk situation: the safety gate is additionally safeguarded by means of a locking mechanism that only allows the gate to be opened if the manipulator is safely at a standstill.
- The device for setting the signal for operator safety, e.g. the button for acknowledging the safety gate, is located outside the space limited by the safeguards.

Further information is contained in the corresponding standards and regulations. These also include EN ISO 14120.

Other safety equipment

Other safety equipment must be integrated into the system in accordance with the corresponding standards and regulations.

5.4 Safety measures

5.4.1 General safety measures

The industrial robot may only be used in perfect technical condition in accordance with its intended use and only by safety-conscious persons. Operator errors can result in personal injury and damage to property.

It is important to be prepared for possible movements of the industrial robot even after the robot controller has been switched off and locked out. Incorrect installation (e.g. overload) or mechanical defects (e.g. brake defect) can cause the manipulator to sag. If work is to be carried out on a switched-off industrial robot, the manipulator must first be moved into a position in which it is unable to move on its own, whether the payload is mounted or not. If this is not possible, the manipulator must be secured by appropriate means.

DANGER

In the absence of operational safety functions and safeguards, the industrial robot can cause personal injury or material damage. If safety functions or safeguards are dismantled or deactivated, the industrial robot may not be operated.

WARNING

Standing underneath the robot arm can cause death or serious injuries. Especially if the industrial robot is moving objects that can become detached (e.g. from a gripper). For this reason, standing underneath the robot arm is prohibited!

HRC

In the case of collaborative operation (HRC), the system must be equipped with a visual display indicating when the robot is in collaborative operation.

smartPAD

The user must ensure that the industrial robot is only operated with the smartPAD by authorized persons.

If more than one smartPAD is used in the overall system, it must be ensured that each smartPAD is unambiguously assigned to the corresponding industrial robot. It must be ensured that 2 smartPADs are not interchanged.

The smartPAD can be configured as unpluggable.

WARNING

If the smartPAD is disconnected, the system can no longer be switched off by means of the EMERGENCY STOP device on the smartPAD. If the smartPAD is configured as unpluggable, at least one external EMERGENCY STOP device must be installed that is accessible at all times.
Failure to observe this can lead to death, injury or property damage.

WARNING

The operator must ensure that disconnected smartPADs are immediately removed from the system and stored out of sight and reach of personnel working on the industrial robot. This prevents operational and non-operational EMERGENCY STOP devices from becoming interchanged.
Failure to observe this can lead to death, injury or property damage.

Modifications

After modifications to the industrial robot, checks must be carried out to ensure the required safety level. The valid national or regional work safety regulations must be observed for this check. The correct functioning of all safety functions must also be tested.

New or modified programs must always be tested first in Manual Reduced Velocity mode (T1).

After modifications to the industrial robot, existing programs must always be tested first in Manual Reduced Velocity mode (T1). This applies to all components of the industrial robot and includes modifications to the software and configuration settings.

The robot may not be connected and disconnected when the robot controller is running.

Faults

The following tasks must be carried out in the case of faults in the industrial robot:

- Switch off the robot controller and secure it (e.g. with a padlock) to prevent unauthorized persons from switching it on again.
- Indicate the fault by means of a label with a corresponding warning (tagout).
- Keep a record of the faults.
- Eliminate the fault and carry out a function test.

5.4.2 IT security

The industrial robot may only be used in perfect technical condition in accordance with its intended use and only by safety-conscious persons.

In particular, security-conscious use includes that it be operated in an IT environment which meets the current security-relevant standards and for which there is an overall concept for IT security.

IT security entails not only technical aspects but, at a minimum, also those of organization, personnel and infrastructure.
KUKA urgently recommends that operators implement an information security management system for their products which designs, coordinates and monitors the tasks related to information security.

Sources for information about IT security for companies include:

- Independent consulting firms
- National cyber security authorities

National authorities often make their recommendations available on the Internet. In addition to their official language, some national authorities provide their information in English.

5.4.3 Transportation

Manipulator

The prescribed transport position of the manipulator must be observed. Transportation must be carried out in accordance with the operating instructions or assembly instructions of the robot.

Avoid vibrations and impacts during transportation in order to prevent damage to the manipulator.

Robot controller

The prescribed transport position of the robot controller must be observed. Transportation must be carried out in accordance with the operating instructions or assembly instructions of the robot controller.

Avoid vibrations and impacts during transportation in order to prevent damage to the robot controller.

5.4.4 Start-up and recommissioning

Before starting up systems and devices for the first time, a check must be carried out to ensure that the systems and devices are complete and operational, that they can be operated safely and that any damage is detected.

The valid national or regional work safety regulations must be observed for this check. The correct functioning of all safety functions must also be tested.

Prior to start-up, the passwords for the user groups must be modified by the administrator, transferred to the robot controller in an installation procedure and activated. The passwords must only be communicated to authorized personnel.

DANGER

The robot controller is preconfigured for the specific industrial robot. If cables are interchanged, the manipulator may receive incorrect data and can thus cause personal injury or material damage. If a system consists of more than one manipulator, always connect the connecting cables to the manipulators and their corresponding robot controllers.

If additional components (e.g. cables), which are not part of the scope of supply of KUKA Deutschland GmbH, are integrated into the industrial robot, the user is responsible for ensuring that these components do not adversely affect or disable safety functions.

NOTICE

If the internal cabinet temperature of the robot controller differs greatly from the ambient temperature, condensation can form, which may cause damage to the electrical components. Do not put the robot controller into operation until the internal temperature of the cabinet has adjusted to the ambient temperature.

Function test

The following tests must be carried out before start-up and recommissioning:

General test:

It must be ensured that:

- The industrial robot is correctly installed and fastened in accordance with the specifications in the documentation.
- There are no foreign bodies or defective or loose parts on the industrial robot.
- All required safety equipment is correctly installed and operational.
- The power supply ratings of the industrial robot correspond to the local supply voltage and mains type.
- The ground conductor and the equipotential bonding cable are sufficiently rated and correctly connected.
- The connecting cables are correctly connected and the connectors are locked.

Test of the safety functions:

A function test must be carried out for all the safety-oriented functions to ensure that they are working correctly:

Test of the safety-relevant mechanical and electromechanical components:

The following tests must be performed prior to start-up and at least once every 12 months unless otherwise determined in accordance with a workplace risk assessment:

- Function of all connected EMERGENCY STOP devices

  Press the EMERGENCY STOP device. A message must be displayed on the teach pendant indicating that the EMERGENCY STOP has been actuated. At the same time, no error message may be displayed about the EMERGENCY STOP device.

- Function of the enabling switches of all connected enabling devices

  Move the robot in Test mode and release the enabling switch. The robot motion must be stopped. At the same time, no error message may be displayed on the teach pendant about the enabling device.

  The test must always be carried out for all enabling switches of a connected enabling device.

  If the state of the enabling device is configured at an output, the test can also be performed via the output.
- Panic function of the enabling switches of all connected enabling devices

  Move the robot in Test mode and press the enabling switch down fully. The robot motion must be stopped. At the same time, no error message may be displayed on the teach pendant about the enabling device.

  The test must always be carried out for all enabling switches of a connected enabling device.

  If the state of the enabling device is configured at an output, the test can also be performed via the output.
- Function of the keyswitch on the smartPAD (if used as teach pendant)

  Turn the keyswitch to the right and then back again. There must be no error message displayed on the smartPAD.
- Switch-off capability of the safety-oriented outputs

  Switch robot controller off and then on again. After it is switched on, no error message relating to a safety-oriented output may be displayed on the teach pendant.

In the case of incomplete start-up of the system, additional substitute measures for minimizing risk must be taken and documented, e.g. installation of a safety fence, attachment of a warning sign, locking of the main switch. Start-up is incomplete, for example, if not all safety functions have yet been implemented, or if a function test of the safety functions has not yet been carried out.

Test of the functional capability of the brakes:

For the industrial robot, a brake test is available which can be used to check whether the brake of each axis applies sufficient braking torque.

The brake test ensures that any impairment of the braking function is detected, e.g. due to wear, overheating, fouling or damage, thereby eliminating avoidable risks.

The brake test must be performed regularly, unless an application-specific risk assessment has established that a malfunction of the mechanical brakes will not result in inadmissibly high risks. Determination of the interval at which the brake test is to be performed also constitutes part of the risk assessment.

In the absence of a corresponding risk assessment, the following applies:

- The brake test must be carried out for each axis during start-up and recommissioning of the industrial robot.
- The brake test must be performed daily during operation.

5.4.5 Manual mode

General

Manual mode is the mode for setup work. Setup work is all the tasks that have to be carried out on the industrial robot to enable automatic operation. Setup work includes:

- Jog mode
- Teaching
- Program verification

The following must be taken into consideration in manual mode:

- New or modified programs must always be tested first in Manual Reduced Velocity mode (T1).
- The manipulator and its tooling must never touch or project beyond the safety fence.
- Workpieces, tooling and other objects must not become jammed as a result of the industrial robot motion, nor must they lead to short-circuits or be liable to fall off.
- All setup work must be carried out, where possible, from outside the safeguarded area.

Setup work in T1

If it is necessary to carry out setup work from inside the safeguarded area, the following must be taken into consideration in the operating mode **Manual Reduced Velocity (T1)**:

- If it can be avoided, there must be no other persons inside the safeguarded area.

  If it is necessary for there to be several persons inside the safeguarded area, the following must be observed:

  – Each person must have an enabling device.
  – All persons must have an unimpeded view of the industrial robot.
  – Eye-contact between all persons must be possible at all times.
- The operator must be so positioned that he can see into the danger area and get out of harm's way.
- Unexpected motions of the manipulator cannot be ruled out, e.g. in the event of a fault. For this reason, an appropriate clearance must be maintained between persons and the manipulator (including tool). Guide value: 50 cm.

  The minimum clearance may vary depending on local circumstances, the motion program and other factors. The minimum clearance that is to apply for the specific application must be decided by the user on the basis of a risk assessment.

Setup work in T2

If it is necessary to carry out setup work from inside the safeguarded area, the following must be taken into consideration in the operating mode **Manual High Velocity (T2)**:

- This mode may only be used if the application requires a test at a velocity higher than that possible in T1 mode.
- Teaching is not permissible in this operating mode.
- Before commencing the test, the operator must ensure that the enabling devices are operational.
- The operator must be positioned outside the danger zone.

- There must be no-one present inside the safeguarded area. It is the responsibility of the operator to ensure this.

5.4.6 Automatic mode

Automatic mode is only permissible in compliance with the following safety measures:

- All safety equipment and safeguards are present and operational.
- There are no persons in the system, or the requirements for collaborative operation in accordance with EN ISO 10218 have been met.
- The defined working procedures are adhered to.

If the manipulator comes to a standstill for no apparent reason, the danger zone must not be entered until an EMERGENCY STOP has been triggered.

5.4.7 Maintenance and repair

After maintenance and repair work, checks must be carried out to ensure the required safety level. The valid national or regional work safety regulations must be observed for this check. The correct functioning of all safety functions must also be tested.

The purpose of maintenance and repair work is to ensure that the system is kept operational or, in the event of a fault, to return the system to an operational state. Repair work includes troubleshooting in addition to the actual repair itself.

The following safety measures must be carried out when working on the industrial robot:

- Carry out work outside the danger zone. If work inside the danger zone is necessary, the user must define additional safety measures to ensure the safe protection of personnel.
- Switch off the industrial robot and secure it (e.g. with a padlock) to prevent it from being switched on again. If it is necessary to carry out work with the robot controller switched on, the user must define additional safety measures to ensure the safe protection of personnel.
- If it is necessary to carry out work with the robot controller switched on, this may only be done in operating mode T1.
- Label the system with a sign indicating that work is in progress. This sign must remain in place, even during temporary interruptions to the work.
- The EMERGENCY STOP devices must remain active. If safety functions or safeguards are deactivated during maintenance or repair work, they must be reactivated immediately after the work is completed.

DANGER

Before work is commenced on live parts of the robot system, the main switch must be turned off and secured against being switched on again. The system must then be checked to ensure that it is deenergized.
It is not sufficient, before commencing work on live parts, to execute an EMERGENCY STOP or a safety stop, or to switch off the drives, as this does not disconnect the robot system from the mains power supply. Parts remain energized. Death or severe injuries may result.

Faulty components must be replaced using new components with the same article numbers or equivalent components approved by KUKA Deutschland GmbH for this purpose.

Cleaning and preventive maintenance work is to be carried out in accordance with the operating instructions.

Robot controller

Even when the robot controller is switched off, parts connected to peripheral devices may still carry voltage. The external power sources must therefore be switched off if work is to be carried out on the robot controller.

The ESD regulations must be adhered to when working on components in the robot controller.

Voltages in excess of 60 V can be present in various components for several minutes after the robot controller has been switched off! To prevent life-threatening injuries, no work may be carried out on the industrial robot in this time.

Water and dust must be prevented from entering the robot controller.

5.4.8 Decommissioning, storage and disposal

The industrial robot must be decommissioned, stored and disposed of in accordance with the applicable national laws, regulations and standards.

5.4.9 Safety measures for “single point of control”

Overview

If certain components in the industrial robot are operated, safety measures must be taken to ensure complete implementation of the principle of “single point of control” (SPOC).

Components:

- Tools for configuration of bus systems with online functionality

The implementation of additional safety measures may be required. This must be clarified for each specific application; this is the responsibility of the user of the system.

Since only the system integrator knows the safe states of actuators in the periphery of the robot controller, it is his task to set these actuators to a safe state.

T1, T2, CRR

In modes T1, T2 and CRR, a robot motion can only be initiated if an enabling switch is held down.

Tools for configuration of bus systems

If these components have an online functionality, they can be used with write access to modify programs, outputs or other parameters of the robot controller, without this being noticed by any persons located inside the system.

Such tools include:

- KUKA Sunrise.Workbench
- WorkVisual from KUKA
- Tools from other manufacturers

Safety measure:

- In the test modes, programs, outputs or other parameters of the robot controller must not be modified using these components.

5.5 Applied standards and directives

Name/Edition	Definition
2006/42/EC:2006	**Machinery Directive:** Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery, and amending Directive 95/16/EC (recast)
2014/30/EU:2014	**EMC Directive:** Directive 2014/30/EC of the European Parliament and of the Council dated 26 February 2014 on the approximation of the laws of the Member States concerning electromagnetic compatibility
EN ISO 13850:2015	**Safety of machinery:** Emergency stop - Principles for design
EN ISO 13849-1:2015	**Safety of machinery:** Safety-related parts of control systems - Part 1: General principles of design
EN ISO 13849-2:2012	**Safety of machinery:** Safety-related parts of control systems - Part 2: Validation
EN ISO 12100:2010	**Safety of machinery:** General principles of design, risk assessment and risk reduction
EN ISO 10218-1:2011	**Industrial robots – Safety requirements:** Part 1: Robots **Note:** Content equivalent to **ANSI/RIA R.15.06-2012, Part 1**
EN 614-1:2006+A1:2009	**Safety of machinery:** Ergonomic design principles - Part 1: Terms and general principles
EN 61000-6-2:2005	**Electromagnetic compatibility (EMC):** Part 6-2: Generic standards; Immunity for industrial environments
EN 61000-6-4:2007 + A1:2011	**Electromagnetic compatibility (EMC):** Part 6-4: Generic standards; Emission standard for industrial environments
EN 60204-1:2006/ A1:2009	**Safety of machinery:** Electrical equipment of machines - Part 1: General requirements
EN 62061:2005 + A1:2013 + A2:2015	**Safety of machinery:** Functional safety of safety-related electrical, electronic and programmable electronic control systems

6 Planning

6.1 Overview

This is an overview of the most important planning specifications. The precise planning depends on the application, the manipulator type, the technology packages used and other customer-specific circumstances. For this reason, the overview does not claim to be comprehensive.

Step	Description	Information
1	Electromagnetic compatibility (EMC)	(>>> *6.2 "Electromagnetic compatibility (EMC)" Page 49*)
2	Installation conditions for robot controller	(>>> *6.3 "Installation conditions" Page 50*)
3	Connection conditions	(>>> *6.4 "Connection conditions" Page 51*)
4	Power supply connection	
5	Safety interface X11	(>>> *6.6 "Interface X11" Page 52*)
6	Safety interface X11 default connector pin allocation	
7	KUKA Extension Bus interface X65	(>>> *6.7 "KUKA Extension Bus X65" Page 57*)
8	KUKA Line Interface X66	(>>> *6.8 "KUKA Line Interface X66" Page 58*)
9	Service interface X69	(>>> *6.9 "X69 KUKA Service Interface" Page 59*)
10	Media flange interface X650	(>>> *6.10 "Media flange interface X650" Page 60*)
11	Equipotential bonding	(>>> *6.11 "PE equipotential bonding" Page 60*)
12	Performance Level	(>>> *6.12 "Performance level" Page 61*)

6.2 Electromagnetic compatibility (EMC)

Description

If connecting cables (e.g. field buses, etc.) are routed to the control PC from outside, only shielded cables with an adequate degree of shielding may be used.

The robot controller corresponds to EMC class A, Group 1, in accordance with EN 55011 and is intended for use in an **industrial setting**. Assuring the electromagnetic compatibility in other environments may be difficult due to conducted and radiated disturbances that are liable to occur.

6.3 Installation conditions

Dimensions

The robot controller can be installed in a 19" rack or as a standalone device. The specifications in the “Technical data” chapter (>>> *4 "Technical data" Page 21*) must be observed. If the robot controller is to be installed in a 19" rack, the depth must be at least 600 mm.

If the robot controller is to be installed in a 19" rack, it must be fastened in the rack by appropriate means (preferably angle plates) along the entire side edge in order to prevent distortion of the housing.

Both sides of the robot controller must be accessible to the cooling air. Clearance of 70 mm on each side.

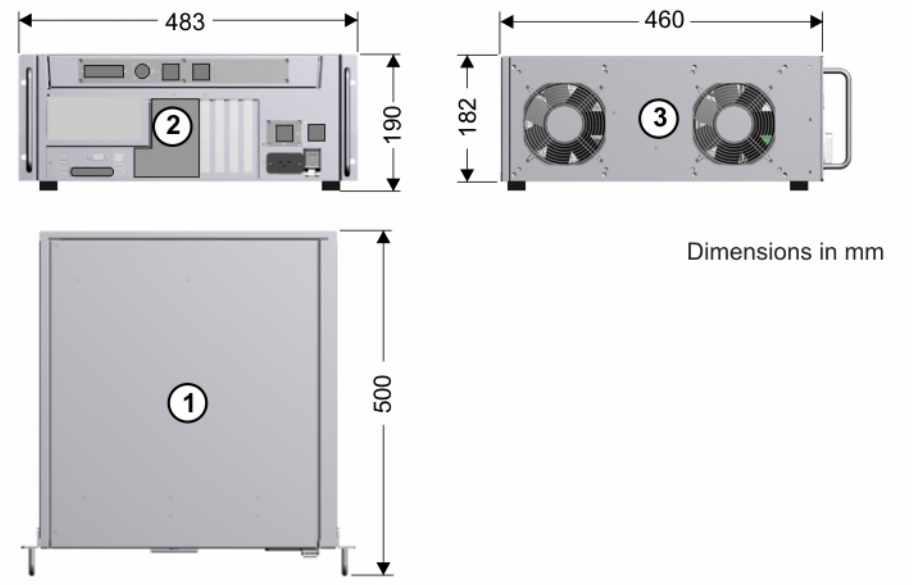


Fig. 6-1: Dimensions

Handle brackets

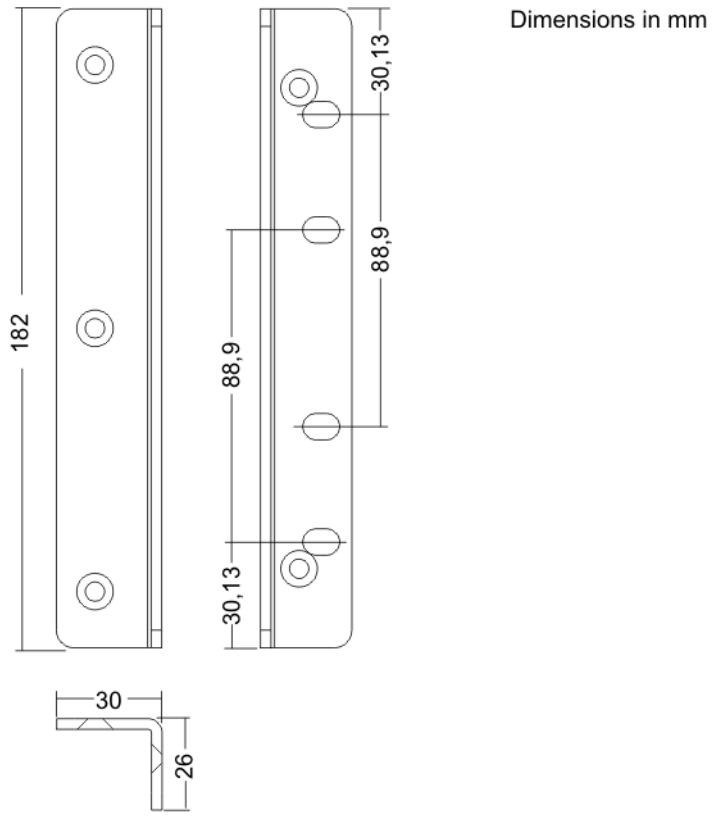


Fig. 6-2: Dimensions of handle brackets

6.4 Connection conditions

Power supply connection

The robot controller may only be connected to grounded-neutral power supply systems.

Rated supply voltage	110 V/230 V AC, single-phase
Permissible tolerance of rated supply voltage	Rated supply voltage ±10%
Mains frequency	50 Hz ± 1 Hz or 60 Hz ± 1 Hz
Rated power input	1 kVA, see rating plate
Thermal power dissipation	370 W
Mains-side fusing	2x 15 A slow-blowing (1x phase; 1x neutral conductor (optional))
Equipotential bonding	The common neutral point for the equipotential bonding conductors and all protective ground conductors is the reference bus of the power unit.

CAUTION

If the robot controller is connected to a power system **without** a grounded neutral, this may cause malfunctions in the robot controller and material damage to the power supply units. Electrical voltage can cause injuries. The robot controller may only be operated with grounded-neutral power supply systems.

If use of a residual-current circuit-breaker (RCCB) is planned, we recommend the following RCCB: trip current difference 300 mA per robot controller, universal-current sensitive, selective.

Cable lengths

For cable designations, standard lengths and optional lengths, please refer to the operating instructions or assembly instructions of the manipulator.

When using smartPAD cable extensions, only two extensions may be used. An overall cable length of 50 m must not be exceeded.

6.5 Power supply connection

Description

For connection to the mains, the robot controller is equipped with a 3-pole socket for non-heating appliances. The robot controller must be connected to the mains via the device connection cable included in the scope of supply.

The robot controller can be connected to the mains via the following device connection cables:

- with mains connector
- without mains connector

Infeed

- 110 V/230 V AC, single-phase, two-phase (with grounded neutral (as symmetrical as possible) between the phases used)
- 50 Hz ± 1 Hz or 60 Hz ± 1 Hz

Fusing

- 2x 15 A slow-blowing, type C (1 (2)x phase; 1x neutral conductor (optional))

6.6 Interface X11

Description

EMERGENCY STOP devices must be connected via interface X11 or linked together by means of higher-level controllers (e.g. PLC).

Wiring

Take the following points into consideration when wiring interface X11:

- System concept
- Safety concept

6.6.1 Contact diagram, connector X11

Description

The counterpart to interface X11 is a 50-contact D-Sub connector with a male insert, type Harting F-95972.

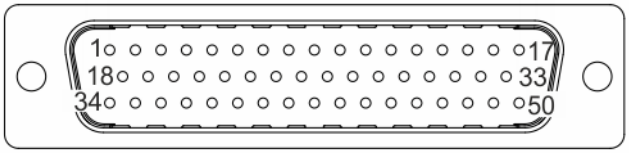


Fig. 6-3: Contact diagram, view from connection side

Outer diameter of cable: max. 12 mm

Recommended wire cross-section: AWG 20 (0.75 mm^2)

In the cabling for the input signals and test signals in the system, suitable measures must be taken to prevent a cross-connection between the voltages (e.g. separate cabling of input signals and test signals).

In the cabling for the output signals and test signals in the system, suitable measures must be taken to prevent a cross-connection between the output signals of a channel (e.g. separate cabling).

6.6.2 X11 safety interface

The X11 safety interface is wired internally to the CCU_SR.

Connector pin allocation

			Default settings		
Signal	**Pin**	**Designation**	**Assignment**	**Description**	**Note**
Test output A	1	Safe input 1 (CIB_SR.1)	External E-STOP, channel A	For 2-channel connection of an EMERGENCY STOP device max. 24 V	Triggers an EMERGENCY STOP
Input 1 A	2				
Test output B	10		External E-STOP, channel B		
Input 1 B	11				
Test output A	3	Safe input 2 (CIB_SR.2)	Operator safety, channel A	For 2-channel connection of a safety gate locking mechanism max. 24 V	Triggers a safety stop 1
Input 2 A	4				
Test output B	12		Operator safety, channel B		
Input 2 B	13				
Test output A	5	Safe input 3 (CIB_SR.3)	Safety stop 1, channel A	Input, safety stop 1	Triggers a safety stop 1 of all axes
Input 3 A	6				
Test output B	14		Safety stop 1, channel B		
Input 3 B	15				
Test output A	7	Safe input 4 (CIB_SR.4)	-	-	-
Input 4 A	8				
Test output B	16		-	-	-
Input 4 B	17				
Test output A	18	Safe input 5 (CIB_SR.5)	-	-	-
Input 5 A	19				
Test output B	28		-	-	-
Input 5 B	29				

			Default settings		
Signal	**Pin**	**Designation**	**Assignment**	**Description**	**Note**
Test output A	20	Safe input 6 (CIB_SR.6)	-	-	-
Input 6 A	21				
Test output B	30		-	-	-
Input 6 B	31				
Test output A	22	Safe input 7 (CIB_SR.7)	-	-	-
Input 7 A	23				
Test output B	32		-	-	-
Input 7 B	33				
Output 12 A	34	Safe output 12 (CIB_SR.12)	E-STOP local channel A	Output, floating contacts from internal EMERGENCY STOP	The contacts are closed if the following conditions are met: • E-STOP on smartPAD not actuated • Controller switched on and operational The contacts open if any condition is not met.
	35				
Output 12 B	45		E-STOP local channel B		
	46				
Output 13 A	36	Safe output 13 (CIB_SR.13)	Test mode, channel A	Output, floating contacts for Test mode	The contacts are open when Test mode is selected.
	37				
Output 13 B	47		Test mode, channel B		
	48				
Output 14 A	38	Safe output 14 (CIB_SR.14)	Automatic mode, channel A	Output, floating contacts for Automatic mode	The contacts are open when Automatic mode is selected.
	39				
Output 14 B	49		Automatic mode, channel B		
	50				

The assignments of the inputs and outputs are freely configurable. The assignments specified in the table correspond to the default settings of the safety configuration.

In the cabling for the input signals and test signals in the system, suitable measures must be taken to prevent a cross-connection between the voltages (e.g. separate cabling of input signals and test signals).

In the cabling for the output signals and test signals in the system, suitable measures must be taken to prevent a cross-connection between the output signals of a channel (e.g. separate cabling).

The voltage switched with the safe outputs must be generated by a safely isolated PELV power supply according to EN 60950.

6.6.3 Wiring example for E-STOP circuit and safeguard

Description

The EMERGENCY STOP devices are connected to X11 in the robot controller.

EMERGENCY STOP

WARNING

The EMERGENCY STOP devices on the robot controller must be integrated into the EMERGENCY STOP circuit of the system by the system integrator.
Failure to do this may result in death, severe injuries or considerable damage to property.

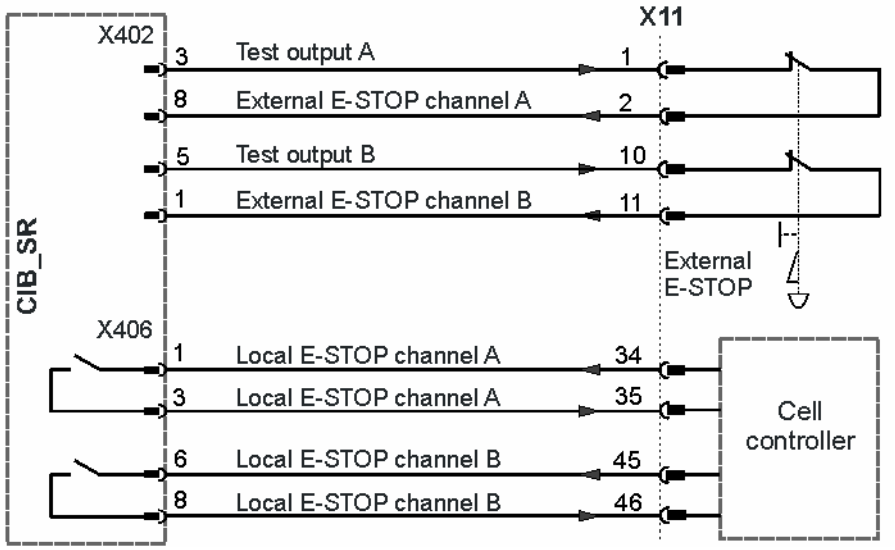


Fig. 6-4: Wiring example: EMERGENCY STOP

6.6.4 Wiring example for safe inputs and outputs

Safe input

The switch-off capability of the inputs is monitored cyclically.

The inputs of the CIB_SR are of dual-channel design with external testing. The dual-channel operation of the inputs is monitored cyclically.

The following diagram illustrates the connection of a safe input to a floating contact provided by the customer.

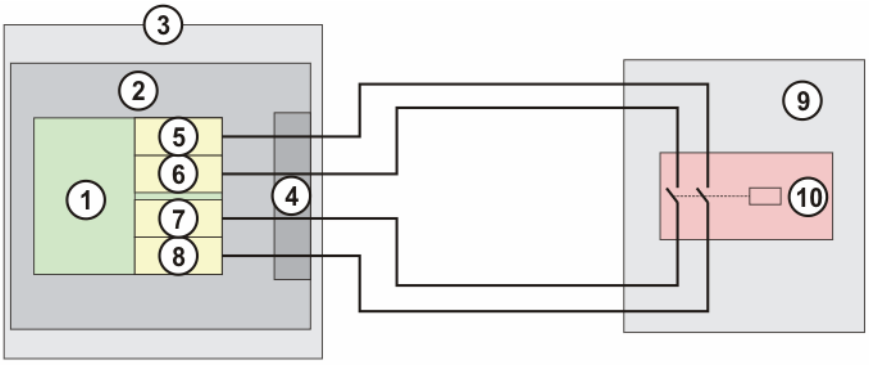


Fig. 6-5: Connection schematic for safe input

1 Failsafe input CIB_SR
2 CIB_SR
3 Robot controller
4 Interface X11
5 Test output channel B
6 Test output channel A
7 Input X, channel A
8 Input X, channel B
9 System side
10 Floating contact

Test outputs A and B are fed with the supply voltage of the CIB_SR. Test outputs A and B are sustained short-circuit proof. The test outputs must only be used to supply the CIB_SR inputs, and for no other purpose.

The wiring example can be used to achieve compliance with SIL2 (DIN EN 62061) and Cat. 3 (DIN EN 13849).

Dynamic testing

- The switch-off capability of the inputs is tested cyclically. For this, the test outputs TA_A and TA_B are switched off alternately.
- The switch-off pulse length is defined for the CIB_SRs as t1 = 625 µs (125 µs – 2.375 ms).
- The duration t2 between two switch-off pulses on one channel is 106 ms.
- The input channel SIN_x_A must be supplied by the test signal TA_A. The input channel SIN_x_B must be supplied by the test signal TA_B. No other power supply is permissible.
- It is only permitted to connect sensors which allow the connection of test signals and which provide floating contacts.
- The signals TA_A and TA_B must not be significantly delayed by the switching element.

Switch-off pulse diagram

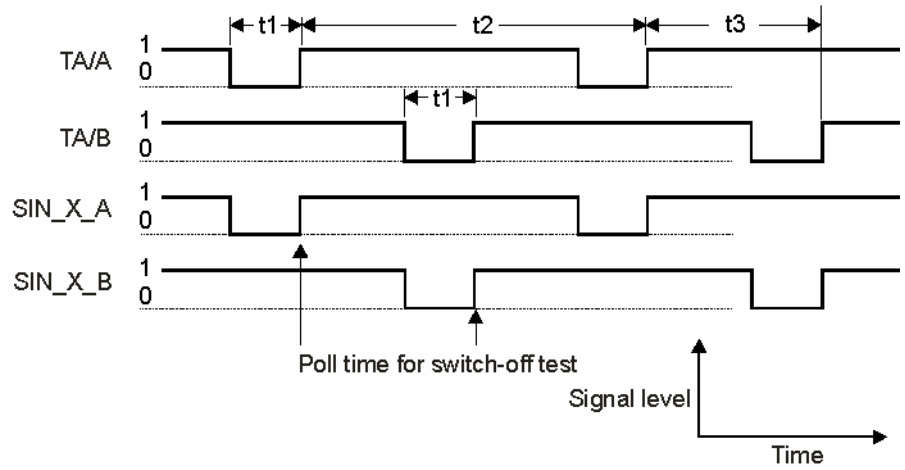


Fig. 6-6: Switch-off pulse diagram, test outputs

t1 Switch-off pulse length
t2 Switch-off period per channel (106 ms)
t3 Offset between switch-off pulses of both channels (53 ms)

TA/A	Test output channel A
TA/B	Test output channel B
SIN_X_A	Input X, channel A
SIN_X_B	Input X, channel B

Safe output

On the CIB_SR, the outputs are provided as dual-channel floating relay outputs.

The following diagram illustrates the connection of a safe output to a safe input provided by the customer with external test facility. The input used by the customer must be monitored externally for cross-connection.

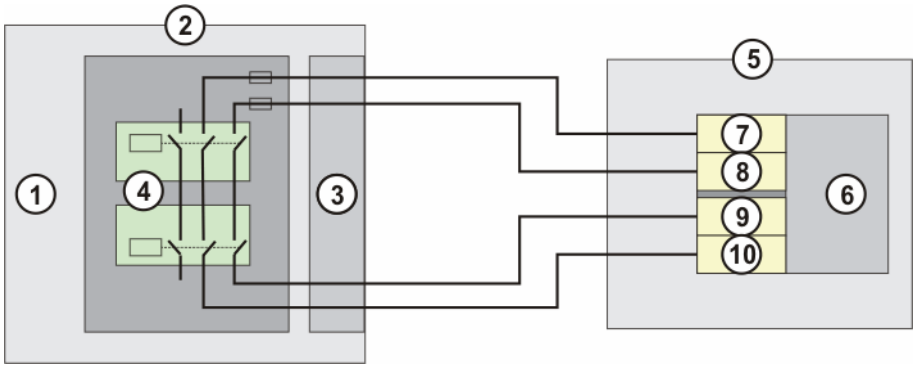


Fig. 6-7: Connection schematic for safe output

1 CIB_SR
2 Robot controller
3 Interface X11, safe output
4 Output wiring
5 System side
6 Safe input (Fail Safe PLC, safety switching device)
7 Test output channel B
8 Test output channel A
9 Input X, channel A
10 Input X, channel B

The wiring example shown can be used to achieve compliance with SIL2 (DIN EN 62061) and Cat. 3 (DIN EN 13849).

6.7 KUKA Extension Bus X65

Description

Connector X65 is intended for connecting EtherCAT slaves outside the robot controller. The EtherCAT line is routed out of the robot controller.

The devices in the EtherCAT line must be configured with WorkVisual and transferred to the controller using Sunrise Workbench.

Necessary equipment

- RJ45 connector

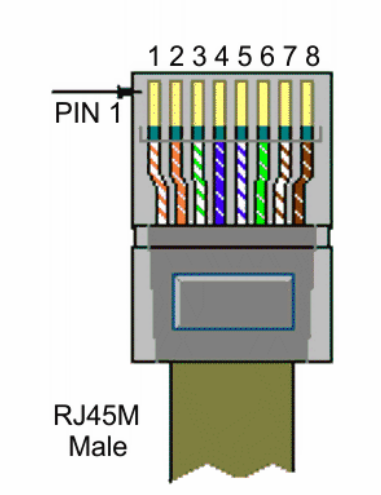


Fig. 6-8: Pin assignment

- Recommended connecting cable: Ethernet-compatible, min. category CAT 5
- Maximum cable cross-section: AWG22

Connector pin allocation X65 via CIB

Pin	Description
1	TPFO_P
2	TPFO_N
3	TPFI_P
6	TPFI_N

6.8 KUKA Line Interface X66

Description

Connector X66 is intended for connecting an external computer for the purpose of installation, programming, debugging and diagnosis.

Necessary equipment

- Connector RJ45

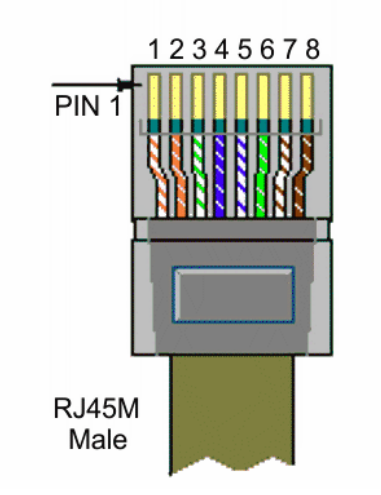


Fig. 6-9: Pin assignment

- Recommended connecting cable: Ethernet-compatible, min. category CAT 5e
- Maximum cable cross-section: AWG22

Connector pin allocation X66

Pin	Description
1	TD+
2	TD-
3	RD+
6	RD-
4	C+
5	C-
7	D+
8	D-

6.9 X69 KUKA Service Interface

Description

Interface X69 is intended for connecting a notebook for the purpose of diagnosis, WorkVisual configuration, update, etc., via the KSI (KUKA Service Interface). The service notebook does not have to be connected to the shop network for this.

Necessary equipment

- RJ45 connector

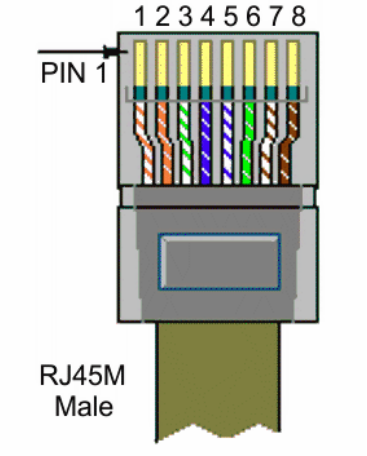


Fig. 6-10: Pin assignment

- Recommended connecting cable: Ethernet-compatible, min. category CAT 5
- Maximum cable cross-section: AWG22

Connector pin allocation X69

Pin	Description
1	TFPO_P
2	TFPO_N
3	TFPI_P
6	TFPI_I
-	PE

6.10 Media flange interface X650

Description

Connector X650 is intended for supplying power to an external media flange on the LBR iiwa wrist.

Necessary equipment

- Connector HAN 3A EMC

Fig. 6-11: Contact diagram, view from contact side

- Maximum cable cross-section: AWG22

Connector pin allocation X650

Pin	Description
1	48 V
2	0 V
5	24 V
6	0 V
9	TD+
11	TD-
10	RD+
12	RD-
PE	-

6.11 PE equipotential bonding

Description

The robot controller must be grounded by means of the PE equipotential bonding rail at the installation site.

6.12 Performance level

The safety functions of the robot controller conform to Category 3 and Performance Level d according to EN ISO 13849-1.

6.12.1 PFH values of the safety functions

The safety values are based on a service life of 20 years.

The PFH value classification of the robot controller is only valid if all safety-relevant mechanical and electromechanical components of the industrial robot are tested at least once every 12 months. The “Safety” chapter describes which components these are and how they are to be tested.

When evaluating system safety functions, it must be remembered that the PFH values for a combination of multiple controllers may have to be taken into consideration more than once. This is the case for systems with cooperating robots or higher-level hazard areas. The PFH value determined for the safety function at system level must not exceed the limit for PL d.

- The PFH values relate to the safety functions of the different controller variants.
- The PFH values apply to all safety functions provided by KUKA Sunrise.

Further information about the available safety functions is contained in the operating and programming instructions for the System Software.

Overview

Controller variant PFH values:

Robot controller	PFH value
KUKA Sunrise Cabinet	$< 1 \times 10^{-7}$

7 Transportation

7.1 Transportation with trolley

Preconditions

- The housing of the robot controller must be closed.
- No cables may be connected to the robot controller.

Procedure

- Transport the robot controller on a trolley.

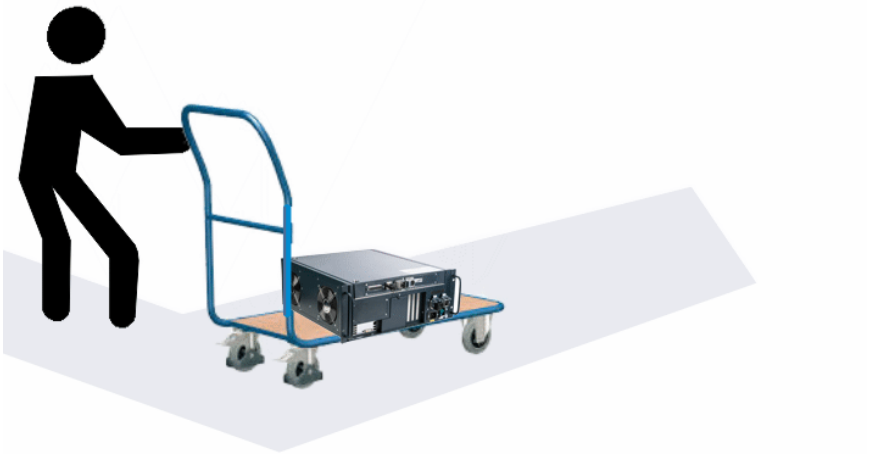


Fig. 7-1: Transportation with trolley

7.2 Transportation without trolley

Preconditions

- The housing of the robot controller must be closed.
- No cables may be connected to the robot controller.

Procedure

- Transport the robot controller using the carrying handles.

Fig. 7-2: Transportation without trolley

1 Carrying handles

8 KUKA Service

8.1 Requesting support

Introduction

This documentation provides information on operation and operator control, and provides assistance with troubleshooting. For further assistance, please contact your local KUKA subsidiary.

Information

The following information is required for processing a support request:

- Description of the problem, including information about the duration and frequency of the fault
- As comprehensive information as possible about the hardware and software components of the overall system

  The following list gives an indication of the information which is relevant in many cases:

  – Model and serial number of the kinematic system, e.g. the manipulator
  – Model and serial number of the controller
  – Model and serial number of the energy supply system
  – Designation and version of the system software
  – Designations and versions of other software components or modifications
  – Diagnostic package KRCDiag

    Additionally for KUKA Sunrise: existing projects including applications

    For versions of KUKA System Software older than V8: archive of the software (KRCDiag is not yet available here.)
  – Application used
  – External axes used

8.2 KUKA Customer Support

Availability

KUKA Customer Support is available in many countries. Please do not hesitate to contact us if you have any questions.

Argentina

Ruben Costantini S.A. (Agentur)
Luis Angel Huergo 13 20
Parque Industrial
2400 San Francisco (CBA)
Argentina
Tel. +54 3564 421033
Fax +54 3564 428877
ventas@costantini-sa.com

Australia

KUKA Robotics Australia Pty Ltd
45 Fennell Street
Port Melbourne VIC 3207
Australia
Tel. +61 3 9939 9656
info@kuka-robotics.com.au
www.kuka-robotics.com.au

Belgium

KUKA Automatisering + Robots N.V.
Centrum Zuid 1031
3530 Houthalen
Belgium
Tel. +32 11 516160
info@kuka.be
www.kuka.be

Brazil

KUKA Roboter do Brasil Ltda.
Travessa Claudio Armando, nº 171
Bloco 5 - Galpões 51/52
Bairro Assunção
CEP 09861-7630 São Bernardo do Campo - SP
Brazil
Tel. +55 11 4942-8299
Fax +55 11 2201-7883
info@kuka-roboter.com.br
www.kuka-roboter.com.br

Chile

Robotec S.A. (Agency)
Santiago de Chile
Chile
Tel. +56 2 331-5951
Fax +56 2 331-5952
robotec@robotec.cl
www.robotec.cl

China

KUKA Robotics China Co., Ltd.
No. 889 Kungang Road
Xiaokunshan Town
Songjiang District
201614 Shanghai
P. R. China
Tel. +86 21 5707 2688
Fax +86 21 5707 2603
info@kuka-robotics.cn
www.kuka-robotics.com

Germany

KUKA Deutschland GmbH
Zugspitzstr. 140
86165 Augsburg
Germany
Tel. +49 821 797-1926
Fax +49 821 797-41 1926
Hotline.robotics.de@kuka.com
www.kuka.com

France

KUKA Automatisme + Robotique SAS
Techvallée
6, Avenue du Parc
91140 Villebon S/Yvette
France
Tel. +33 1 6931660-0
Fax +33 1 6931660-1
commercial@kuka.fr
www.kuka.fr

India

KUKA India Pvt. Ltd.
Office Number-7, German Centre,
Level 12, Building No. - 9B
DLF Cyber City Phase III
122 002 Gurgaon
Haryana
India
Tel. +91 124 4635774
Fax +91 124 4635773
info@kuka.in
www.kuka.in

Italy

KUKA Roboter Italia S.p.A.
Via Pavia 9/a - int.6
10098 Rivoli (TO)
Italy
Tel. +39 011 959-5013
Fax +39 011 959-5141
kuka@kuka.it
www.kuka.it

Japan

KUKA Japan K.K.
YBP Technical Center
134 Godo-cho, Hodogaya-ku
Yokohama, Kanagawa
240 0005
Japan
Tel. +81 45 744 7531
Fax +81 45 744 7541
info@kuka.co.jp

Canada

KUKA Robotics Canada Ltd.
2865 Argentia Road, Unit 4-5
Mississauga
Ontario L5N 8G6
Canada
Tel. +1 905 858-5852
Fax +1 905 858-8581
KUKAFocusCenter@KUKARobotics.com
www.kukarobotics.ca

Korea

KUKA Robotics Korea Co. Ltd.
RIT Center 306, Gyeonggi Technopark
1271-11 Sa 3-dong, Sangnok-gu
Ansan City, Gyeonggi Do
426-901
Korea
Tel. +82 31 501-1451
Fax +82 31 501-1461
info@kukakorea.com

Malaysia

KUKA Robot Automation (M) Sdn Bhd
South East Asia Regional Office
No. 7, Jalan TPP 6/6
Taman Perindustrian Puchong
47100 Puchong
Selangor
Malaysia
Tel. +60 (03) 8063-1792
Fax +60 (03) 8060-7386
info@kuka.com.my

Mexico

KUKA de México S. de R.L. de C.V.
Progreso #8
Col. Centro Industrial Puente de Vigas
Tlalnepantla de Baz
54020 Estado de México
Mexico
Tel. +52 55 5203-8407
Fax +52 55 5203-8148
info@kuka.com.mx
www.kuka-robotics.com/mexico

Norway

KUKA Sveiseanlegg + Roboter
Sentrumsvegen 5
2867 Hov
Norway
Tel. +47 61 18 91 30
Fax +47 61 18 62 00
info@kuka.no

Austria

KUKA CEE GmbH
Gruberstraße 2-4
4020 Linz
Austria
Tel. +43 732 784 752 0
Fax +43 732 793 880
KUKAAustriaOffice@kuka.com
www.kuka.at

Poland

KUKA CEE GmbH Poland
Spółka z ograniczoną odpowiedzialnością
Oddział w Polsce
Ul. Porcelanowa 10
40-246 Katowice
Poland
Tel. +48 327 30 32 13 or -14
Fax +48 327 30 32 26
ServicePL@kuka.com

Portugal

KUKA Robots IBÉRICA, S.A.
Rua do Alto da Guerra n° 50
Armazém 04
2910 011 Setúbal
Portugal
Tel. +351 265 729 780
Fax +351 265 729 782
info.portugal@kukapt.com
www.kuka.com

Russia

KUKA Russia OOO
1-y Nagatinskiy pr-d, 2
117105 Moskau
Russia
Tel. +7 495 665-6241
support.robotics.ru@kuka.com

Sweden

KUKA Svetsanläggningar + Robotar AB
A. Odhners gata 15
421 30 Västra Frölunda
Sweden
Tel. +46 31 7266-200
Fax +46 31 7266-201
info@kuka.se

Switzerland

KUKA Roboter CEE GmbH
Linz, Zweigniederlassung Schweiz
Heinrich Wehrli-Strasse 27
5033 Buchs
Switzerland
Tel. +41 62 837 43 20
info@kuka-roboter.ch

Slovakia

KUKA CEE GmbH
organizačná zložka
Bojnická 3
831 04 Bratislava
Slovakia
Tel. +420 226 212 273
support.robotics.cz@kuka.com

Spain

KUKA Iberia, S.A.U.
Pol. Industrial
Torrent de la Pastera
Carrer del Bages s/n
08800 Vilanova i la Geltrú (Barcelona)
Spain
Tel. +34 93 8142-353
comercial@kukarob.es

South Africa

Jendamark Automation LTD (Agentur)
76a York Road
North End
6000 Port Elizabeth
South Africa
Tel. +27 41 391 4700
Fax +27 41 373 3869
www.jendamark.co.za

Taiwan

KUKA Automation Taiwan Co. Ltd.
1F, No. 298 Yangguang ST.,
Nei Hu Dist., Taipei City, Taiwan 114
Taiwan
Tel. +886 2 8978 1188
Fax +886 2 8797 5118
info@kuka.com.tw

Thailand

KUKA (Thailand) Co. Ltd.
No 22/11-12 H-Cape Biz Sector Onnut
Sukhaphiban 2 road, Prawet
Bangkok 10250
Thailand
Tel. +66 (0) 90-940-8950
HelpdeskTH@kuka.com

Czech Republic

KUKA Roboter CEE GmbH
organizační složka
Pražská 239
25066 Zdiby
Czech Republic
Tel. +420 226 212 273
support.robotics.cz@kuka.com

Hungary

KUKA HUNGÁRIA Kft.
Fö út 140
2335 Taksony
Hungary
Tel. +36 24 501609
Fax +36 24 477031
info@kuka-robotics.hu

USA

KUKA Robotics Corporation
51870 Shelby Parkway
Shelby Township
48315-1787
Michigan
USA
Tel. +1 866 873-5852
Fax +1 866 329-5852
CustomerService@kuka.com
www.kuka.com

United Kingdom

KUKA Robotics UK Ltd
Great Western Street
Wednesbury West Midlands
WS10 7LL
United Kingdom
Tel. +44 121 505 9970
Fax +44 121 505 6589
service@kuka-robotics.co.uk
www.kuka-robotics.co.uk

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