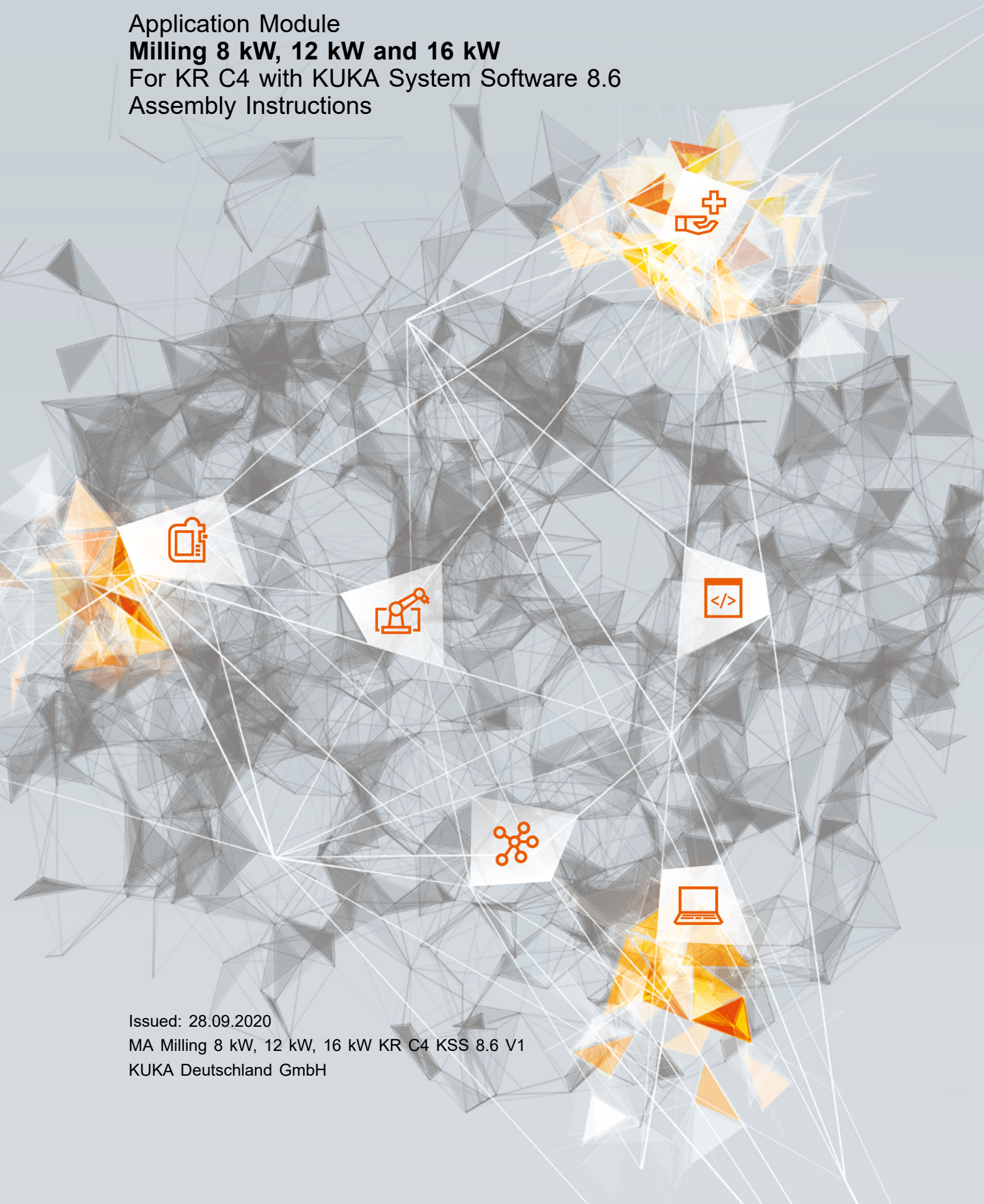
KUKA

Application Module
Milling 8 kW, 12 kW and 16 kW
For KR C4 with KUKA System Software 8.6
Assembly Instructions



Issued: 28.09.2020
MA Milling 8 kW, 12 kW, 16 kW KR C4 KSS 8.6 V1
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Other functions not described in this documentation may be operable in the controller. The user has no claims to these functions, however, in the case of a replacement or service work.

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

Subject to technical alterations without an effect on the function.

KIM-PS5-DOC

Translation of the original documentation

Publication:	Pub MA Milling 8 kW, 12 kW, 16 kW KR C4 KSS 8.6 (PDF) en PB16011
Book structure:	MA Milling 8 kW, 12 kW, 16 kW KR C4 KSS 8.6 V1.2 BS14433
Version:	MA Milling 8 kW, 12 kW, 16 kW KR C4 KSS 8.6 V1

Contents

1 Introduction

1.1 Target group

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

- Advanced KRL programming skills
- Advanced PLC programming skills
- Advanced knowledge of the robot controller system
- Advanced system knowledge of KUKA.PLC

For optimal use of KUKA products, we recommend the training courses offered by KUKA College. Information about the training program can be found at www.kuka.com or can be obtained directly from our subsidiaries.

1.2 Milling robot system documentation

The milling robot system documentation consists of the following parts:

- Documentation for the manipulator
- Documentation for the robot controller
  - Operating instructions for KR C4
  - Assembly Instructions
    “Optional Interfaces” for KR C4
- Documentation for the energy supply system
- Documentation for the smartPAD-2
- Operating and programming instructions for the KUKA System Software
- Documentation for ForceTorqueControl (optional)
  - Documentation for KUKA.RobotSensorInterface
  - Documentation for KUKA.ForceTorqueControl
  - Documentation from the sensor manufacturer
- Operating instructions for the KUKA Posiflex or KUKA DKP positioner (optional)
- Documentation for KUKA.CNC (optional)
- Instructions for options and accessories
- Spare parts overview in KUKA Xpert

Documentation from other manufacturers:

- Assembly, installation and operating instructions for the recooling system
- Assembly instructions of the electrically-driven spindle
- Operating instructions for the frequency converter control unit, power unit and PROFINET
- Operating instructions for operator safety with lock

The component manufacturer documentation must be read by the system integrator and the user. The safety instructions they contain must be taken into consideration in a risk assessment and must be observed.

Each set of instructions is a separate document.

1.3 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.

1.4 Terms used

Term	Description
Axis range	Range of each axis, in degrees or millimeters, within which it may move. The axis range must be defined for each axis.
Stopping distance	Stopping distance = reaction distance + braking distance The stopping distance is part of the danger zone.
Workspace	Area within which the robot may move. The workspace is derived from the individual axis ranges.
User	The user of the industrial robot can be the management, employer or delegated person responsible for use of the industrial robot.

CNC	Computerized Numerical Control Method for implementing computer-aided control of machine tools. A special programming language (G-code) is often used to program the movements of these machines.
CSP	Controller System Panel Display element and connection point for USB and network
Ethernet	Data network technology for local data networks Ethernet allows data to be exchanged between the connected devices in the form of data frames.
Danger zone	The danger zone consists of the workspace and the stopping distances of the manipulator.
Main air	Central air supply of the milling controller
Main air valve	The main air valve can be used to shut off the air supply of the milling robot system completely at a central location.
HMI	Human-Machine Interface KUKA.HMI is the KUKA user interface.
KR C	KUKA Robot Control Robot controller
KRL	KUKA Robot Language KUKA robot programming language
KSS	KUKA System Software
Manipulator	The robot arm and the associated electrical installations
PPE	Personal protective equipment
Safety zone	The safety zone is situated outside the danger zone.
smartHMI	smart Human-Machine Interface User interface on the smartPAD
smartPAD	Programming device for the robot controller The smartPAD has all the operator control and display functions required for operating and programming the industrial robot. 2 models exist: • smartPAD • smartPAD-2 In turn, for each model there are variants, e.g. with different lengths of connecting cables. For robot controllers of the KR C5 series, only the model “smartPAD-2” is used. For other robot controllers, the designation “KUKA smartPAD” or “smartPAD” always refers to both models unless an explicit distinction is made.

PLC	Programmable Logic Controller Used in systems as a higher-level master module in the bus system.
Stop category 0	The drives are deactivated immediately and the brakes are applied. The manipulator and any external axes (optional) perform path-oriented braking. **Note:** This stop category is called STOP 0 in this document.
Stop category 1	The manipulator and any external axes (optional) perform path-maintaining braking. • Operating mode T1: the drives are deactivated as soon as the robot has stopped, but no later than after 680 ms. • Operating modes T2, AUT (KR C controller), AUT EXT (KR C controller), EXT (VKR C controller): The drives are switched off after 1.5 s. **Note:** This stop category is called STOP 1 in this document.
Stop category 2	The drives are not deactivated and the brakes are not applied. The manipulator and any external axes (optional) are braked with a path-maintaining braking ramp. **Note:** This stop category is called STOP 2 in this document.
System integrator (plant integrator)	The system integrator is responsible for safely integrating the industrial robot into a complete system and commissioning it.
Compressed air	Air for pressurizing the interior of the spindle The pressurization prevents particles from entering the interior of the spindle.
T1	Test mode, Manual Reduced Velocity (<= 250 mm/s)
T2	Test mode, Manual High Velocity (> 250 mm/s permissible)
External axis	Axis of motion that does not belong to the manipulator, yet is controlled with the robot controller. e.g. KUKA linear unit, turn-tilt table, Posiflex

2 Product description

2.1 Overview of the milling robot system

The milling robot system includes components for setting up a machine tool. The milling controller contains the components for controlling the electrically-driven spindle and the safety equipment. The components are pre-configured; connecting cables are supplied.

The milling robot system consists of the following components:

- Industrial robot
  - Manipulator
  - Robot controller
  - Energy supply system
  - KUKA smartPAD teach pendant
  - Connecting cables
  - Software
    - KUKA System Software
    - KUKA.MillTech or KUKA.MillTech CNC
- Milling 8 kW, 12 kW or 16 kW technology cabinet
  - Milling controller
  - Recooling system
  - Cooling water stop (optional)
- Electrically-driven spindle and adapter plate for mounting on the robot flange
- Tool rack without cover (optional)
- Tool rack with cover (optional)
- Operator safety with gate lock
- External EMERGENCY STOP devices (optional)
- Tool clamping set (optional)
- KUKA.ForceTorqueControl + sensor (optional)
- KUKA.CNC (optional)
- Positioner (optional)

Fig. 2-1: Example of a milling robot system

1	Manipulator	5	KUKA smartPAD
2	Energy supply system	6	Technology cabinet 8 kW
3	Electrically-driven spindle	7	Tool cover
4	KR C4 robot controller	8	Tool rack

2.2 Description of the robot with energy supply system

Description

The diagram (>>> *Fig. 2-2*) shows an example of a robot with energy supply system for an 8 kW milling application. The following media are supplied to the electrically-driven spindle via the energy supply system:

- Motor and signal cables for the electrically-driven spindle
- Water cooling for the electrically-driven spindle
- Air supply for the tool release system
- Empty hose, e.g. cleaning air for the tool (controllable by the PLC)
- Cleaning air for the tool taper (taper cleaning)
- Compressed air

Fig. 2-2: Robot with energy supply system

1 Electrically-driven spindle
2 Energy supply system
3 Manipulator
4 Junction box and media panel on the base frame

Electrical and media connections for Milling 8 kW

The diagram (>>> *Fig. 2-3*) shows the electrical and media connections of a robot, taking the connections for an 8 kW milling application as an example. All media and the energy supply must be routed via the adapter plate. It may also be necessary to route customer supply lines through the energy supply system. All supply lines must be routed to the in-line wrist through the tube of the energy supply system.

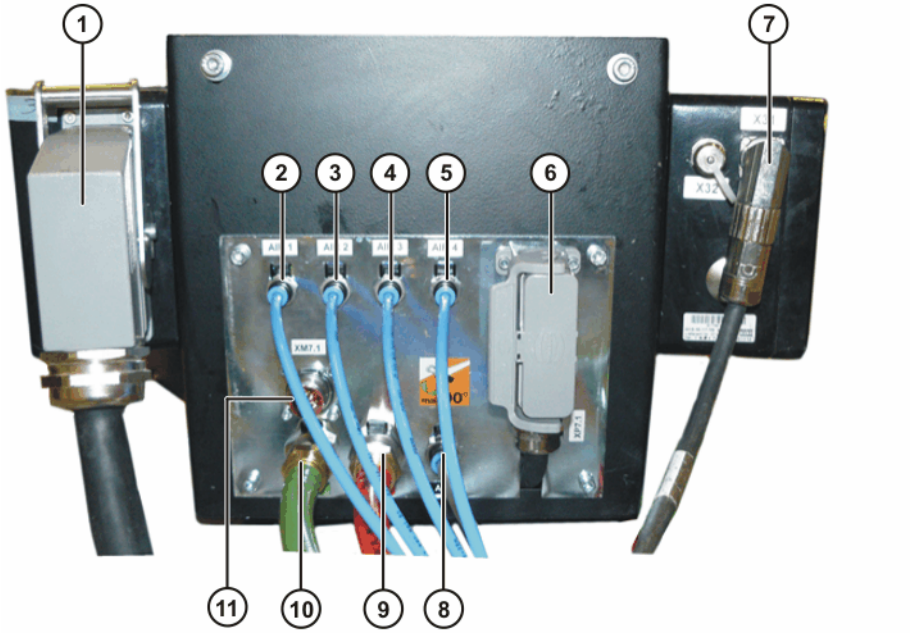


Fig. 2-3: Electrical and media connections on the base frame

1 Motor connector X30
2 Compressed air AIR1
3 Taper cleaning AIR3
4 Release tool AIR4a
5 Clamp tool AIR4b
6 Signal cable XP7.1 for ES350 electrically-driven spindle
7 RDC connection
8 Tool cleaning air AIR2
9 Cooling water return, Water OUT
10 Cooling water supply, Water IN
11 Motor cable XM7.1 for ES350 electrically-driven spindle

2.3 Description of the electrically-driven spindle

Description

The milling robot system can be operated with the following electrically-driven spindles:

- Milling 8 kW: ES350
- Milling 12 kW: ES779
- Milling 16 kW: ES789

The electrically-driven spindle is controlled by a frequency converter in the milling controller and cooled by means of water cooling.

The spindle and motor cable is plugged directly into the connections of the electrically-driven spindle without an adapter plug.

The electrically-driven spindle has a pneumatic clamping fixture for the tool. This, together with a tool rack, allows automatic tool changing.

Detailed information can be found in the assembly instructions of the electrically-driven spindle.

Electrical and media connections

The electrical and media connections on the ES350 spindle are shown in the diagram (>>> *Fig. 2-4*).

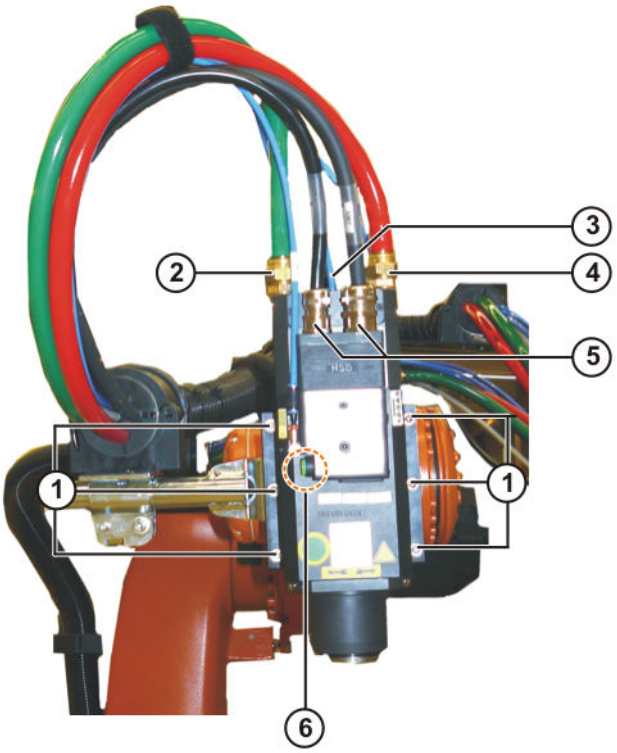


Fig. 2-4: Electrical and media connections on the ES350 spindle

1 Attachment to robot flange
2 Cooling water supply connection (IN)
3 Air connections
4 Cooling water return connection (OUT)
5 Motor and signal cable connection
6 “Manual tool release” pushbutton

The electrical and media connections on the ES789 spindle are shown in the diagram (>>> *Fig. 2-5*). The connection diagram also applies to the ES779 spindle.

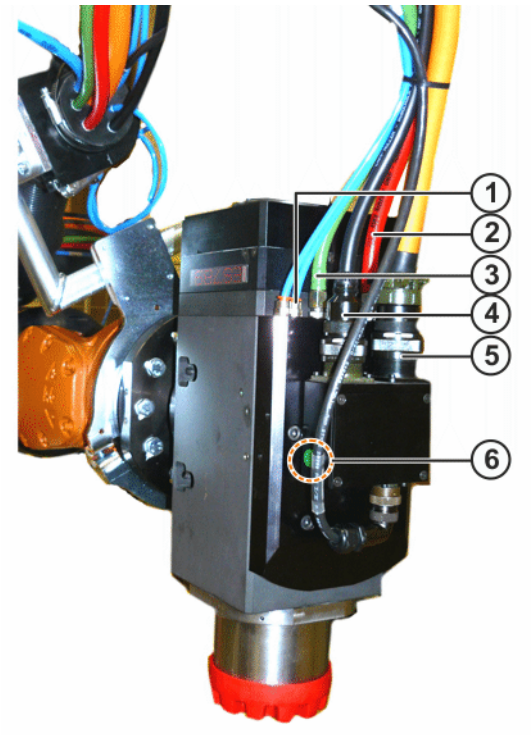


Fig. 2-5: Electrical and media connections on the ES789 spindle

1	Air connections
2	Cooling water return connection (OUT)
3	Cooling water supply connection (IN)
4	Signal cable connection
5	Motor cable connection
6	“Manual tool release” pushbutton

2.4 Description of the robot controller

Description

The following robot controller is available for the application module:

- KR C4

The KUKA smartPAD is the hand-held control panel of the robot controller.

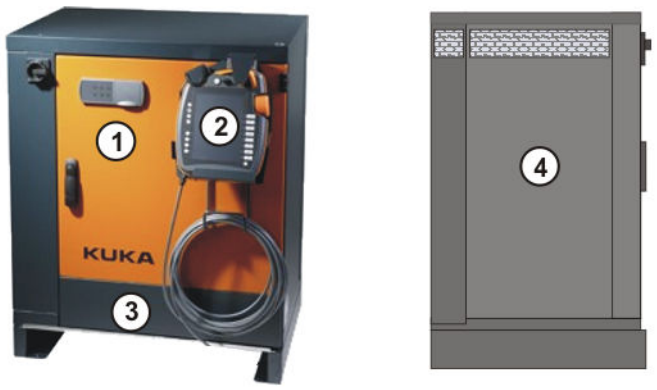


Fig. 2-6: KR C4 robot controller

1	Front view	3	Connection panel
2	KUKA smartPAD	4	Side view

Further information about the interfaces in the KR C4 connection panel can be found in the assembly instructions for the robot controller and in the assembly instructions “Optional Interfaces” for KR C4 robot controllers.

Digital I/O modules

Information about the digital I/O modules (16/16/4) can be found in the assembly instructions “Optional Interfaces” for KR C4 robot controllers.

2.5 Overview of technology cabinet

The Milling technology cabinet consists of the following components:

- Milling controller
- Recooling system
- Transformer for recooling system integrated into milling controller (Milling 8 kW only)

The components of the Milling 8 kW technology cabinet are shown in the diagram (>>> *Fig. 2-7*). The Milling 12/16 kW technology cabinet has 4 external fans and may deviate slightly.

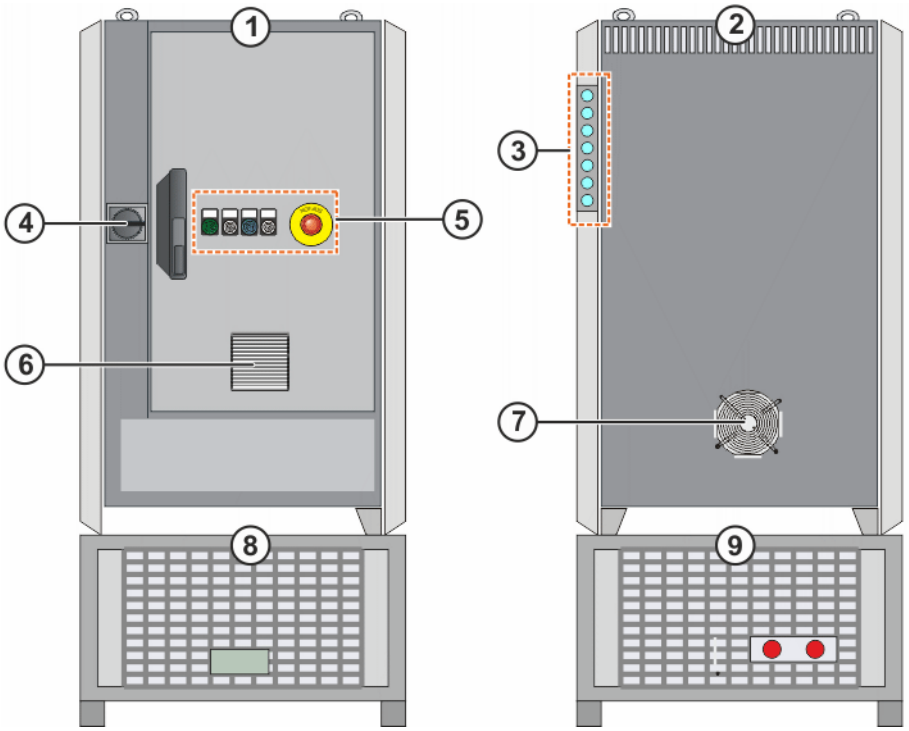


Fig. 2-7: Overview of technology cabinet

1 Milling controller, front view
2 Milling controller, rear view
3 Pneumatic connections
4 Main switch
5 Operator control and display elements
6 Internal fan
7 External fan
8 Recooling system, front view
9 Recooling system, rear view

2.5.1 Overview of milling controller

Description

The diagram (>>> *Fig. 2-8*) shows the components of an 8 kW milling controller.

The 12/16 kW milling controller may deviate slightly from this due to the larger frequency converter.

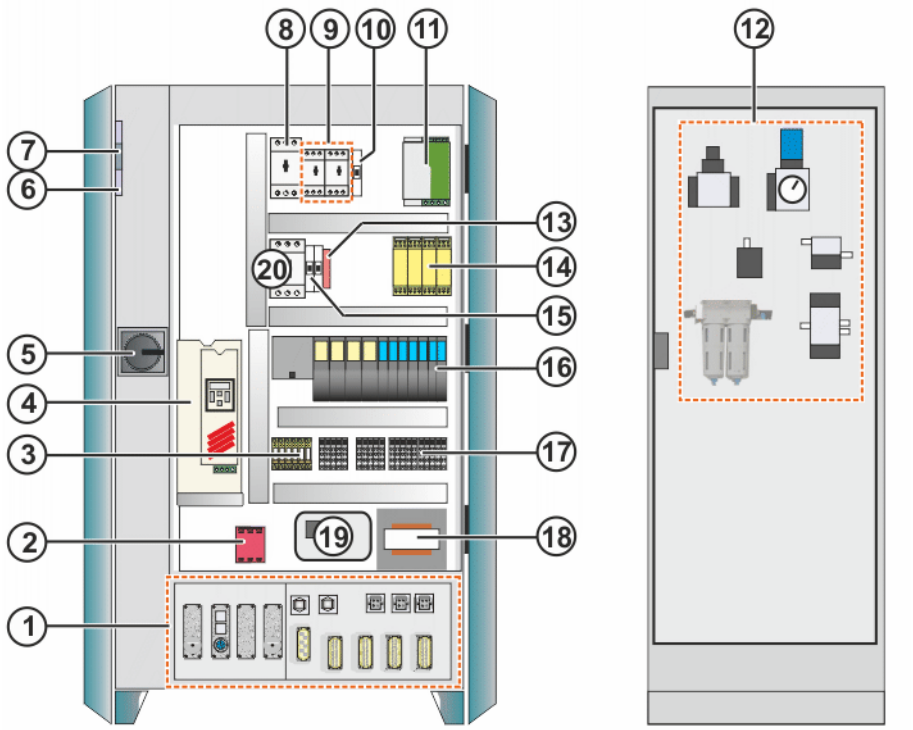


Fig. 2-8: Overview of milling controller

1 Connection panel on milling controller
2 Standstill monitor A4
3 Terminal block PE
4 Frequency converter N1
5 Main switch Q1
6 Temperature controller B1
25 °C internal temperature setting
7 Air filter
8 Main switch Q2
9 Main switch Q3; Q4
10 Miniature circuit-breaker F1 (Milling 8 kW only)
11 24 V power supply unit G1
12 Pneumatic system
13 Standstill monitor relay K10
14 Safety relays A26, A27, A28, A31
15 Miniature circuit-breakers F11, F12
16 Safety PLC
17 Terminal block X10 … X14
18 Transformer for recooling system T1 (Milling 8 kW only)
19 NET box (optional)
20 Recooling system contactor K1

Fuses, Milling 8 kW

Designation	Value	Circuit
F1	10 A	230 V AC recooling system
F11	6 A	24 V DC power supply

Designation	Value	Circuit
F12	4 A	24 V control voltage
Q2	31 A	Frequency converter N1
Q3	4 A	24 V DC power supply unit G1
Q4	4 A	Transformer T1

Fuses, Milling 12/16 kW

Designation	Value	Circuit
F11	6 A	24 V DC distribution
F12	4 A	24 V DC distribution
Q2	80 A	Frequency converter N1
Q3	4 A	400 V for 24 V DC power supply unit G1
Q4	7 A	400 V recooling system

Connection panel

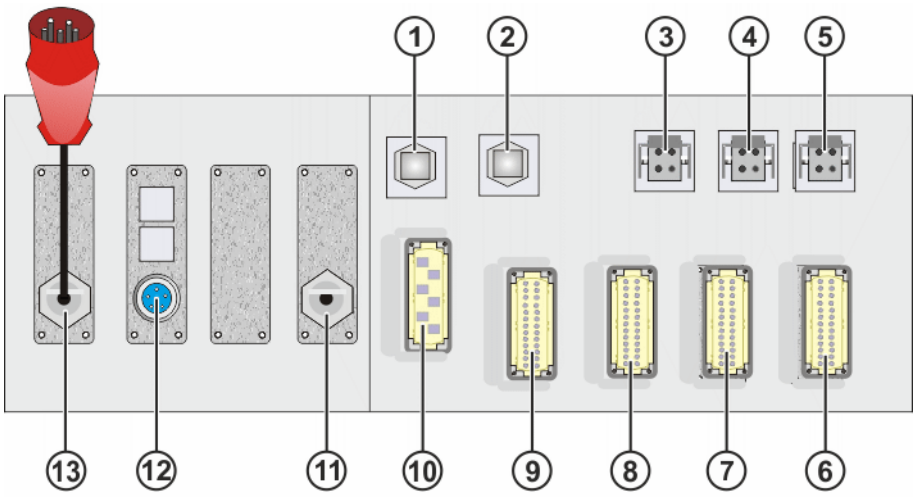


Fig. 2-9

1 KR C4 connection XS15A
2 Tool rack PROFINET connection XS15B
3 Tool rack supply connection XS51
4 EMERGENCY STOP device 1 XS41
5 EMERGENCY STOP device 2 XS41.1
6 Safety gate 4 XS4.3
7 Safety gate 3 XS4.2
8 Safety gate 2 XS4.1
9 Safety gate 1 XS4
10 Signal cable XS0.1 for electrically-driven spindle
11 Cable inlet
12 Motor cable XS2 for electrically-driven spindle
13 CEE connection for supply voltage XS1

Pneumatic connections, Milling 8 kW

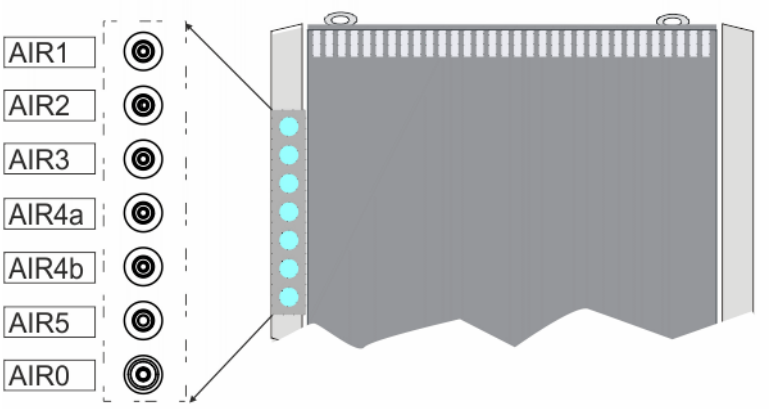


Fig. 2-10: Milling 8 kW controller, pneumatic connections

Connection	Description
AIR0	Main air
AIR1	Compressed air
AIR2	Tool cleaning air (optional)
AIR3	Taper cleaning
AIR4a	Release tool
AIR4b	Clamp tool
AIR5	Air supply, tool rack cover (optional)

Pneumatic connections, Milling 12/16 kW

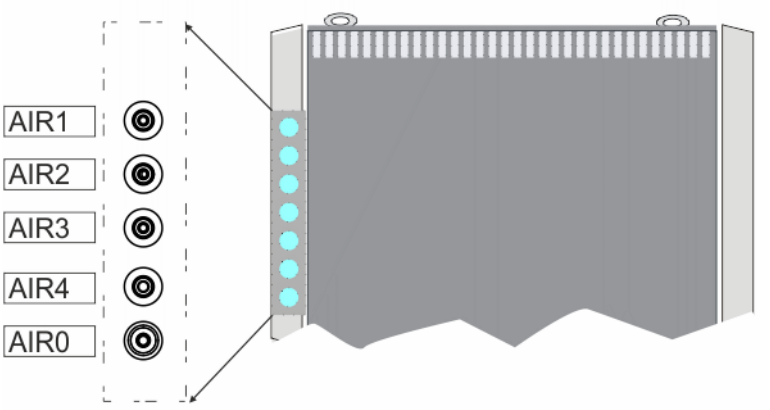


Fig. 2-11: Milling 12/16 kW controller, pneumatic connections

Connection	Description
AIR0	Main air
AIR1	Release tool
AIR2	Compressed air and taper cleaning
AIR3	Tool cleaning air (optional)
AIR4	Air supply, tool rack cover (optional)

2.5.2 Milling controller cooling

Description

The cooling system is divided into two cooling circuits. The inner zone, containing the control electronics, is cooled by a fan in the door. In the outer zone, the brake resistor is cooled directly by ambient air.

Cooling, Milling 8 kW

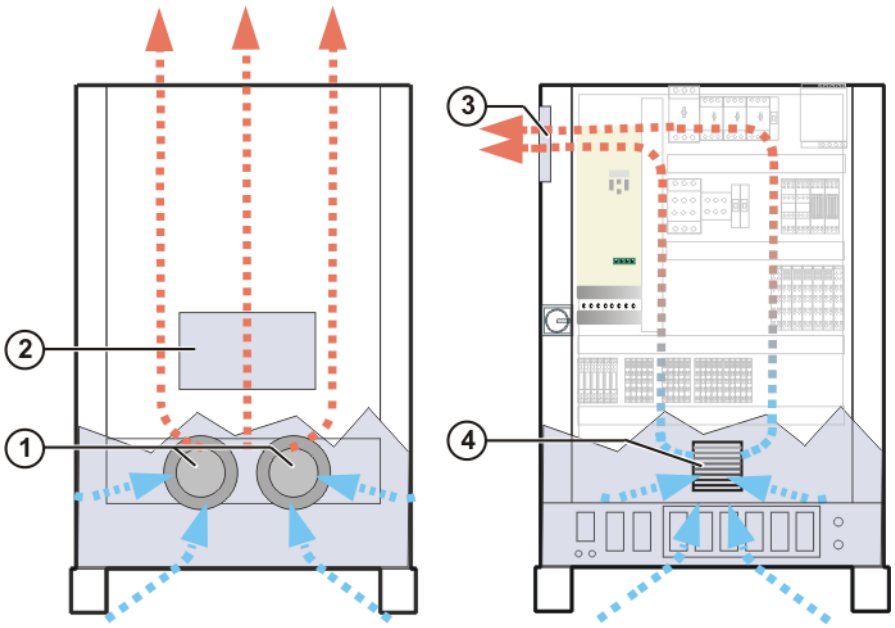


Fig. 2-12: Milling controller cooling

1 Rear fan
2 Brake resistor
3 Air filter
4 Internal fan on the front side

Cooling, Milling 12/16 kW

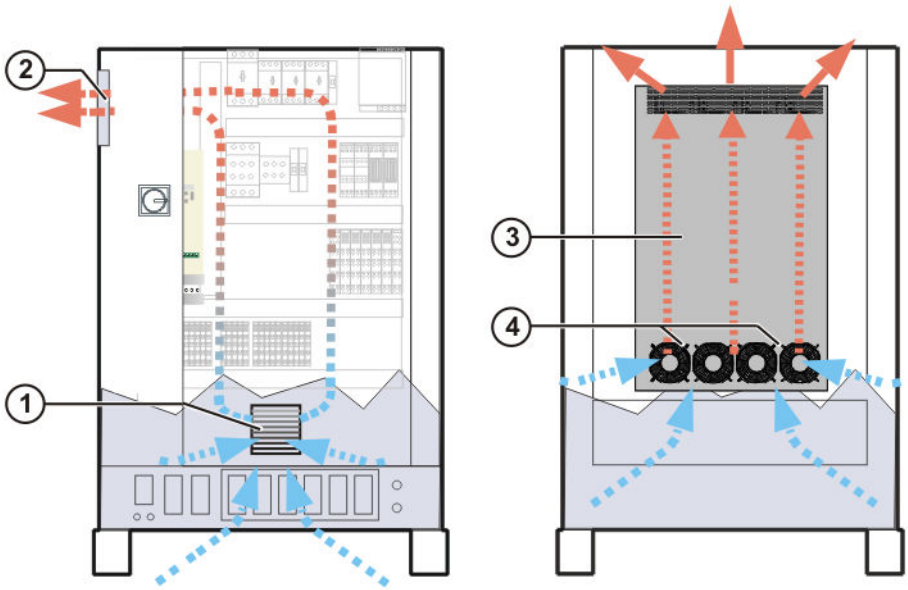


Fig. 2-13: Milling controller cooling

1 Internal fan on the front side
2 Air filter
3 Brake resistor
4 Rear fan

2.5.3 Recooling system

Description

The recooling system for water cooling of the electrically-driven spindle is installed beneath the milling controller. The recooling system is controlled by means of temperature sensors.

Recooling system, Milling 8 kW

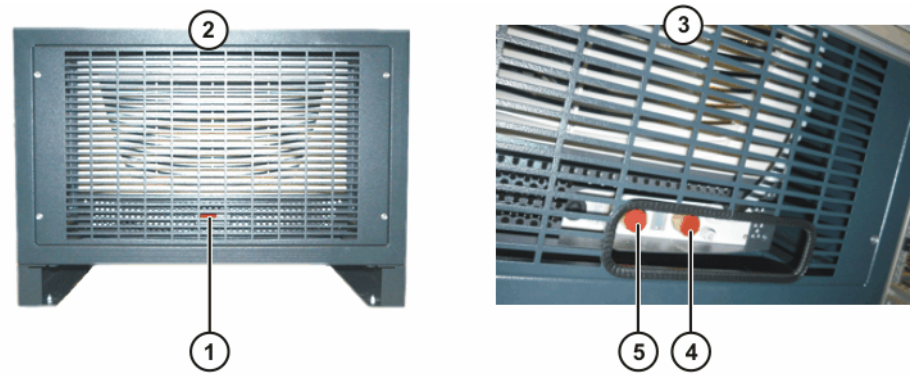


Fig. 2-14: Recooling system

1 Display and operator control element
2 Front view
3 Rear view
4 Water OUT connection
5 Water IN connection

Further information is contained in the assembly, installation and operating instructions of the recooling system.

Recooling system, Milling 12/16 kW

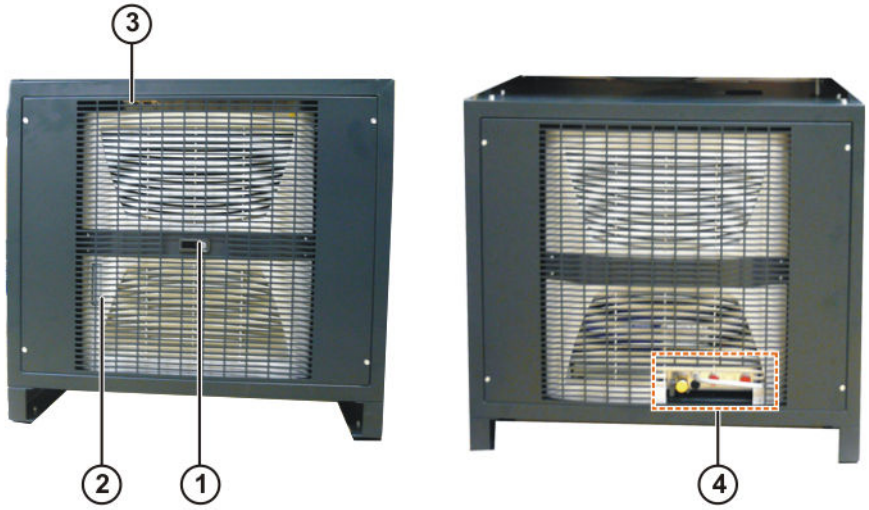


Fig. 2-15: Recooling system

1 Display and operator control element
2 Fluid level indicator
3 Tank filler neck
4 Water connections

Further information is contained in the assembly, installation and operating instructions of the recooling system.

2.6 Description of the tool rack (optional)

Up to 10 tool stations of the following sizes can be set down in the tool rack.

- Milling 8 kW: HSK E40
- Milling 12/16 kW: HSK F63

There is a sensor on every tool rack which checks whether there is a tool station present. An optional tool cover protects the tool station against dirt. The tool cover is opened and closed by means of a pneumatic cylinder. The end positions of the tool cover are monitored by a sensor.

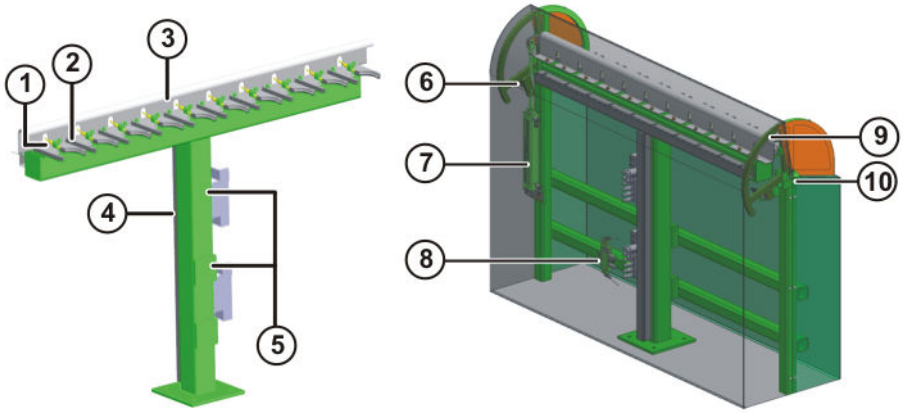


Fig. 2-16: Overview of tool rack

1	Tool station grippers
2	“Gripper occupied” sensors
3	Contact strip
4	Pedestal (welded construction)
5	Bus modules
6	Fork head
7	Flap cylinder
8	Valve
9	Tool cover
10	End position sensor

2.7 ForceTorqueControl (optional)

Description

The ForceTorqueControl option can be used in conjunction with a force/torque sensor to manipulate the path of the manipulator in accordance with the process forces.

The milling results can be improved in this way if required.

The following components are included in the ForceTorqueControl option

- Force/torque sensor between flange and spindle
- Adapted adapter flange between spindle and sensor

- Energy supply system and connecting cable set expanded to include a sensor cable
- Evaluation unit of the sensor (NET box)
- KUKA.ForceTorqueControl software package
- KUKA.RobotSensorInterface software package

Software parameterization must be carried out by the system integrator / user.

Information about the individual components can be found in the KUKA.ForceTorqueControl and KUKA.RobotSensorInterface documentation and the documentation of the sensor manufacturer.

Functions

- Execution of motions in accordance with the measured forces
- Detection of, and reaction to, specific load conditions and associated events
- Distortion-free positioning (motion up against a stop)
- Maintenance of process forces irrespective of the position and tolerances of the component
- Maintenance of complex process force characteristics during machining
- Compensation for component tolerances by programming active compliance of the robot
- Sensitive collision monitoring
- Monitoring of the sensor load limits
- Programmable tolerances for defined force and torque setpoints
- Monitored control response to the programmed force setpoints
- Time-controlled maintenance of the force setpoint
- Path limitation of the force-controlled motion

Functional principle

ForceTorqueControl and a force/torque sensor system supported by the software give the robot a sense of touch. It is able to react sensitively to external forces and torques and to exert programmable forces and torques on a workpiece.

Servo-control is possible in up to 6 degrees of freedom (Fx, Fy, Fz, Tx, Ty, Tz). When force/torque control is active, the robot moves until the sensor detects the defined force or torque. In the case of superposed force/torque control, the robot also moves on a programmed path. A reference coordinate system is defined as a reference system.

2.8 Positioner (optional)

Description

With the optional positioner, the position between the workpiece and the manipulator can be changed, e.g. to allow undercutting or rotationally symmetrical machining.

The individual axes can be controlled using KUKA external axes or external drives. It must be ensured that any resulting hazards are taken into consideration

Further information can be found in the “KUKA Posiflex” or “KUKA DKP” operating instructions.

2.9 Intended use and misuse

Use

The milling robot system enables the planning, programming and execution of milling processes on workpieces and is intended exclusively for machining (milling and drilling) the following materials:

- Wood and wood derivatives
- Plastics and fiber-reinforced plastics
- Aluminum and aluminum alloys

Materials and machining processes not listed here must be approved by KUKA in writing.

Permissible tools (drill, milling tool):

The maximum lengths and diameters of the tools are specified in the assembly instructions of the electrically-driven spindle. The maximum speed of the electrically-driven spindle for a particular tool is derived from the data of the tool.

- The tools must be adapted to the speed, cutting speed and feed rate.
- The tools must be dynamically balanced for the corresponding spindle.

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

NOTICE

Fire hazard if using non-approved materials
If non-approved materials are machined, this can cause the material to ignite and result in material damage to the tool, electrically-driven spindle or other components of the system.

- Only the materials specified under intended use may be machined.

NOTICE

Damage to property due to use of unsuitable tools
If unsuitable tools are used, this can result in material damage to the tool, electrically-driven spindle or other components of the system.

- Before they are used, calculate all tools in accordance with the specifications of the manufacturer of the electrically-driven spindle and have them approved in writing by KUKA.

WARNING

Risk of fatal injury due to use without a physical safeguard
Without a physical safeguard, the partly completed machinery can cause death or serious injuries.

- Only use the partly completed machinery with a physical safeguard that is suitable for preventing expected hazards.
- When integrating the partly completed machinery, the system integrator must consider and comply with the standards for machine tools DIN EN 13128 and DIN EN 12417.

Misuse

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

Examples of such misuse include:

- Machining of abrasive or brittle materials, such as stone and steel
- Machining of non-approved materials
- Use of non-approved tools
- Operation outside the specified operating parameters
- Use in potentially explosive environments
- Operation in underground mining
- Outdoor operation

3 Safety

3.1 General

3.1.1 Disclaimer

The device described in this document is a milling robot system.

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

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

Safety information

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

No modifications may be carried out to the milling robot system without the authorization of the manufacturer. Unauthorized modifications will result in the loss of warranty and liability claims.

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

In addition to the Safety chapter, this documentation and all other relevant documents contain further safety instructions. These must also be observed. The fundamental safety information for the milling robot system can be found in the “Safety” chapter of the operating or assembly instructions of the robot controller.

3.1.2 EC declaration of conformity and declaration of incorporation

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

- The milling robot system is integrated into an overall system.

  Or: The milling robot system, together with other machines, constitutes an overall system.

  Or: All safety functions and safeguards required for operation of the complete machine as defined by the EC Machinery Directive have been added to the milling robot system.
- 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 dec-

laration of conformity forms the basis for the CE mark for the system. The milling robot system must be operated in accordance with the applicable national laws, regulations and standards.

The milling robot system 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.

3.2 Personnel

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

- User
- Personnel

Qualification of personnel
Work on the system must only be performed by personnel that is able to assess the tasks to be carried out and detect potential hazards. Death, severe injuries or damage to property may otherwise result. The following qualifications are required:

- Adequate specialist training, knowledge and experience
- Knowledge of the relevant operating or assembly instructions, knowledge of the relevant standards
- All persons working on the system must have read and understood the documentation of the milling robot system, 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 assign the groups of persons according to the type and scope of the work they perform.
- The user must carry out briefing at defined intervals.
- The user must comply with the regulations relating to personal protective equipment (PPE). Recommendation to wear personal protective equipment in accordance with the nature of the hazard, e.g. safety footwear, protective gloves, safety goggles, closely fitting clothing, hair net in the case of long hair, ear protectors.
- The user must create and implement an emergency escape concept.

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

System integrator

The milling robot system must be safely integrated into an overall system by the system integrator.

The system integrator is responsible for the following tasks:

- Installation of the milling robot system
- Ensuring that no ergonomic hazards arise, e.g.:
  - Selecting the location and height of the operator control elements in such a way that it is possible to observe and operate the machine simultaneously.
  - In the case of loading and unloading stations:
    - Ensure that it is possible to see into working areas and hazard areas.
    - Avoid tripping, crushing, cutting and impact hazards.
    - Provide the operator with plenty of room to move freely.
  - Maintenance-friendly installation: Route cables and supply lines in such a way that all system components can be accessed safely.
  - Avoid milling residue on the floor (slipping hazard).
- Connection of the milling robot system
- Performance of the risk assessment for the system, taking the following risks into consideration:
  - Risk arising from the machining process, e.g.:
    - Hazard due to fire and dust explosions
    - Hazard due to the materials approved by KUKA

Hazard due to dust explosions
When working with certain materials that can generate dust (e.g. wood), an explosive atmosphere may form.
- Suitable corrective measures must be implemented by the system integrator/user.

  - Risks from milling and drilling swarf
  - If non-conductive tools and tool holders are used:
    - Risk due to electrostatic hazards
  - Risk due to motion of robot arm against any fixed object:
    - Avoid crushing hazards
  - Risk arising from a power failure and liable to cause damage to the electrically-driven spindle, manipulator and tool rack
  - Risk arising from damaged cables due to short circuit, taking into account the working environment and the material to be machined
  - If a positioner is used:
    - Risk arising from rotating parts on the positioner

  - If a tool rack is used:
    - Risk from damaged moving parts of the tool rack, including the tool cover
    - Risk arising from dirty or non-functioning sensors
    - Risk from damaged fastening and coupling of the pressure cylinder
- Implementing the required safety functions and safeguards
- Implementing the required safety measures
- Issuing the EC declaration of conformity
- Affixing the CE mark
- Creating the operating instructions for the system

  These operating instructions must refer to the Safety chapter in the operating instructions of the milling robot 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.

3.3 Stopping response of the electrically-driven spindle

Trigger	Description
E-STOP pressed	The electrically-driven spindle is stopped as quickly as possible under servo control.
Program stop	
Milling controller switched off	Electrically-driven spindle coasts unbraked to a stop.
Power failure	

CAUTION

Risk of injury due to electrically-driven spindle after power failure
In the case of a power failure, the electrically-driven spindle is shut down without being braked. Entering the cell while the electrically-driven spindle is still rotating may result in injuries.

- Ensure that the cell is not entered until the electrically-driven spindle is no longer rotating.

3.4 Safety functions

3.4.1 Operating mode selection

Operating modes

The milling robot system can be operated in the following modes:

- Manual Reduced Velocity (T1)

  The drive of the electrically-driven spindle can only be operated with the door closed and locked.

- Manual High Velocity (T2)
  The drive of the electrically-driven spindle can only be operated with the door closed and locked.
- Automatic (AUT)
- Automatic External (AUT EXT)

Do not change the operating mode while a program is running. If the operating mode is changed during program execution, the industrial robot is stopped with a STOP 2.

Operating mode	Use	Velocities
T1	For test operation, programming and teaching	• Program verification: Programmed velocity, maximum 250 mm/s • Jog mode: Jog velocity, maximum 250 mm/s
T2	For test operation	• Program verification: Programmed velocity
AUT	For industrial robots without higher-level controllers Only possible with operator safety closed	• Program mode: Programmed velocity • Jog mode: not possible
AUT EXT	For industrial robots with higher-level controllers, e.g. PLC Only possible with operator safety closed	• Program mode: Programmed velocity • Jog mode: not possible

Mode selector switch

The user can change the operating mode via the connection manager. The connection manager is a view that is called by means of the mode selector switch on the smartPAD.

The mode selector switch may be one of the following variants:

- With key
  It is only possible to change operating mode if the key is inserted.
- Without key

WARNING

Danger to life and limb due to mode selector switch without access restriction
If the smartPAD is equipped with a mode selector switch without a key, all persons can operate the mode selector switch, irrespective of their field of activity or qualifications. Death, severe injuries or damage to property may result.

- An additional device must be installed to ensure that the mode selector switch can only be operated by a restricted group of people.
- The device itself must not trigger motions of the industrial robot or other hazards.

3.4.2 “Operator safety” signal

The “Operator safety” signal is active in all operating modes of the milling robot system, i.e. the electrically-driven spindle cannot be operated with the safety gate open.

WARNING

Danger to life and limb due to resumed automatic operation without adequate acknowledgement
Following loss of the “Operator safety” signal, it must not be possible to restart automatic operation by merely closing the safeguard. Otherwise, for example, the safety gate could close unintentionally, thereby causing automatic operation to resume while there are persons in the danger zone. Death, severe injuries or damage to property may result.

- Automatic operation must not be resumed until the safeguard has been closed and the closing has been acknowledged.
- The acknowledgement must be designed in such a way that an actual check of the danger zone can be carried out first. Other acknowledgement functions (e.g. an acknowledgement which is automatically triggered by closure of the safeguard) are not permitted.

3.4.3 EMERGENCY STOP devices

The EMERGENCY STOP devices of the milling robot system are the EMERGENCY STOP device on the smartPAD and on the milling controller. The system integrator can additionally connect external EMERGENCY STOP devices to the milling controller. The device must be pressed in the event of a hazardous situation or emergency.

Reactions of the milling robot system if the EMERGENCY STOP device is pressed:

- Manual Reduced Velocity (T1) and Manual High Velocity (T2) modes.
  The manipulator drives are switched off immediately. The manipulator stops with a STOP 0. The drive of the electrically-driven spindle is brought to a standstill under servo control.
- Automatic modes (AUT and AUT EXT)
  The manipulator drives are switched off after 1 second. The manipulator stops with a STOP 1. The drive of the electrically-driven spindle is brought to a standstill under servo control.

Before operation can be resumed, the EMERGENCY STOP device must be turned to release it, and the stop message must be acknowledged using the “Acknowledge” illuminated pushbutton S3/P3.

Fig. 3-1: EMERGENCY STOP device on smartPAD and milling controller

1 EMERGENCY STOP device on smartPAD
2 EMERGENCY STOP device on milling controller

WARNING

Danger to life and limb due to tools and equipment without EMERGENCY STOP
If tools and other equipment connected to the robot are not integrated into the EMERGENCY STOP circuit, this can result in death, severe injuries or damage to property.

- Integrate tools and other equipment into the EMERGENCY STOP circuit if they could constitute a potential hazard.

3.5 Additional protective equipment

3.5.1 Labeling on the milling robot system

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

In accordance with the risk assessment, the system integrator must attach warnings to the physical safeguard, e.g. “PPE must be worn”, “No entry for unauthorized persons”, etc.

WARNING

Danger to life and limb due to missing or damaged labels
If plates and labels, signs, symbols and markings are missing or damaged, this can lead to human error. Death, severe injuries or damage to property may result.

- Do not modify or remove labels.
- Replace missing or damaged labels.

Labeling on the milling robot system consists of:

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

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

3.5.2 Physical safeguard

Description

The workspace of the manipulator must be protected by a physical safeguard.

The physical safeguard must meet the following requirements and be designed by the system integrator:

- The tool must be secured to prevent it being ejected from the safeguarded area.
- Components of the tool rack (optional) including tool cover must be secured to prevent them being ejected from the safeguarded area.
- It must not be possible for unauthorized persons to access the area.

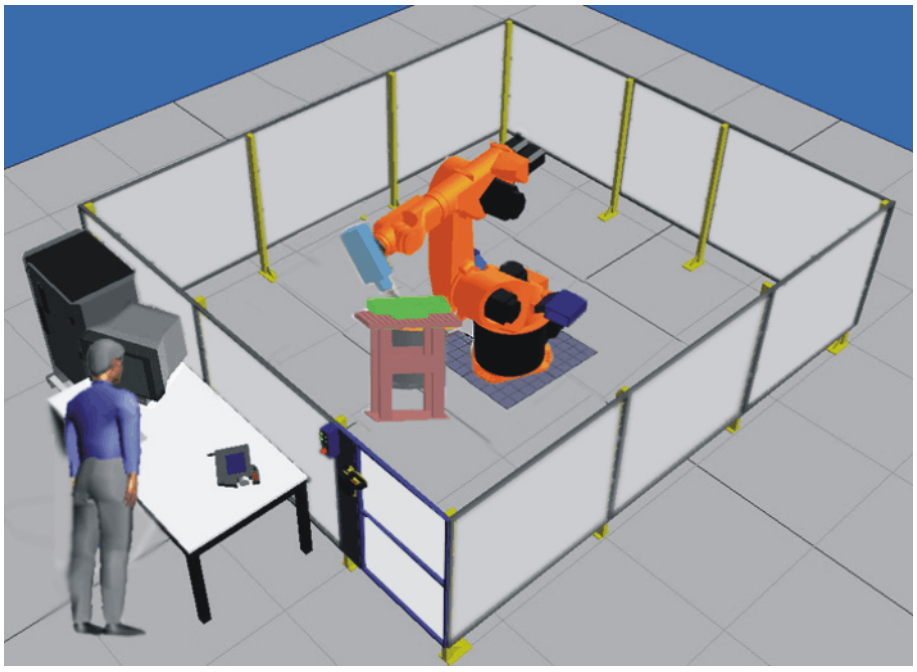


Fig. 3-2: Example: Guard

Safety gates

Requirements on the safety gates are:

- The number of safety gates in the fencing must be kept to a minimum.
- The system integrator must use a manipulation-resistant gate lock.
  The following gate lock must be installed for each safety gate:
  - Door lock, Euchner type MGB-L1H
- Automatic mode must be prevented until all safety gates are closed, locked and acknowledged.
- If a safety gate is opened in Automatic mode, a STOP 1 must be triggered.
- It must only be possible to open the safety gates if the electrically-driven spindle is no longer turning.

Further information is contained in the corresponding standards and regulations.

3.6 Safety measures

3.6.1 General safety measures

DANGER

Hazards when working on the milling robot system
If it is necessary to enter the cell with the robot controller and milling controller switched on in order to work on the milling robot system, suitable safety measures must be implemented. Death or severe injuries may otherwise result.

- Secure the open safety gate, e.g. with a padlock, against being closed unintentionally.
- The user is responsible for defining additional safety measures to ensure safe protection of personnel.

CAUTION

Risk of injury due to sharp-edged tool or workpiece
The tool and workpiece may have sharp edges that can cause cutting injuries.

- Avoid contact.
- If the tool is changed manually, take appropriate safety precautions and wear personal protective equipment, e.g. protective gloves, safety footwear and long, closely fitting clothing.

CAUTION

Risk of burns due to hot tool or workpiece
During operation, the tool and workpiece can reach temperatures which can cause burns.

- Avoid contact.
- If the tool is changed manually, take appropriate safety precautions and wear personal protective equipment, e.g. protective gloves, safety footwear and long, closely fitting clothing.

WARNING

Risk of crushing and shearing due to the tool rack
The moving parts of the tool rack constitute crushing and shearing hazards, with the result that motions of the tool rack can cause serious injuries and material damage.

- When the milling robot system is in operation, ensure that no persons or objects come into contact with the tool rack.

WARNING

Risk of injury due to rotating and moving parts
In the case of work near rotating and moving parts (milling tool, turntable, linear unit, tool rack), body parts, hair, clothing and jewelry, etc., can be caught or pulled in. Death or severe injuries may result.

- Avoid contact.
- Take appropriate safety precautions and wear personal protective equipment, e.g. hair net or other head covering, closely fitting clothing and no jewelry.

Faults

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

- Wear personal protective equipment.
- Switch off the robot controller and secure it (e.g. with a padlock) to prevent unauthorized persons from switching it on again.
- Switch off the milling 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.
- Remove tool and workpiece.
- Eliminate the fault and carry out a function test.

3.6.2 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. The spindle can remain installed during transportation.

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.

Technology cabinet

The technology cabinet must be transported and installed in an upright position. Transportation must be carried out in accordance with the assembly instructions of the Milling application module.

(>>> *6.1 "Transporting the technology cabinet using lifting tackle" Page 67*)

(>>> *6.2 "Transporting the technology cabinet by fork lift truck/pallet truck" Page 68*)

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

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

NOTICE

Damage to property due to condensation
If the internal cabinet temperature of the milling and robot controllers differs greatly from the ambient temperature, condensation can form. Damage to property may result.

- Wait until the internal cabinet temperature has adapted to the ambient temperature in order to avoid condensation.

Safety measures to be carried out during start-up:

- When the milling robot system is put back into operation following a power failure, the EMERGENCY STOP and operator safety functions must be reset.
- Prior to start-up, a visual inspection of the components and the workspace must be carried out.

WARNING

Risk of injury due to electrostatic charging
The chuck for the tool is not conductive. If materials are used that generate an electrostatic charge during machining, this can cause serious injuries.

- Ground the tool using a slip ring or similar device.

NOTICE

If the cell is not being operated, the robot controller and technology cabinet must be switched off and secured to prevent unauthorized persons from switching them on again.

3.6.4 Manual mode

- In manual mode, the electrically-driven spindle may only be operated with the safety gate closed.

- Optional tool rack

  The couplings and the pressure cylinder of the tool rack must be checked for damage before manual operation.

3.6.5 Maintenance and repair

It must only be possible to open electrical compartments using suitable and approved tools or a key.

Technology cabinet

The discharging time of the capacitors must be taken into consideration before any maintenance, repair or cleaning work is carried out.

Further information about the capacitors can be found in the operating instructions of the frequency converter.

Tool/workpiece

The tool and workpiece must be removed before any maintenance, repair or cleaning work is carried out.

Tool rack

The compressed air must be shut off and the system vented before any maintenance, repair or cleaning work is carried out on the tool rack.

WARNING

Risk of injury due to motions of the tool rack
Undesired motions of the tool rack can cause serious injuries if no precautionary measures are taken.

- The compressed air must be shut off and the system vented before any maintenance, repair or cleaning work is carried out on the tool rack.

Hazardous substances

The following safety measures must be carried out when handling cooling water:

- Wear personal protective equipment (hand protection, eye protection) prescribed by the user.
- Avoid prolonged and repeated intensive contact with the skin.
- Avoid breathing in cooling water spray or vapors.
- Clean skin and apply skin cream.

CAUTION

Risk of injury due to contact with cooling water
Glycol is added to the cooling water to prevent build-up of bacteria and viruses. Contact with cooling water or cooling water mist can cause injury.

- Wear personal protective equipment (hand protection, eye protection, etc.).
- In the case of unintentional contact with eyes, flush the eyes immediately with clean water.
- In the case of unintentional contact with skin, wash thoroughly with plenty of soap and water.

Use current safety data sheets
Knowledge of the safety data sheets of the substances and mixtures used is a prerequisite for the safe use of KUKA products. Death, injuries or damage to property may otherwise result.

- Request up-to-date safety data sheets from the manufacturers of hazardous substances regularly.

3.6.6 Decommissioning, storage and disposal

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

3.6.7 Troubleshooting

The following safety measures must be carried out when troubleshooting on the milling robot system:

- The tool and workpiece must be removed before troubleshooting.

CAUTION

Risk of burns due to hot tool or workpiece
During operation, the tool and workpiece can reach temperatures which can cause burns.

- Avoid contact.
- If the tool is changed manually, take appropriate safety precautions and wear personal protective equipment, e.g. protective gloves, safety footwear and long, closely fitting clothing.

CAUTION

Risk of injury due to sharp-edged tool or workpiece
The tool and workpiece may have sharp edges that can cause cutting injuries.

- Avoid contact.
- If the tool is changed manually, take appropriate safety precautions and wear personal protective equipment, e.g. protective gloves, safety footwear and long, closely fitting clothing.

- Work must generally be carried out 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 robot controller and milling controller and secure them (e.g. with a padlock) to prevent unauthorized persons from switching them on again. If it is necessary to carry out work with the robot controller and milling controller switched on, the user must define additional safety measures to ensure the safe protection of personnel.

4 Technical data

4.1 Basic data, Milling 8 kW components

Milling controller

Mains supply voltage	3 x 400 V AC
Control voltage	24 V DC
Rated frequency	50/60 Hz
Rated current	32 A
Loop impedance (system impedance up to the connection point of the milling controller)	≤ 200 mΩ
Weight	265 kg
Protection rating	IP 54
Electrical connection	CEE-CON 32 A

Ambient temperature during operation	+15 ... 43 °C (288 ... 316 K)
Temperature change	max. 1.1 K/min
Humidity class	3k3 acc. to DIN EN 60721-3-3; 1995
Altitude	• up to 1000 m above mean sea level with no reduction in power • 1000 to 4000 m above mean sea level with a reduction in power of 5%/1000 m

Compressed air connection	min. 6 bar
Pneumatic connection	Hose with 10 mm outer diameter for plug-in connection
Pneumatic setting	6 bar

Manipulator

Further information is contained in the assembly instructions for the manipulator.

Robot controller

The power supply ratings can be found in the robot controller assembly instructions.

Further information is contained in the assembly instructions for the robot controller.

ES350 electrically-driven spindle

Detailed information can be found in the assembly instructions of the electrically-driven spindle.

Recooling system

The distance between the manipulator and the recooling system must not exceed 25 m. This gives a maximum hose length (supply and return) for the cooling circuit of 50 m.

Further information is contained in the assembly, installation and operating instructions of the recooling system.

Tool rack

Tool mount	HSK E40
Rated supply voltage	24 V DC
Field bus interface	PROFINET
Weight without cover	47 kg
Weight with cover	118 kg

4.2 Basic data, Milling 12 kW components

Milling controller

Mains supply voltage	3 x 400 V AC
Control voltage	24 V DC
Rated frequency	50/60 Hz
Rated current	63 A
Loop impedance (system impedance up to the connection point of the milling controller)	≤ 200 mΩ
Weight	360 kg
Protection rating	IP 54

Ambient temperature during operation	+15 ... 43 °C (288 ... 316 K)
Temperature change	max. 1.1 K/min
Humidity class	3k3 acc. to DIN EN 60721-3-3; 1995
Altitude	• up to 1000 m above mean sea level with no reduction in power • 1000 to 4000 m above mean sea level with a reduction in power of 5%/1000 m

Compressed air connection	min. 6 bar
Pneumatic connection	Hose with 10 mm outer diameter for plug-in connection
Pneumatic settings	4 bar at AIR2, 6 bar at AIR3 and AIR4, 10 bar at AIR1

Manipulator

Further information is contained in the assembly instructions for the manipulator.

Robot controller

The power supply ratings can be found in the robot controller assembly instructions.

Further information is contained in the assembly instructions for the robot controller.

ES779 electrically-driven spindle

Detailed information can be found in the assembly instructions of the electrically-driven spindle.

Recooling system

The distance between the manipulator and the recooling system must not exceed 25 m. This gives a maximum hose length (supply and return) for the cooling circuit of 50 m.

Further information is contained in the assembly, installation and operating instructions of the recooling system.

Tool rack

Tool mount	HSK F63
Rated supply voltage	24 V DC
Field bus interface	PROFINET
Weight without cover	35 kg
Weight with cover	105 kg

4.3 Basic data, Milling 16 kW components

Milling controller

Mains supply voltage	3 x 400 V AC
Control voltage	24 V DC
Rated frequency	50/60 Hz
Rated current	125 A
Loop impedance (system impedance up to the connection point of the milling controller)	≤ 200 mΩ
Weight	365 kg
Protection rating	IP 54

Ambient temperature during operation	+15 ... 43 °C (288 ... 316 K)
Ambient temperature during storage/transportation without cooling water	-25 ... +70 °C (248 ... 343 K)
Temperature change	max. 1.1 K/min
Humidity class	3k3 acc. to DIN EN 60721-3-3; 1995

Altitude	• up to 1000 m above mean sea level with no reduction in power • 1000 to 4000 m above mean sea level with a reduction in power of 5%/1000 m

Compressed air connection	min. 6 bar
Pneumatic connection	Hose with 10 mm outer diameter for plug-in connection
Pneumatic settings	4 bar at AIR2, 6 bar at AIR3 and AIR4, 10 bar at AIR1

Robot controller

The power supply ratings can be found in the robot controller assembly instructions.

Further information is contained in the assembly instructions for the robot controller.

Manipulator

Further information is contained in the assembly instructions for the manipulator.

ES789 electrically-driven spindle

Detailed information can be found in the assembly instructions of the electrically-driven spindle.

Recooling system

The distance between the manipulator and the recooling system must not exceed 25 m. This gives a maximum hose length (supply and return) for the cooling circuit of 50 m.

Further information is contained in the assembly, installation and operating instructions of the recooling system.

Tool rack

Tool mount	HSK F63
Rated supply voltage	24 V DC
Field bus interface	PROFINET
Weight without cover	35 kg
Weight with cover	105 kg

4.4 Dimensions, Milling 8 kW technology cabinet

The dimensions of the Milling 8 kW technology cabinet are shown in the diagram (>>> *Fig. 4-1*).

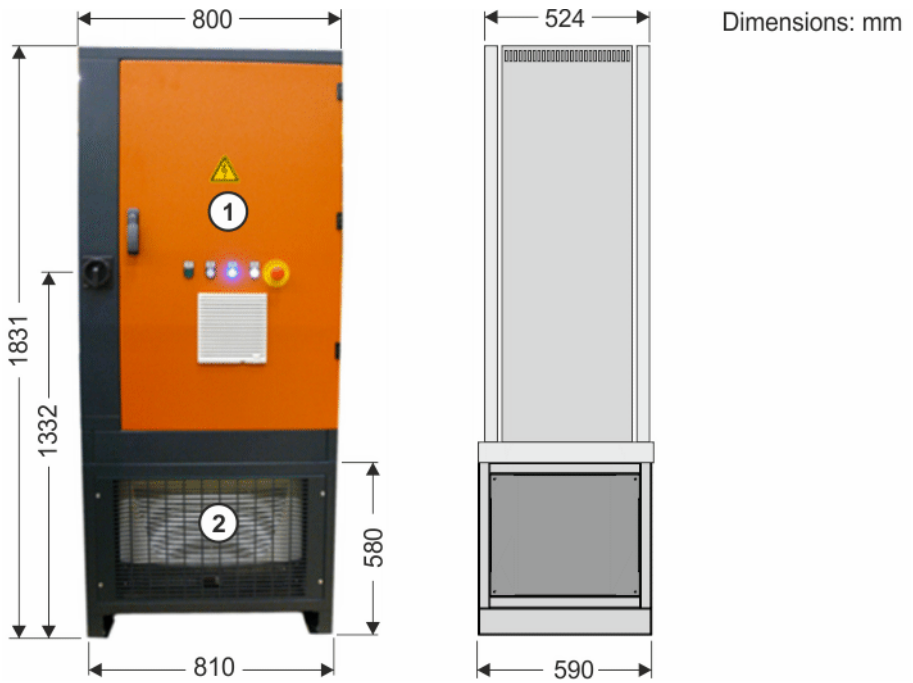


Fig. 4-1: Dimensions

1 Milling controller
2 Recooling system

4.5 Dimensions, Milling 12/16 kW technology cabinet

The dimensions of the Milling 12/16 kW technology cabinet are shown in the diagram (>>> *Fig. 4-2*).

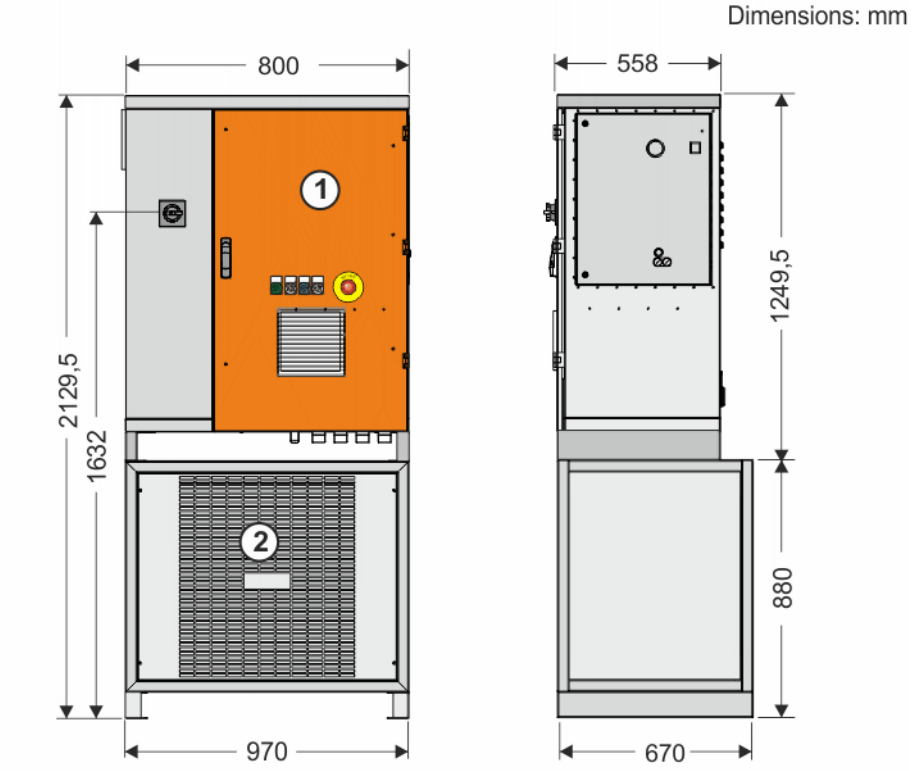


Fig. 4-2: Dimensions

1 Milling controller
2 Recooling system

4.6 Minimum clearances, Milling 8 kW technology cabinet

The minimum clearances to be maintained for the Milling 8 kW technology cabinet are shown in the diagram (>>> *Fig. 4-3*).

Fig. 4-3: Minimum clearances

1 Front view
2 Side view

NOTICE

Damage to property due to failure to maintain minimum clearances
If the minimum clearances are not maintained, this can result in damage to the technology cabinet.

- Always maintain the specified minimum clearances.

4.7 Minimum clearances, Milling 12/16 kW technology cabinet

The minimum clearances to be maintained for the Milling 12/16 kW technology cabinet are shown in the diagram (>>> *Fig. 4-3*).

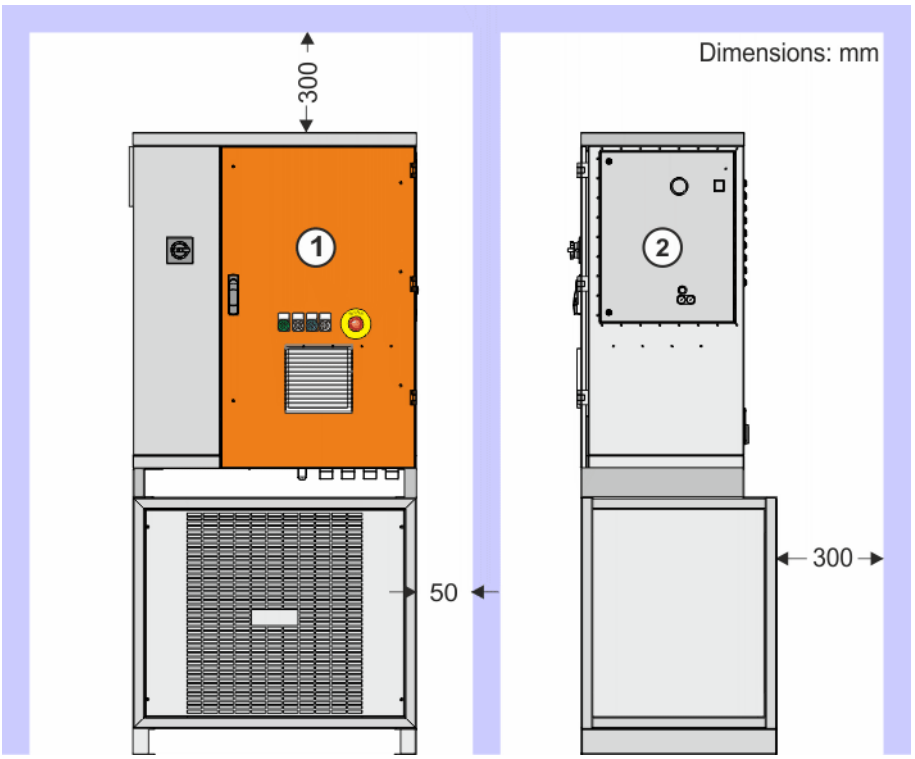


Fig. 4-4: Technology cabinet minimum clearances

1 Front view
2 Side view

NOTICE

Damage to property due to failure to maintain minimum clearances
If the minimum clearances are not maintained, this can result in damage to the technology cabinet.

- Always maintain the specified minimum clearances.

4.8 Dimensions of boreholes for floor mounting of Milling 8 kW technology cabinet

The dimensions of the boreholes for floor mounting are indicated in the diagram (>>> *Fig. 4-5*).

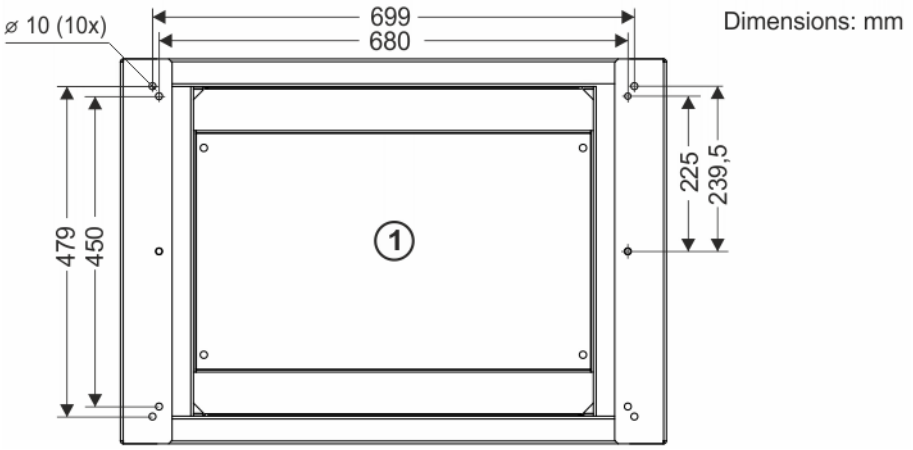


Fig. 4-5: Boreholes for floor mounting

1 View from below

4.9 Dimensions of boreholes for floor mounting of Milling 12/16 kW technology cabinet

The dimensions of the boreholes for floor mounting are indicated in the diagram (>>> *Fig. 4-6*).

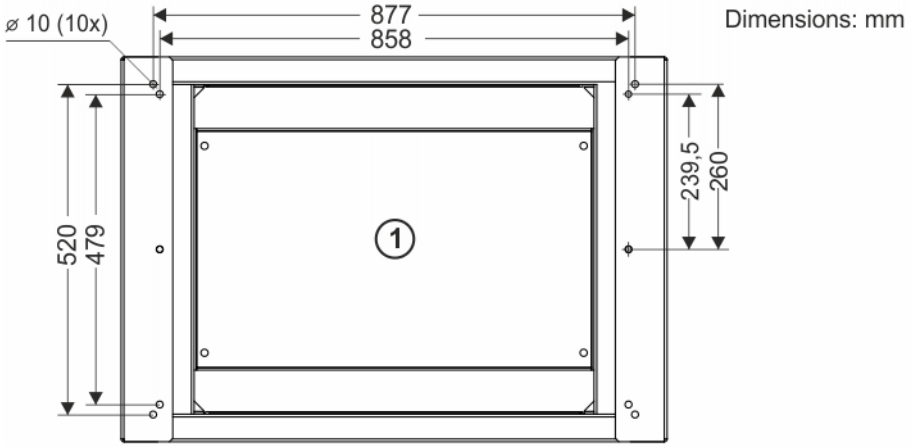


Fig. 4-6: Boreholes for floor mounting

1 View from below

4.10 Dimensions of boreholes for floor mounting of tool rack

The dimensions of the boreholes for floor mounting are indicated in the diagram (>>> *Fig. 4-7*).

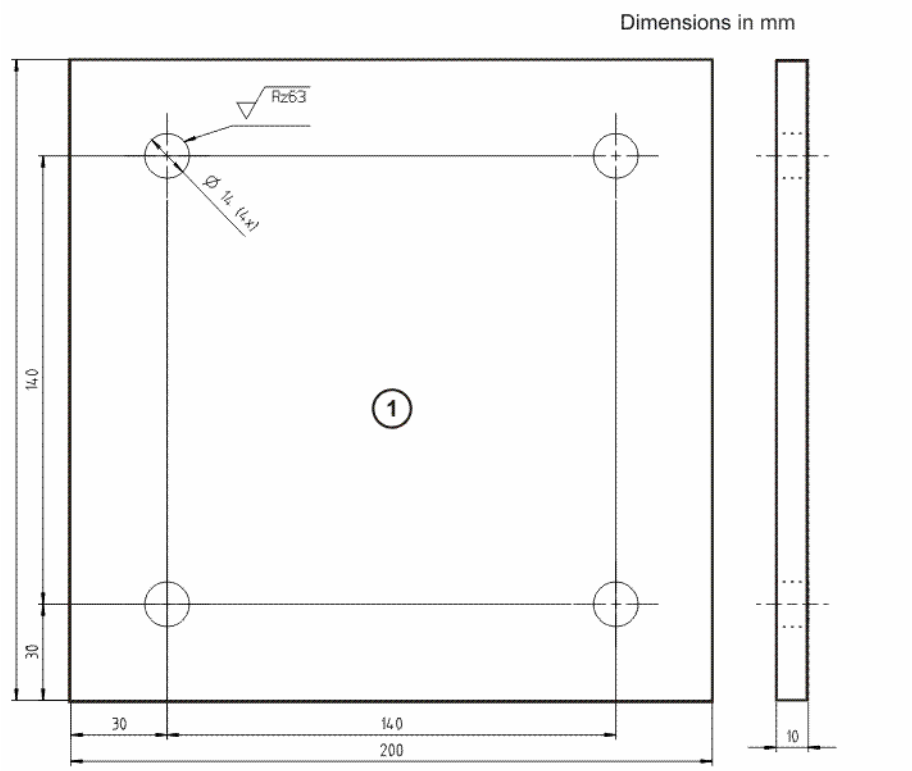


Fig. 4-7: Dimensions of boreholes for floor mounting

1 View from below

4.11 Plates and labels on milling controller

Overview

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

Milling 8 kW controller

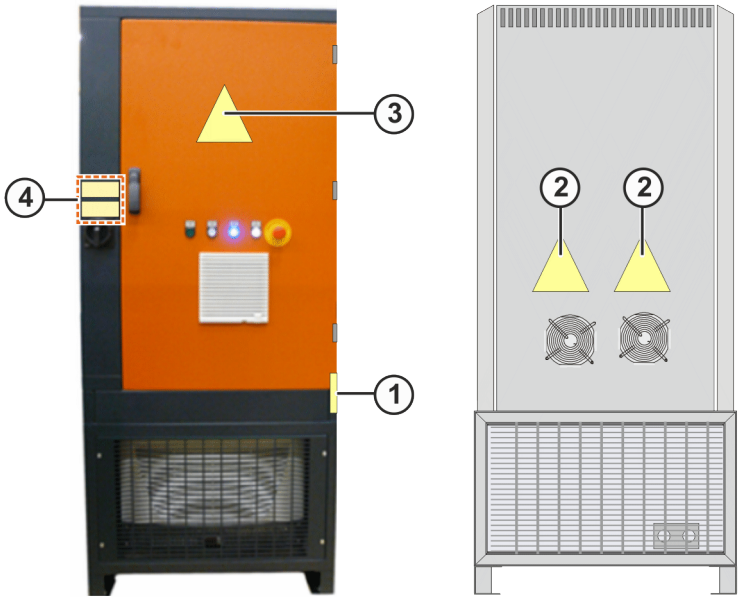


Fig. 4-8: Plates and labels on milling controller

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

Item	Description
1	 **Robot controller identification plate (example)**
2	 **Hot surface** During operation of the controller, surface temperatures may be reached that could result in burn injuries. Protective gloves must be worn!
3	 **High voltage** Any improper handling can lead to contact with current-carrying components. Electric shock hazard!
4	Milling cabinet | Milling cabinet Note: Technology cabinet main switch

Milling controller technology cabinet 12/16 kW

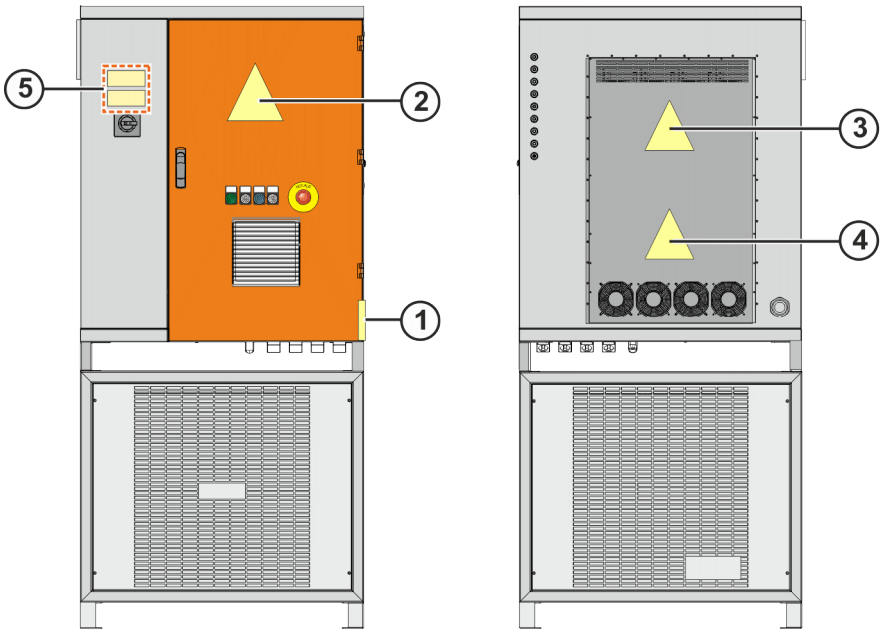


Fig. 4-9: Plates and labels on technology cabinet

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

Item	Description
1	 **Robot controller identification plate (example)**
2	 **High voltage** Any improper handling can lead to contact with current-carrying components. Electric shock hazard!
3	 **Hot surface** During operation of the controller, surface temperatures may be reached that could result in burn injuries. Protective gloves must be worn!
4	 **Crushing hazard** Installation of the rear panel poses a crushing hazard. Protective gloves must be worn!
5	Milling cabinet Milling cabinet Note: Technology cabinet main switch

4.12 Plates and labels on tool rack

Overview

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

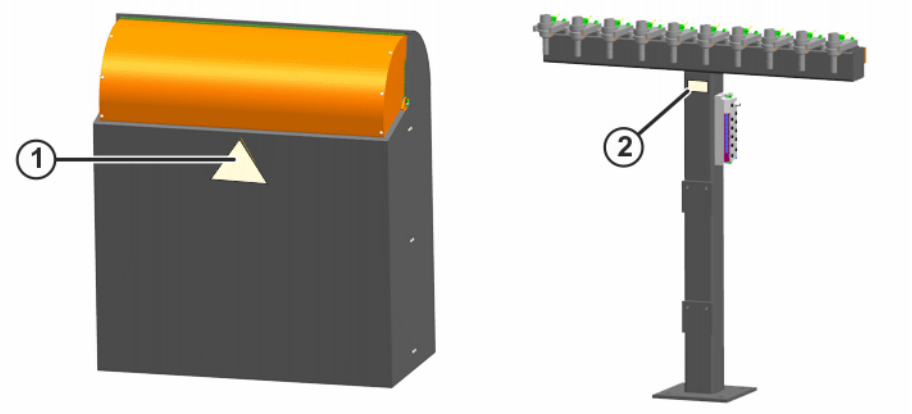
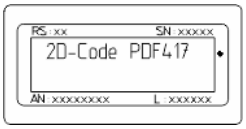


Fig. 4-10: Plates and labels on tool rack

The plates may vary slightly from those illustrated as a result of updates.

Item	Description
1	 **Crushing hazard** Installation of the rear panel poses a crushing hazard. Protective gloves must be worn!
2	 **Tool rack identification plate (example)**

4.13 REACH duty to communicate information acc. to Art. 33

As of June 2007, the Regulation (EC) 1907/2006 of the European Parliament and of the Council dated 18 December 2006 on the registration, evaluation and authorization of chemicals (REACH Regulation) is in force.

Detailed REACH information can be found in the product information in KUKA Xpert.

5 Planning

5.1 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.

System integrator

The system integrator is responsible for integrating the safety devices:

- External EMERGENCY STOP devices
- Physical safeguard
- Safety gates

  The system integrator must ensure that the safety gates can only be opened if the electrically-driven spindle is no longer turning.
- Cell controller, higher-level cell controller if applicable
- Safety light barriers, safety light curtains
- Connection of the individual components
- Creation of a grounding concept

Step	Description	Information
1	Manipulator	Detailed information is contained in the manipulator assembly instructions, in the chapter “Planning”.
2	System planning	(>>> *5.3 "System planning for the milling robot system" Page 58*)
3	Installation conditions	Detailed information is contained in the robot controller assembly instructions, in the chapter “Planning”. (>>> *5.4 "Installation conditions for robot controller and technology cabinet" Page 59*)
4	PROFINET interface	(>>> *5.5 "PROFINET interface XS15A, XS15B" Page 60*)
5	Physical safeguard	(>>> *5.6 "Physical safeguard" Page 60*)
6	Safety gates	(>>> *5.7 "Safety gates" Page 61*)
7	External EMERGENCY STOP devices	(>>> *5.8 "External EMERGENCY STOP devices (optional)" Page 62*)
8	Grounding the tool	(>>> *5.9 "Grounding the tool" Page 63*)
9	Preheating the electrically-driven spindle	(>>> *5.10 "Preheating the electrically-driven spindle" Page 63*)
10	Configuration of digital I/O modules (optional)	(>>> *5.11 "Configuring digital I/O modules (optional)" Page 63*)

Step	Description	Information
11	Cooling water stop (optional)	(>>> *5.12 "Cooling water stop (optional)" Page 64*)
12	Configuration of tool rack (optional)	(>>> *5.13 "Tool rack (optional)" Page 64*)
13	Grounding concept	(>>> *5.14 "Connection example for grounding concept" Page 65*)
14	Performance Level	(>>> *5.15 "Performance level" Page 65*)

5.2 Preset interrupts and I/O ranges

Description

The following interrupts and I/O ranges are factory presets and must not be modified.

Interrupts

Interrupt	Number	Description
cItrMillError	8	Interrupts in the event of an error
cItrMillWarning	9	

I/O ranges

Variable	Number
$IN[*x*]	1 … 128
$OUT[*x*]	1 … 128

5.3 System planning for the milling robot system

5.3.1 Designing the clamping fixture

The user must design the clamping fixture in accordance with the machining forces.

5.3.2 Installation site

Manipulator

When planning the system, it must be ensured that the installation site has the required grade of concrete and load-bearing capacity. The principal loads acting on the mounting base are indicated in the assembly and operating instructions of the manipulators.

Robot controller

- It is imperative to comply with the minimum clearances of the robot controller from walls, cabinets and other system components in accordance with the technical data of the robot controller.
- The robot controller may only be installed outside the physical safeguard.

Technology cabinet

- It is imperative to comply with the minimum clearances of the technology cabinet from walls, cabinets and other system components.
- The technology cabinet may only be installed outside the physical safeguard.

Recooling system

The maximum hose length from the recooling system to the manipulator/ electrically-driven spindle must not exceed 25 m. If a hose length greater than 25 m is required, this must be checked by KUKA.

5.3.3 Use in SME workshops

If the system is to be used in an SME workshop and connected to the public mains, approval must be received from the power utility.

5.3.4 Noise protection

Noise protection measures depend on the materials to be machined. Noise protection measures must be implemented in accordance with a risk assessment by the user.

CAUTION

Noise from milling operation
Depending on the material machined, the milling operation may cause considerable noise. This noise can cause damage to health.

- Take measures to protect against noise.
- If the limit value is permanently exceeded, instruct that ear protectors must be worn.

5.3.5 Fume extraction

The user must determine in a risk assessment what if any fume extraction is required.

CAUTION

Dust due to milling operation
Depending on the material machined, the milling operation may cause considerable quantities of dust. If this dust comes into contact with hot surfaces, this can result in hazardous vapors which, if inhaled, can be harmful to health.

- Implement measures to protect against dust and vapors (fume extraction).

5.4 Installation conditions for robot controller and technology cabinet

The robot controller and technology cabinet may only be installed outside the safety fence or physical safeguard.

The connecting cables and hoses must be routed in such a way (e.g. cable ducts) as to prevent the risk of tripping. The system integrator and the operator must consider the hazard in a risk assessment. Where there is an unavoidable risk of tripping, this must be marked accordingly.

5.5 PROFINET interface XS15A, XS15B

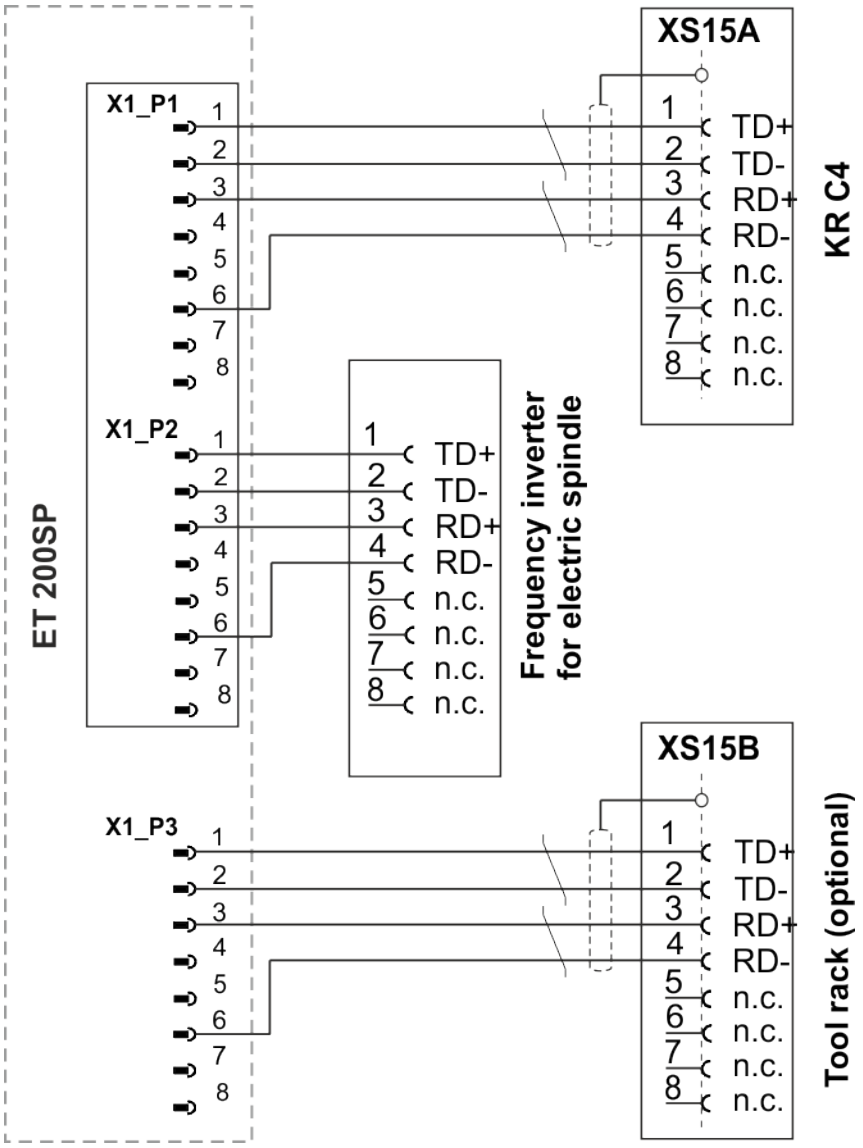


Fig. 5-1: Connector pin allocation XS15A and XS15B

5.6 Physical safeguard

Description

The workspace of the manipulator must be protected by a physical safeguard.

The physical safeguard must meet the following requirements and be designed by the system integrator:

- The tool must be secured to prevent it being ejected from the safeguarded area.
- Components of the tool rack (optional) including tool cover must be secured to prevent them being ejected from the safeguarded area.
- It must not be possible for unauthorized persons to access the area.

In accordance with the required risk assessment, the system integrator must attach warnings to the physical safeguard, e.g. “PPE must be worn”, “No entry for unauthorized persons”, etc.

The physical safeguard is not included with the milling robot system and must be erected by the user.

5.7 Safety gates

Description

The milling controller supports up to 4 safety gates:

- Safety gate 1 XS4
- Safety gate 2 XS4.1 (optional)
- Safety gate 3 XS4.2 (optional)
- Safety gate 4 XS4.3 (optional)

Every safety gate must be safeguarded with a gate lock. The connectors of non-connected safety gates must be jumpered as shown in the example for safety gate 2 (>>> *Fig. 5-5*).

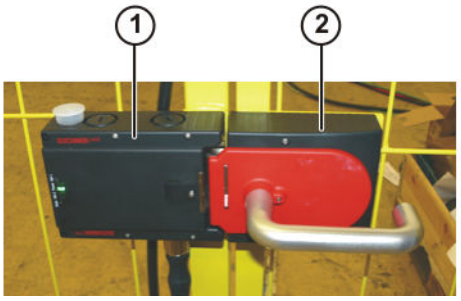


Fig. 5-2: Safety gate with lock

1	Locking module	2	Handle module

Example of safety gate 1

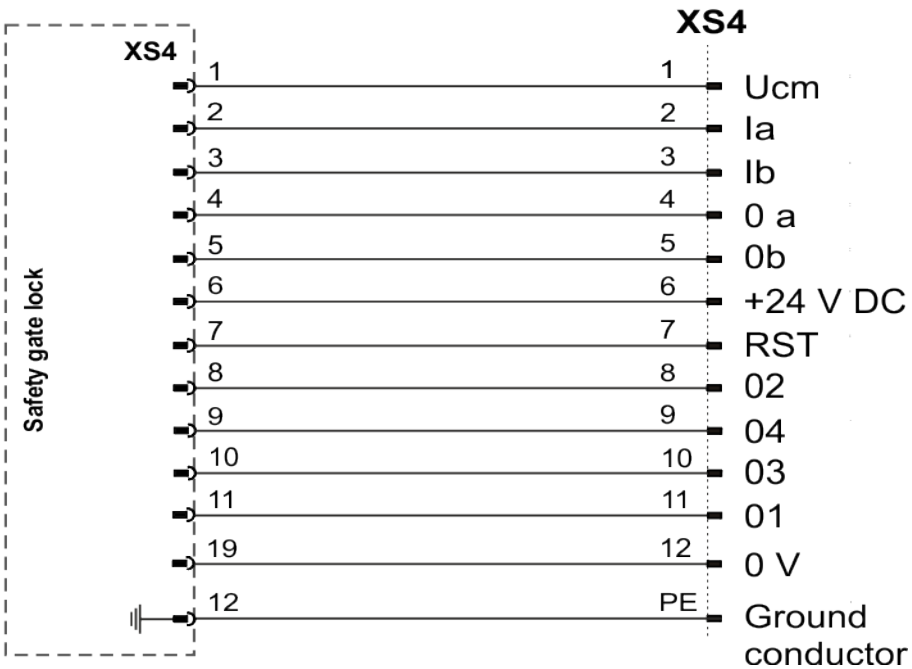


Fig. 5-3: Connection of safety gate lock

Example of safety gate 2

Safety gates 3 and 4 are connected in the same way.

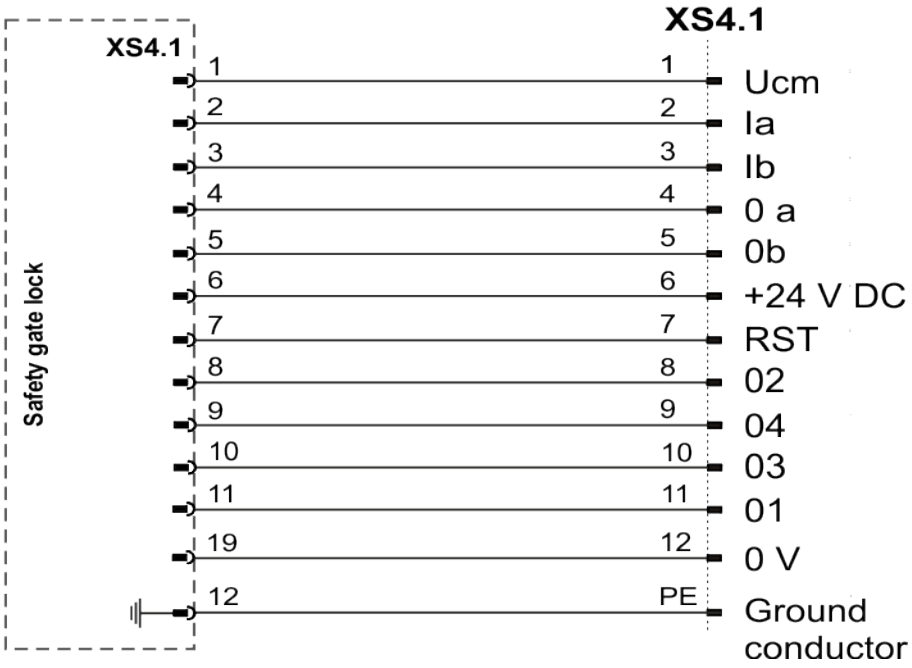


Fig. 5-4: Connection of safety gate lock 2

Jumpers

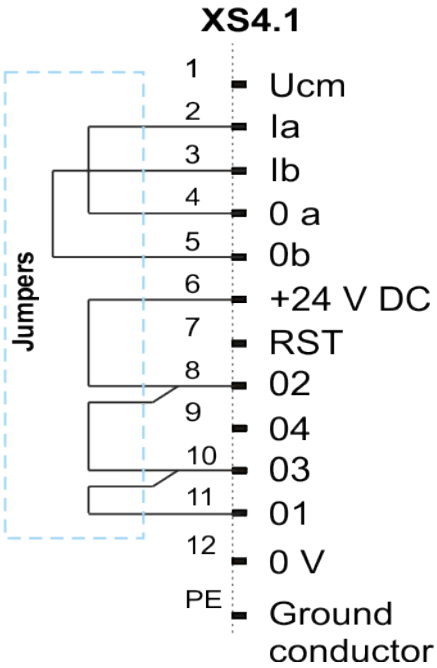


Fig. 5-5: Jumpers XS4.1

Tool cover

If a safety gate is open (operator safety deactivated), the tool cover can no longer be opened or closed automatically. The outputs (A52/A0.0, A52/A0.1) are deactivated.

5.8 External EMERGENCY STOP devices (optional)

Description

Up to 2 external EMERGENCY STOP devices can be connected to the milling controller:

- EMERGENCY STOP device 1 XS41
- EMERGENCY STOP device 2 XS41.1

The connectors of non-connected external EMERGENCY STOP devices must be jumpered.

The diagram (>>> *8.4 "Overview of electrical connections" Page 88*) shows how both EMERGENCY STOP devices are connected. Further EMERGENCY STOP devices can be connected in series.

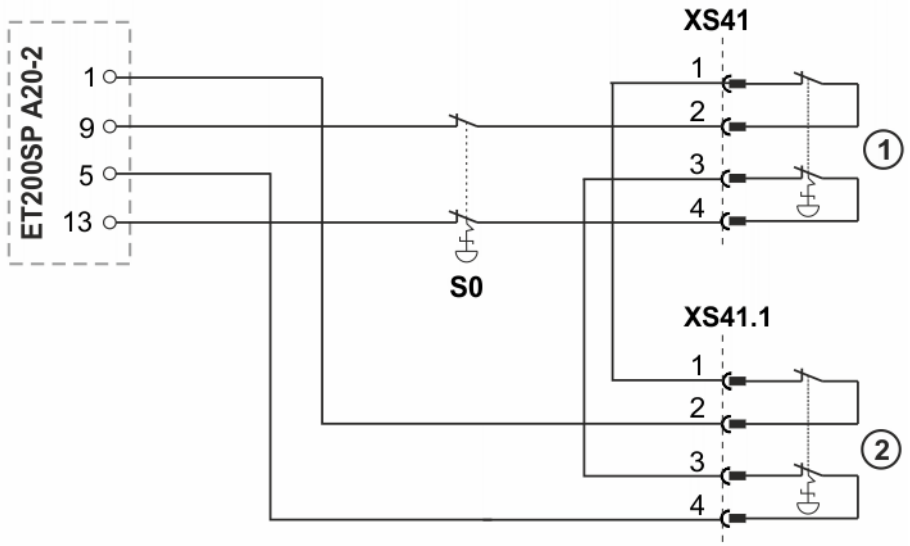


Fig. 5-6: Connection of external EMERGENCY STOP devices

1 EMERGENCY STOP device 1 2 EMERGENCY STOP device 2

5.9 Grounding the tool

The tool is not included in the scope of supply. The spindle chuck of the electrically-driven spindle is not conductive. The tools are not grounded via the electrically-driven spindle. If the user uses materials that can generate a static charge during machining, the tool must be grounded by attaching a slip ring or similar device.

A measurement on a connected mains power supply must be carried out in accordance with EN 60204-1, Section 18. Measurement using measuring equipment in accordance with EN 61557-3. (System impedance)

5.10 Preheating the electrically-driven spindle

To prevent damage to the bearing, the electrically-driven spindle must always be subjected manually to a brief preheating cycle in accordance with the assembly instructions of the electrically-driven spindle before starting work. This requires the creation of a program. The inline forms can be used for this. (>>> *10.1 "Overview of the inline forms" Page 105*)

Further information can be found in the assembly instructions of the electrically-driven spindle.

5.11 Configuring digital I/O modules (optional)

If digital I/O modules (16/16/4) are used, they can be configured via the KRL variables $IN 2049-2065 and $OUT 2049-2068.

5.12 Cooling water stop (optional)

If the difference in height between the cooling water tank of the recooling system and the highest point of the cooling water line is >3 m, the cooling water stop option must be installed. The water stop function prevents the cooling water tank from overflowing and is switched on and off by the milling system as required.

The cooling water stop consists of the following components:

- Mechanical check valve in the supply to the chiller
- Solenoid valve in the return of the cooling circuit

5.13 Tool rack (optional)

Power supply via XS51

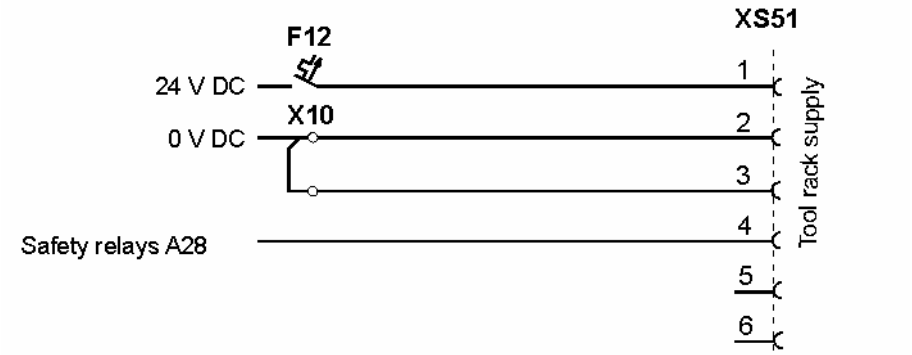


Fig. 5-7: Connector pin allocation XS51

I/O bus modules

A101	Description	Switch / display element
I0	Tool 1 set down	B101
I1	Tool 2 set down	B102
I2	Tool 3 set down	B103
I3	Tool 4 set down	B104
I4	Tool 5 set down	B105
I5	Tool 6 set down	B106
I6	Tool 7 set down	B107
I7	Tool 8 set down	B108
I8	Tool 9 set down	B109
I9	Tool 10 set down	B1010
I10	Spare	-
I11	Spare	-
I12	Spare	-
I13	Spare	-
I14	Spare	-
I15	Tool cover open	B116

Only if a tool rack with cover is present.

A102	Description	Switch / display element
O0	Spare	-
O1	Spare	-
O2	Close tool rack	Y101
O3	Spare	-
O4	Spare	-
O5	Spare	-
O6	Open tool rack	Y101
O7	Spare	-

5.14 Connection example for grounding concept

The grounding concept must be taken into consideration and designed by the user.

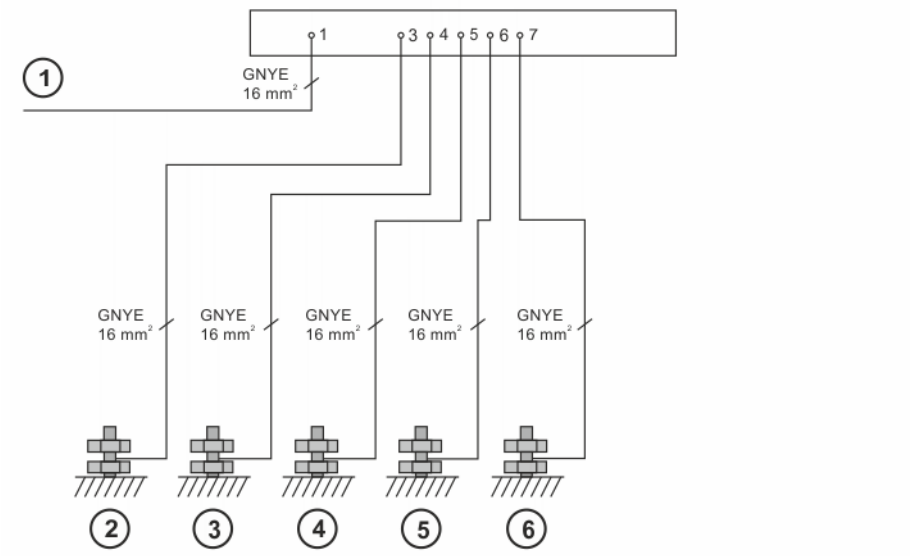


Fig. 5-8: Grounding concept (example)

1 Equipotential bonding rail, shop
2 Equipotential bonding connection, manipulator
3 Equipotential bonding connection, KR C4
4 Equipotential bonding connection, technology cabinet
5 Equipotential bonding connection, e.g. floor frame
6 Equipotential bonding connection, e.g. worktable, tool rack, tool changer

5.15 Performance level

The safety functions of the safety gates and the EMERGENCY STOP circuit conform to category 3 and Performance Level (PL) d according to EN ISO 13849-1.

5.15.1 PFH values of the safety functions

The safety values are based on a service life of 6-10 years.

The PFH value classification of the controller is only valid if the EMERGENCY STOP device is tested at least once every 6 months.

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 RoboTeam systems or higher-level hazard areas. The PFH value determined for the safety function at system level must not exceed the limit for PL d.

Safety function	PFH value
EMERGENCY STOP device	2.1×10^{-7}
External EMERGENCY STOP device 1 (optional)	2.1×10^{-7}
External EMERGENCY STOP device 2 (optional)	2.1×10^{-7}
Safety gate 1	2.4×10^{-7}
Safety gate 2 (optional)	2.4×10^{-7}
Safety gate 3 (optional)	2.4×10^{-7}
Safety gate 4 (optional)	2.4×10^{-7}

6 Transportation

6.1 Transporting the technology cabinet using lifting tackle

Preconditions

- Technology cabinet must be switched off.
- The cooling circuit of the recooling system is empty.
- No cables or hoses may be connected to the technology cabinet.
- The door of the technology cabinet must be closed.
- The technology cabinet must be upright.

Necessary equipment

- Lifting tackle with or without lifting frame

Procedure

1. Attach the lifting tackle with or without a lifting frame to all 4 transport eyebolts on the technology cabinet.

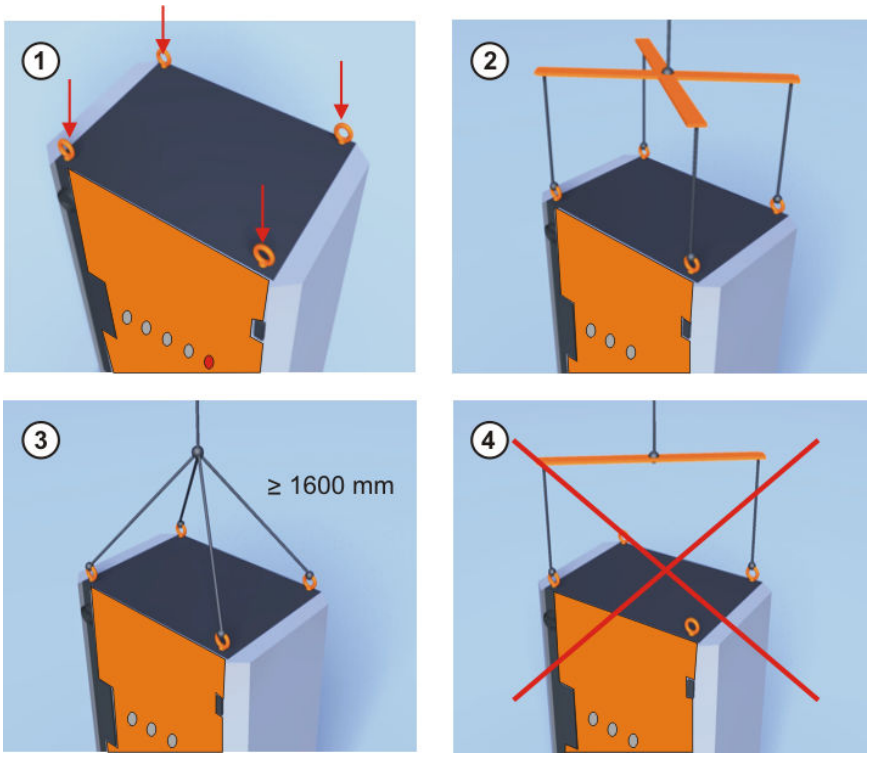


Fig. 6-1: Transportation using lifting tackle

1 Transport eyebolts on the technology cabinet
2 Correctly attached lifting tackle
3 Correctly attached lifting tackle
4 Incorrectly attached lifting tackle

2. Attach the lifting tackle to the crane.

WARNING

Danger to life and limb due to swinging load
If the suspended cabinet is transported too quickly, it may swing. Death, severe injuries or damage to property may result.
– Transport the cabinet slowly.

3. Slowly lift and transport the technology cabinet.
4. Slowly lower the technology cabinet at its destination.
5. Detach the lifting tackle from the technology cabinet.

6.2 Transporting the technology cabinet by fork lift truck/pallet truck

Preconditions

- Technology cabinet must be switched off.
- The cooling circuit of the recooling system is empty.
- No cables or hoses may be connected to the technology cabinet.
- The door of the technology cabinet must be closed.
- The technology cabinet must be upright.

Procedure

1. Pick up and transport the technology cabinet using a fork lift truck or pallet truck.

6.3 Transporting the tool rack

Preconditions

- All dirt and deposits (swarf) have been removed.
- All tools have been removed from the tool rack.
- The compressed air line has been depressurized, vented and disconnected.
- The electrical power supply and bus cables have been disconnected.

Procedure

1. Transportation on pallet (EUR-pallet)
   Fasten the tool rack and base plate to the pallet and secure them with ratchet straps to prevent them from falling over.
2. Transportation by gantry crane/fork lift truck
   With the tool cover open, place the harness around the vertical central bar of the base frame of the tool rack and secure it to prevent it from sliding off the top. During transportation, the tool rack must additionally be secured to prevent it from tipping or slipping.

7 Operation

7.1 Operator control and display elements

Description

The diagram (>>> *Fig. 7-1*) shows the operator control and display elements for the 8 kW milling robot system as an example.

Fig. 7-1: Operator control and display elements

1 Controller System Panel (CSP)
2 Robot controller main switch
3 KUKA smartPAD
4 Milling controller main switch
5 Operator control and display elements on milling controller
6 Operator control and display elements for recooling system

Milling controller

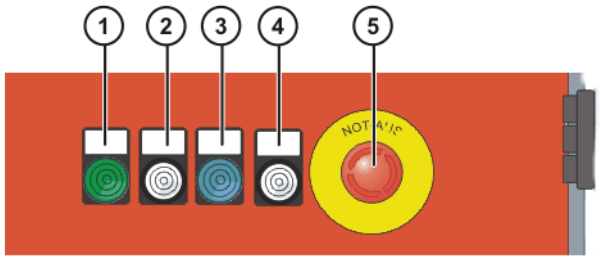


Fig. 7-2: Operator control and display elements on milling controller

Item	Element	Function
1	Illuminated green pushbutton S1/P1 “Automatic ON”	**Activate and indicate Automatic mode on the milling controller** P1 off: No Automatic mode P1 flashing: Request Automatic mode P1 on: Automatic mode active
2	White pushbutton S2 “Automatic Off”	**Deactivate Automatic mode on the milling controller** When the pushbutton is pressed, Automatic mode is deactivated
3	Illuminated blue pushbutton S3/P3 “Acknowledge”	**Acknowledgement** After rectifying the fault, acknowledge the E-STOP, operator safety and standstill monitor. P3 off: No fault present P3 flashing: E-STOP pressed, operator safety triggered, standstill monitor fault
4	Illuminated white pushbutton S4/P4 “Gate request”	**Gate request** Once the motion program has been terminated and the electrically-driven spindle is at a standstill, pressing this button releases the gate lock. P4 on: Gate unlocked, access possible P4 flashing: Request active, gate remains locked until the manipulator and electrically-driven spindle are stationary. P4 off: Gate locked, request possible
5	EMERGENCY STOP device S0	When this is pressed, the manipulator drives and the electrically-driven spindle are immediately brought to a halt.

Recooling system

Operating states can be displayed and parameters set on the recooling system.

Once the power supply has been switched on, the current software version is displayed for approx. 2 seconds. During operation, the supply temperature (to the device) of the coolant circuit is displayed and, alternately, any active messages in the form of error codes.

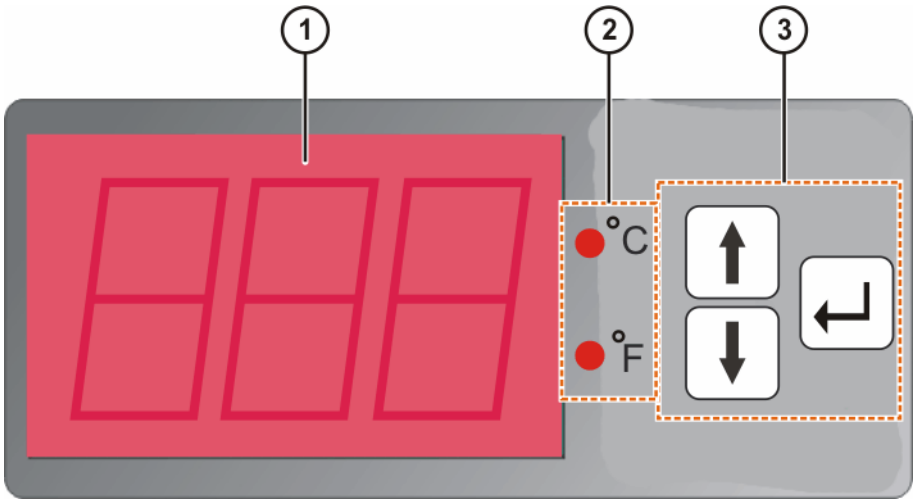


Fig. 7-3: Operator control and display elements for recooling system

1	7-segment display	3	Operator control keys
2	Temperature unit LEDs		

7.1.1 Start-up after an EMERGENCY STOP

Description

The following EMERGENCY STOP devices can be found on the milling robot system:

- EMERGENCY STOP device on the smartPAD
- EMERGENCY STOP device on the milling controller
- External EMERGENCY STOP devices (optional)
  (>>> *5.8 "External EMERGENCY STOP devices (optional)" Page 62*)

If an EMERGENCY STOP device is pressed, the milling robot system is stopped under servo control.

Precondition

- An EMERGENCY STOP device has been pressed.

Procedure

1. Check and eliminate the situation that led to the EMERGENCY STOP.
2. Release the EMERGENCY STOP device on the smartPAD, milling controller or an external EMERGENCY STOP device.
3. Acknowledge the EMERGENCY STOP with the illuminated pushbutton S3/P3 **Acknowledge** on the milling controller or the smartPAD.
4. Press the illuminated pushbutton S1/P1 **Automatic mode ON** on the milling controller. (Only effective if Automatic External mode is active.)
   The milling robot system resumes the program.

7.1.2 Deactivating and activating operator safety

Description

The inputs are used for monitoring and locking the safety equipment. Safety equipment, e.g. safety gates, can be connected to the dual-channel

input. If nothing is connected to this input, operation in Automatic mode is not possible. Operator safety is not active in test modes T1 and T2.

Procedure

1. Press the illuminated pushbutton S4/P4 **Gate request** on the milling controller.
2. Enter the system and rectify the fault.
3. Exit the system again and make sure no-one remains within the safeguarded zone.
4. Press the illuminated pushbutton S3/P3 **Acknowledge** on the milling controller.
5. Press the illuminated pushbutton S1/P1 **Automatic mode ON** on the milling controller.

   The robot resumes its program.

7.2 HMI Milling user interface

Description

The application-specific user interface HMI Milling is displayed as a plug-in on the KUKA smartHMI.

Procedure

Display the user interface:

- In the main menu, select **Display** > **MillTech**.

Overview

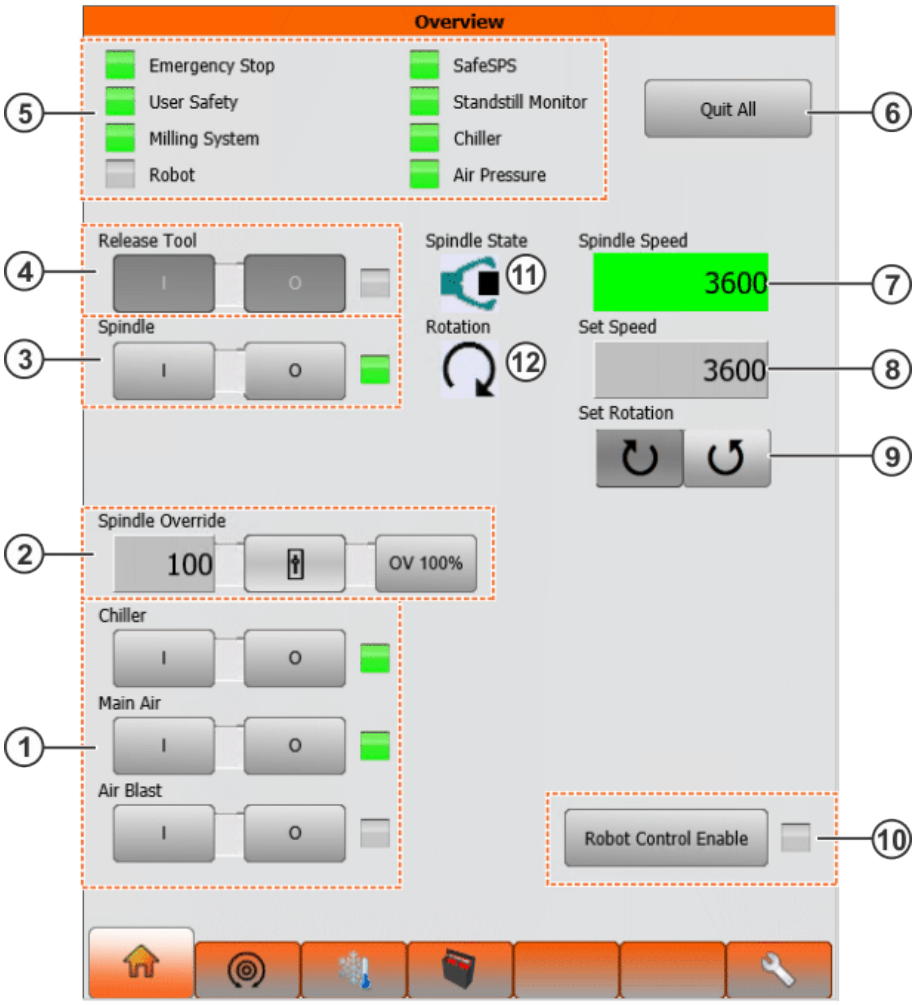


Fig. 7-4: HMI Milling user interface

Item	Description
1	Buttons for switching the chiller, main air and tool cleaning air on/off **I**: Switch on **O**: Switch off Status indication via LED **Green**: Switched on **Gray**: Switched off
2	Setting of the spindle override as a percentage of the spindle speed Can be entered directly or using a slider control (button to the right of the input box).
3	Buttons for switching the spindle on/off **I**: Switch on **O**: Switch off Status indication via LED **Green**: Switched on **Gray**: Switched off

Item	Description
4	Buttons for clamping and releasing the tool **I**: Clamp **O**: Release Status indication via LED **Green**: Tool clamped **Gray**: Tool released
5	Milling system error messages • Emergency Stop **Red**: EMERGENCY STOP active **Green**: No EMERGENCY STOP active • User Safety **Red**: Operator safety is active **Green**: No operator safety active • Milling System **Green**: Milling cell ready **Gray**: Milling cell not ready • Robot **Green**: Robot ready **Gray**: Robot not ready • SafeSPS **Green**: Safety PLC ready **Red**: Fault on the safety PLC **Gray**: Safety PLC not ready • Standstill Monitor **Green**: Standstill monitoring OK **Red**: Standstill monitoring signals an error • Chiller **Green**: Chiller without fault **Red**: Fault in chiller • Air Pressure **Green**: Air pressure without fault **Red**: Air pressure fault
6	Button for acknowledging all error messages of the milling system (not manipulator messages)
7	Display of the spindle speed (unit: rpm)
8	Entry of the spindle speed (unit: rpm)
9	Buttons for setting the spindle direction
10	Button for enabling the robot controller The robot controller takes control of the system. Most of the buttons on the HMI Milling user interface are deactivated. Status indication via LED **Green**: Robot controller enabled **Gray**: Robot controller not enabled

Item	Description
11	Display of the spindle state •  : Error •  : Spindle clamped without tool •  : Spindle clamped with tool •  : Spindle open
12	Display of direction of spindle rotation •  : Error •  : Counterclockwise •  : Clockwise •  : Stop

7.2.1 Spindle view

Spindle control view:

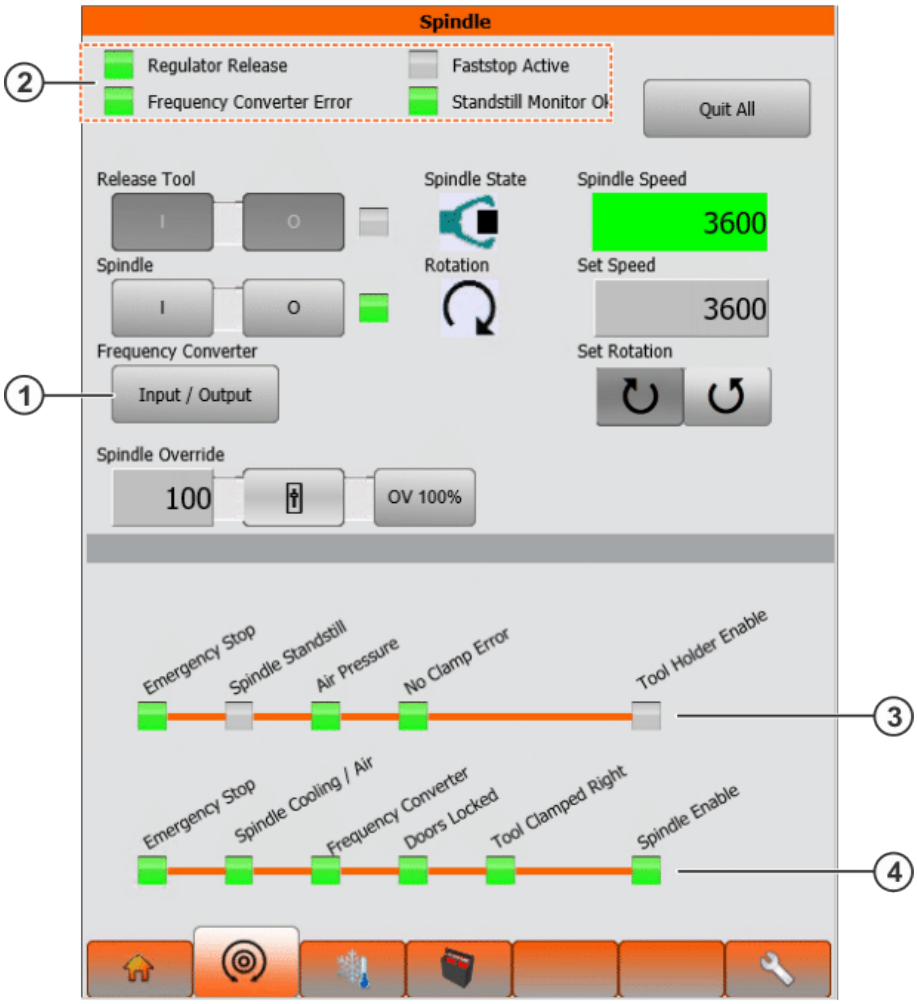


Fig. 7-5: Spindle view

Item	Description
1	Button for displaying the frequency converter I/Os (troubleshooting) (>>> *Fig. 7-6*) Status indication via LED **Green**: I/O set **Gray**: I/O not set
2	Status indicators • Regulator Release **Green**: Controller enabled **Gray**: Controller not enabled • Faststop Active **Green**: Fast stop active **Gray**: Fast stop not active • Frequency Converter Error **Green**: No error **Red**: Error • Standstill Monitor **Green**: No error **Red**: Error
3	Status indicators of tool rack (process sequence) • Emergency Stop **Red**: EMERGENCY STOP active **Green**: No EMERGENCY STOP active • Spindle Standstill **Green**: Spindle is stationary. **Gray**: Spindle is rotating. • Air Pressure **Green**: Air pressure present **Gray**: No air pressure • No Clamp Error **Green**: No error **Red**: Error • Tool Holder Enable **Green**: Tool holder ready **Gray**: Tool holder not ready

Item	Description
4	Status indicators of spindle (process sequence) • Emergency Stop **Red**: EMERGENCY STOP active **Green**: No EMERGENCY STOP active • Spindle Cooling / Air **Green**: No error **Red**: Error • Frequency Converter **Green**: No error **Red**: Error • Doors Locked **Green**: Gates closed **Gray**: Gates not closed • Tool Clamped Right **Green**: Tool clamped correctly **Red**: Tool clamped incorrectly **Gray**: Tool not clamped • Spindle Enable **Green**: Spindle ready **Gray**: Spindle not ready

Frequency converter I/Os (status indication via LED):

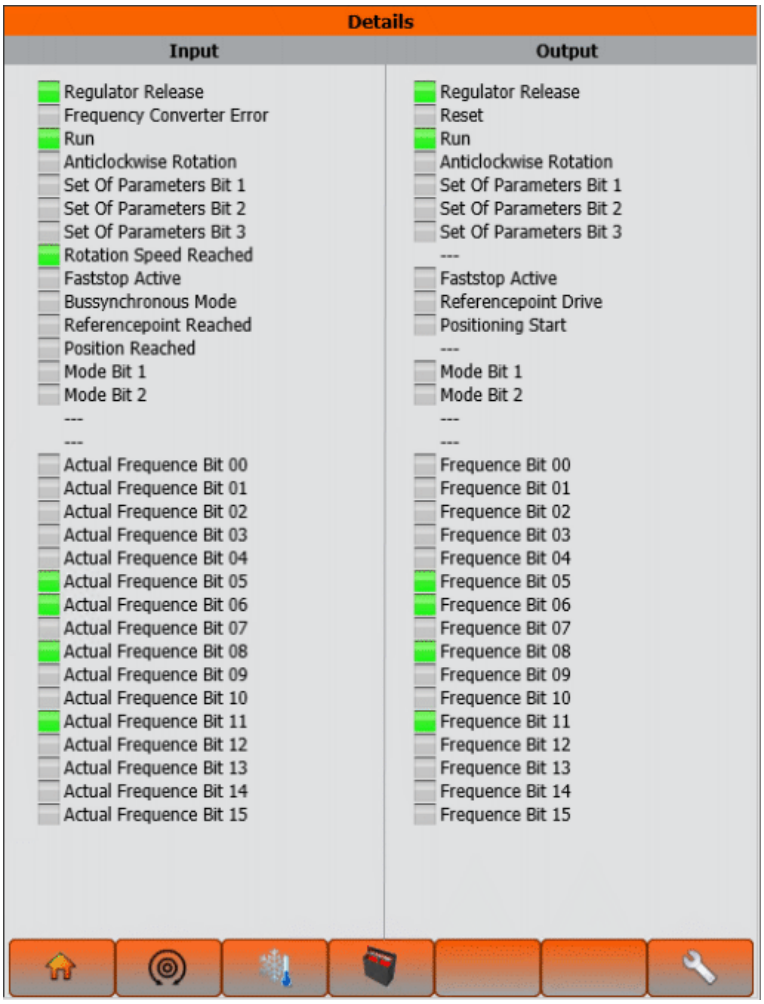


Fig. 7-6: Frequency converter I/Os

Further information about the status indicators can be found in the assembly instructions of the electrically-driven spindle.

7.2.2 Periphery view

Chiller, main air and tool cleaning air control view:

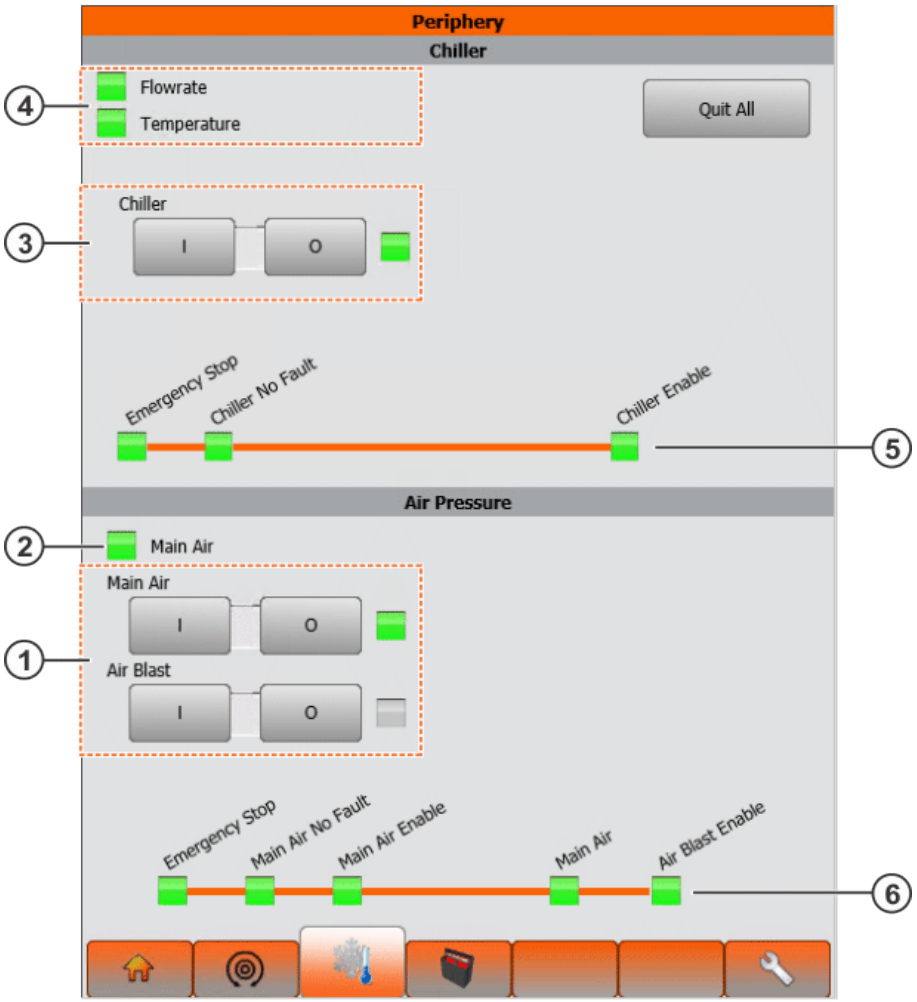


Fig. 7-7: Periphery view

Item	Description
1	Buttons for switching the main air and tool cleaning air on/off **I**: Switch on **O**: Switch off Status indication via LED **Green**: Switched on **Gray**: Switched off
2	Fault indication for main air (air pressure) **Green**: No fault **Red**: Fault
3	Button for switching the chiller on/off **I**: Switch on **O**: Switch off Status indication via LED **Green**: Switched on **Gray**: Switched off

Item	Description
4	Error indication for flow rate/temperature (chiller) **Green**: No error **Red**: Error
5	Chiller status indication • Emergency Stop **Red**: EMERGENCY STOP active **Green**: No EMERGENCY STOP active • Chiller No Fault **Green**: No fault **Red**: Fault • Chiller Enable **Green**: Chiller ready **Gray**: Chiller not ready
6	Main air status indication • Emergency Stop **Red**: EMERGENCY STOP active **Green**: No EMERGENCY STOP active • Main Air No Fault **Green**: No fault **Red**: Fault • Main Air Enable **Green**: Main air ready **Gray**: Main air not ready • Main Air **Green**: Main air on **Gray**: Main air off • Air Blast Enable **Green**: Tool cleaning air ready **Gray**: Tool cleaning air not ready

7.2.3 Tool changer view

Tool rack view (optional):

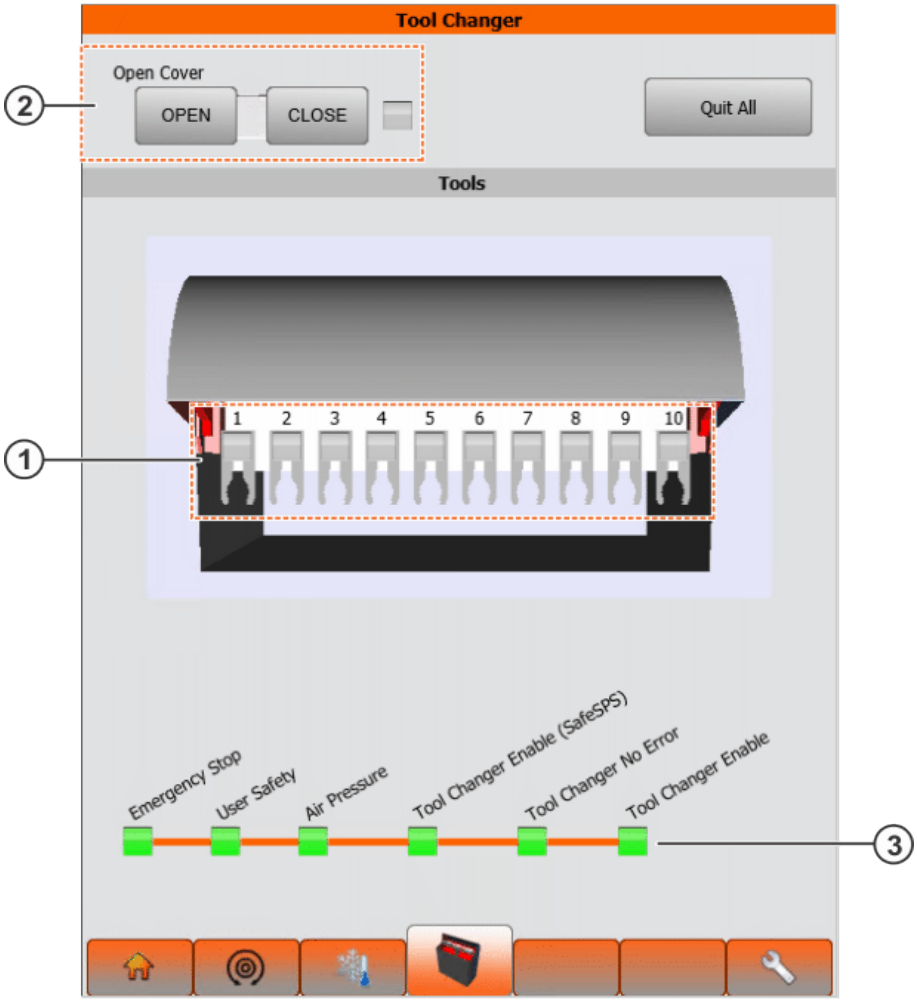


Fig. 7-8: Tool changer view

Item	Description
1	Buttons for opening and closing the tool cover **OPEN**: Open **CLOSE**: Close Status indication via LED **Green**: Open **Gray**: Closed
2	LED display for 10 tools **Green**: Tool rack free **Gray**: Tool rack occupied

Item	Description
3	Tool rack status indication (process sequence) • Emergency Stop **Red**: EMERGENCY STOP active **Green**: No EMERGENCY STOP active • User Safety **Red**: Operator safety active **Green**: No operator safety active • Air Pressure **Green**: Air pressure present **Gray**: Air pressure not present • Tool Changer Enable (SafeSPS) **Green**: Tool rack ready (safety PLC) **Gray**: Tool rack not ready (safety PLC) • Tool Changer No Error **Green**: No error **Red**: Error • Tool Changer Enable **Green**: Tool rack ready **Gray**: Tool rack not ready

7.2.4 Expert view

Fig. 7-9: Expert view

Button	Description
Lamp test	Tests the indicator lamps on the milling controller The following indicator lamps light up: • P1 Automatic ON • P3 Acknowledgement • P4 Gate request
KUKA Config	Displays the KUKA configuration Modification of the configuration is only possible after consultation with KUKA Service.

8 Start-up and recommissioning

8.1 Overview

This is an overview of the most important steps during start-up. The precise sequence 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	Install and connect the robot controller.	Detailed information is contained in the robot controller assembly instructions, in the chapter “Start-up and recommissioning”.
2	Install the milling controller.	(>>> *8.2 "Installing the technology cabinet" Page 86*)
3	Set up the tool rack (optional).	(>>> *8.3 "Installing the tool rack" Page 86*)
4	Perform a visual inspection of the electrically-driven spindle.	-
5	Connect the electrical system of the milling robot system.	(>>> *8.4 "Overview of electrical connections" Page 88*)
6	Connect the recooling system connections, check and fill cooling fluid.	(>>> *8.5 "Connecting and filling the recooling system" Page 89*)
7	Check connections for leaks.	
8	Connect compressed air to the tool rack (optional) and check it for leaks.	-
9	Connect compressed air to the milling controller, activate compressed air, set to 6 bar and check for leaks.	
10	Check filter combination for leaks.	
11	Check the equipment of the tool rack (optional).	-
12	Switch on the milling robot system.	(>>> *8.6 "Switching on the milling robot system" Page 89*)
13	Carry out a function test of the safety equipment.	-
14	Check and set the sensors of the tool rack (including the tool cover).	(>>> *8.7 "Setting the tool rack sensors" Page 90*)
15	Insert tool and ground it according to the type of material used for the workpiece.	(>>> *5.9 "Grounding the tool" Page 63*)
16	Calibrate tool and determine load data.	Detailed information can be found in the operating and programming instructions of the KUKA System Software for system integrators, in the chapter “Start-up and recommissioning”.
17	Check whether the tool cover of the tool rack (optional) is functioning.	(>>> *8.8 "Checking the tool cover of the tool rack" Page 91*)
18	Preheat the electrically-driven spindle.	(>>> *8.9 "Preheating the electrically-driven spindle" Page 91*)

Step	Description	Information
19	Calibrate the base of the tool rack (optional).	(>>> *8.10.1 "Tool rack: base calibration" Page 92*)
20	Teach the setdown/pickup points of the tools in the tool rack, including the approach points (optional).	(>>> *8.10 "Setting up the tool rack" Page 92*)
21	Carry out calibration and test programs required for the industrial robot.	Further information can be found in the assembly instructions of the robot.
22	Switch off the milling robot system.	(>>> *8.11 "Switching the milling robot system off" Page 100*)

8.2 Installing the technology cabinet

Procedure

1. Install the technology cabinet outside the physical safeguard. The minimum clearances to walls, other cabinets, etc. must be observed.
2. Electrical compartments must only be opened using suitable and approved tools or a key.
3. Check the technology cabinet for any damage caused during transportation.
4. Check that fuses, contactors and boards are fitted securely.
5. Secure any modules that have come loose.
6. Check that all screwed and clamped connections are securely fastened.
7. Plug in the connecting cables.

8.3 Installing the tool rack

Description

The tool rack is mounted on an appropriate concrete foundation using stud anchors. The quality of the concrete must conform to DIN 1045=B25.

Precondition

- The concrete foundation has the required dimensions and cross-section.
- The surface of the foundation is smooth and even.
- The power cable is deenergized.

Special tools

The following special tools are required:

- Drill with a Ø 12 mm bit

Procedure

1. Mark the hole pattern for the base plate of the tool rack in the foundation.

It is advisable to ascertain in advance the reachability of all setdown positions (tool grippers), e.g. by means of a reachability analysis.

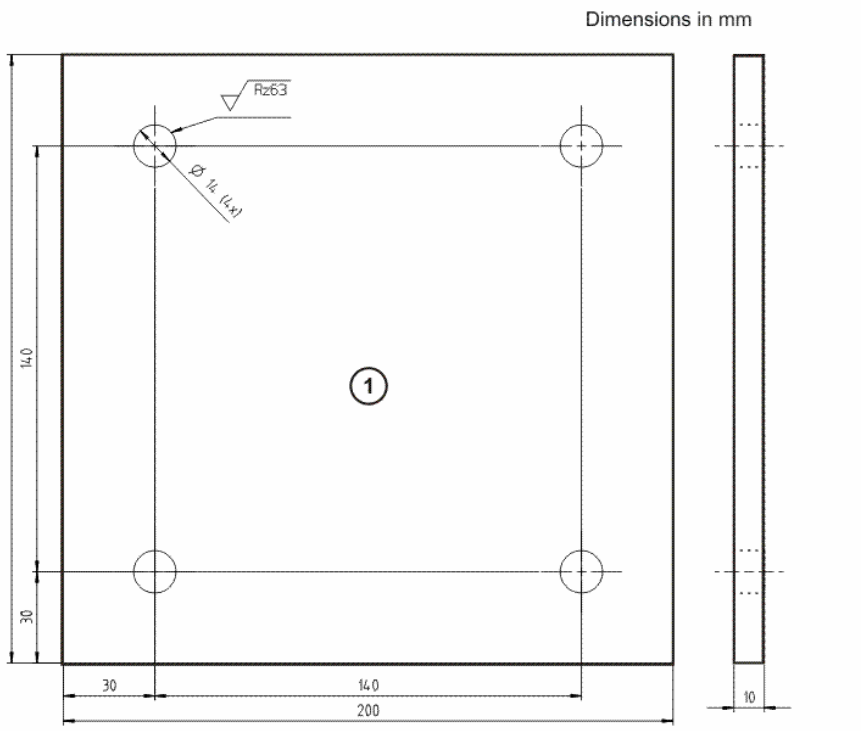


Fig. 8-1: Dimensions of boreholes for floor mounting

2. Drill 4 holes in the foundation for fastening the base plate.
3. Clean the holes.
4. Drive the stud anchors into the holes to the specified anchor depth.

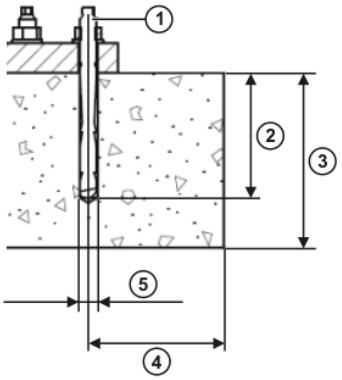


Fig. 8-2: Installing the stud anchors

1 M12x100/5/25 stud anchor (Hilti)
2 Anchor depth: 70 mm
3 Minimum concrete thickness: 150 mm
4 Minimum distance to the edge of the concrete: 90 mm
5 Diameter 12 mm

5. If the tool rack is still fastened to the transport pallet, prepare the tool rack for transportation with a fork lift truck or gantry crane. Secure the tool rack to prevent it from falling over.
6. Remove transport safeguard from the tool rack and tool cover (optional).

7. Lower the tool rack onto the set stud anchor rods using the fork lift truck or gantry crane.
8. Align the tool rack horizontally and fasten it with 4 lock washers and 4 M12 hexagon nuts (tightening torque: 50 Nm).
9. Fasten the frame of the tool cover (optional) onto the tool rack.
10. Connect the compressed air supply, the electrical power supply and the bus connection cable to the bus module.
11. Remove the anti-topple safeguard.
12. Retighten the hexagon nuts after 100 hours of operation.

8.4 Overview of electrical connections

The cables and hoses must be routed in such a way as to prevent the risk of tripping. The milling robot system is supplied with the following components pre-assembled:

- Manipulator with energy supply system and electrically-driven spindle
- Robot controller
- Milling controller with recooling system
- Connecting cables

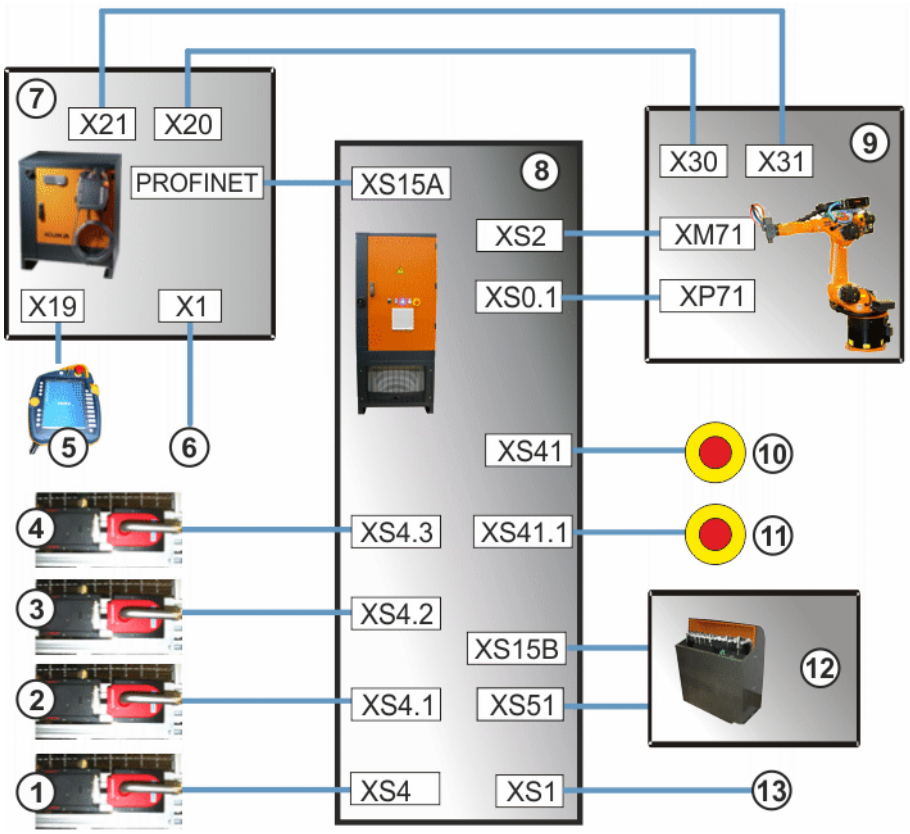


Fig. 8-3: Overview of electrical connections

1 Safety gate circuit 1
2 Safety gate circuit 2 (optional)
3 Safety gate circuit 3 (optional)
4 Safety gate circuit 4 (optional)
5 smartPAD
6 Robot controller power supply cable

7 Connection to KR C4 robot controller
8 Milling controller connection
9 Junction box and media panel on the manipulator
10 EMERGENCY STOP device 1 (optional)
11 EMERGENCY STOP device 2 (optional)
12 Connection to tool rack (optional)
13 Milling controller power supply cable

8.5 Connecting and filling the recooling system

Description

Information about the recooling system can be found in the installation, operating and maintenance instructions of the recooling system.

Procedure

1. Connect the recooling system connections.
2. Check and fill cooling fluid.

CAUTION

Risk of injury due to contact with cooling water
Glycol is added to the cooling water to prevent build-up of bacteria and viruses. Contact with cooling water or cooling water mist can cause injury.

- Wear personal protective equipment (hand protection, eye protection, etc.).
- In the case of unintentional contact with eyes, flush the eyes immediately with clean water.
- In the case of unintentional contact with skin, wash thoroughly with plenty of soap and water.

3. Repeat point 2 several times before the first start-up.
4. Check connections for leaks.

8.6 Switching on the milling robot system

Precondition

- The milling robot system has been installed in accordance with the assembly and operating instructions.
- All electrical connections are correct and the energy levels are within the specified limits.
- The doors of the robot controller and milling controller are closed.
- The peripheral devices are correctly connected.
- It must be ensured that no persons or objects are present within the danger zone of the manipulator.
- All safety devices and protective measures are complete and fully functional.
- The internal temperature of the robot controller and milling controller must have adapted to the ambient temperature.

CAUTION

Risk of injury due to splinters of material
If the tool collides with the workpiece in test mode, splinters of material can cause injuries.

- Wear personal protective equipment (e.g. safety goggles, protective clothing) during operation in test mode.

Procedure

1. Release the EMERGENCY STOP device on the smartPAD and milling controller.
2. Switch on the main switch of the milling controller.
3. Switch on the main switch of the robot controller.
4. Acknowledge messages on the milling controller.

When the milling robot system is put back into operation following a power failure, the EMERGENCY STOP and operator safety functions must be reset.

Further information is contained in the operating and programming instructions for the KUKA System Software (KSS).

8.7 Setting the tool rack sensors

Activity

Set the sensor for the tool rack positions.

Precondition

- Compressed air is shut off and system is vented.

Procedure

1. Insert the appropriate chuck vertically into the relevant tool rack from above.
   The corresponding sensor output must switch from TRUE to FALSE approx. 5 mm before reaching the end position (indicated by LEDs on the sensor).
   The sensor position can be adjusted by loosening the retaining screw with a 4 mm Allen key (gap approx. 2 mm).

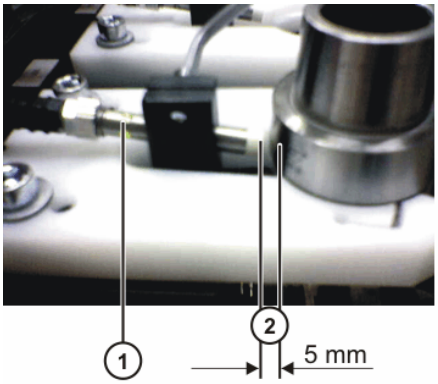


Fig. 8-4: Setting the sensors

1 Sensor LED display TRUE
2 Gap: 2 mm

Activity

Set the sensor for the “Tool cover open” position.

Procedure

1. Remove the rear part of the tool cover.
   Push the moving flap of the depressurized tool cover towards the “Tool cover open” limit stop.
   The corresponding sensor output must switch from FALSE to TRUE approx. 5 mm before reaching the end position (indicated by LEDs on the sensor).
   The sensor position can be adjusted by loosening both union nuts (gap: approx. 4 mm).

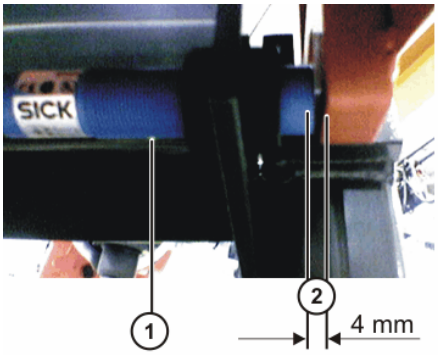


Fig. 8-5: “Tool cover open” sensor

1 Sensor LED display TRUE
2 Gap: 4 mm

8.8 Checking the tool cover of the tool rack

Precondition

- T1 mode is set on the smartPAD.
- Safety circuit is closed and operator safety activated.
  (>>> *7.1.2 "Deactivating and activating operator safety" Page 71*)
- Compressed air supply is connected to the tool rack.

Procedure

1. Display the HMI Milling user interface (“Tool changer” view).
2. Close the tool cover via the user interface.
   The tool cover must close without discernibly rubbing or jamming.
3. Open the tool cover via the user interface.
   The tool cover must open without discernibly rubbing or jamming.
   The end position (tool cover open) must be indicated by sensor signal B116 = FALSE.

8.9 Preheating the electrically-driven spindle

Procedure

- Call and start the “Electrically-driven spindle preheating cycle”.
  (>>> *5.10 "Preheating the electrically-driven spindle" Page 63*)

8.10 Setting up the tool rack

8.10.1 Tool rack: base calibration

Procedure

1. Calibrate the base in accordance with the operating and programming instructions for the KUKA System Software.
2. The figure (>>> *Fig. 8-6*) illustrates the base of the tool rack. The Y plane must be horizontal and not aligned with the edge of the tool rack.

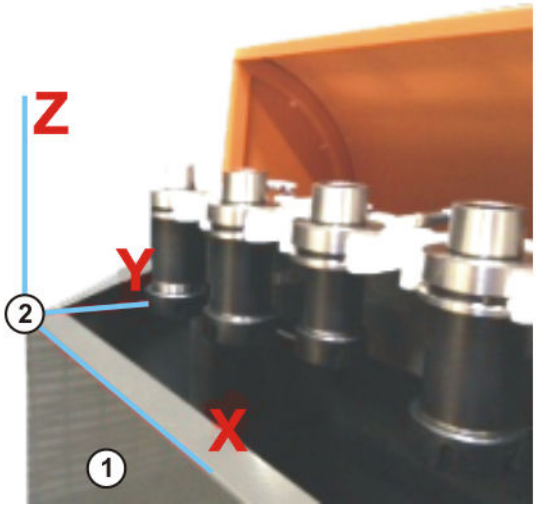


Fig. 8-6: Tool rack base

1 Tool rack 2 Base

8.10.2 Teaching positions for the tool change

Description

The positions for the tool change can be taught in the following program template:

Directory	C:\KRC\Roboter\KRC\R1\TP\MillTech
Program	MillTC_periphery.src

The following points are required:

- Points guiding the robot from the HOME position to the tool rack
- Each setdown position requires 4 points:
  - Position beneath the pre-position for setdown (A1)
  - Pre-position for setdown (B1)
  - Setdown position (SP)
  - Position for pickup above the setdown position (D1)

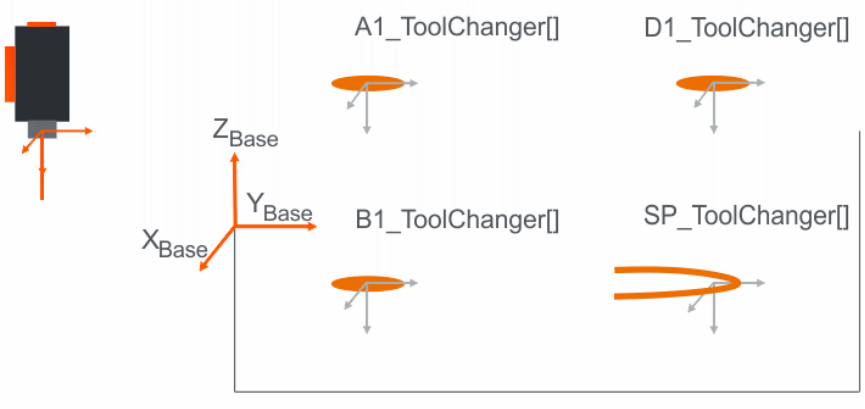


Fig. 8-7: Tool changer positions

These points can also be calculated and entered in the data list of the program template instead of teaching them.

(>>> *8.10.3 "Calculating positions for the tool change" Page 94*)

- Points guiding the robot from the tool rack back to the HOME position

Calculation program

The program MillTC_periphery.src contains the subprogram Calc_ToolChangerPos() for calculating the tool changer positions. For calculation, the following positions must be addressed and taught manually:

- First setdown position of the tool rack SP_ToolChanger[1]
- Last setdown position of the tool rack SP_ToolChanger[10]

Precondition

- User rights of the following function groups:
  - **Program selection and deselection**
  - **General KRL program changes**
  - If the calculation program is used:
    Block selection

  But at least the user group “**Expert**”.
- T1 or T2 mode
- Base of the tool rack has been calibrated.
- Tool has been calibrated.
- Tool is clamped in the spindle.
- The clamped tool matches the current tool MillTC_SpindleActTool (to be checked via the variable display).

Procedure

Teaching with the calculation program:

1. Select the program MillTC_periphery.src.
2. Uncommenting the following line (delete semicolon):

```
;Calc_ToolChangerPos()
```

3. Execute the program through to the HALT instruction.
4. Block selection to TC_Pos1.
5. Address and teach the first setdown position manually.
6. Block selection to TC_Pos10.

7. Address and teach the last setdown position manually.
8. Reset and execute the program MillTC_periphery.src. The required positions are calculated.
9. In the data list MillTC_periphery.dat of the program, check whether all required positions have been correctly calculated.
10. Comment out the following line again (insert semicolon):

```
Calc_ToolChangerPos()
```

11. Execute the positions with the test program.
(>>> *8.10.4 "Checking the tool change" Page 100*)

Procedure

Teaching without the calculation program:

1. Select and execute the program MillTC_periphery.src.
2. The program contains HALT instructions and is stopped at the positions at which points are to be taught.
3. Follow the programming instructions and address and teach all required positions manually.
4. Deselect program.
5. Open the program and delete all HALT instructions.
6. Close and save the program.
7. Execute the positions with the test program.
(>>> *8.10.4 "Checking the tool change" Page 100*)

8.10.3 Calculating positions for the tool change

Description

The positions for the tool change can be calculated and entered in the data list of the program template:

Directory	C:\KRC\Roboter\KRC\R1\TP\MillTech
File	MillTC_periphery.dat

This procedure replaces teaching the positions.
(>>> *8.10.2 "Teaching positions for the tool change" Page 92*)

In order to be able to calculate all positions, the following positions must be addressed manually once:

- First setdown position of the tool rack SP_ToolChanger[1]
- Last setdown position of the tool rack SP_ToolChanger[10]
- Any pre-position B1_ToolChanger[*x*]

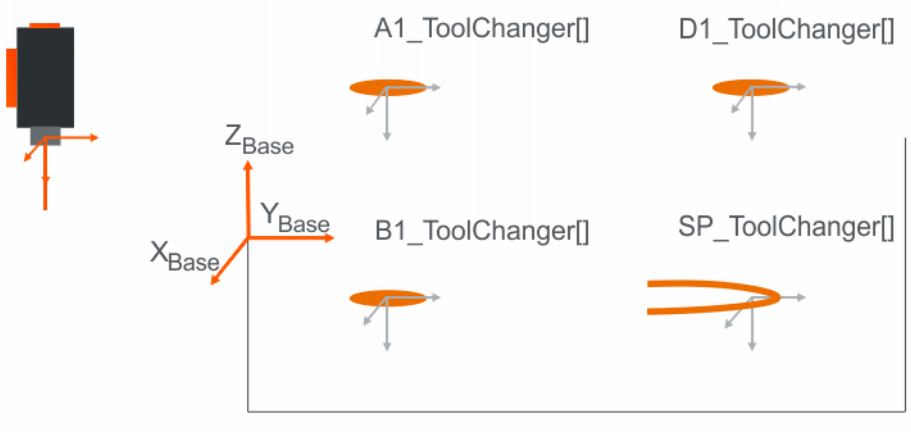


Fig. 8-8: Tool changer positions

Precondition

- T1 mode

Procedure

1. In the main menu, select **Display** > **Actual position** to display the actual position.
2. Address the first setdown position manually and note the X, Y and Z values of the position.
   X1: _____ Y1: _____ Z1: _____
3. Note the A, B and C values of the position, as well as the status and turn values.
   A: _____ B:_____ C: _____ Status: _____
   Turn: _____

   The orientation values (A, B and C), as well as status and turn, must be the same for all positions.

4. Address the last setdown position manually and note the X, Y and Z values of the position.
   X2: _____ Y2: _____ Z2: _____
5. Check: If the Y and Z values are not identical, the base is incorrectly calibrated.
6. Divide the difference between the two X values by the number of setdown positions minus 1. This gives the distance between the individual positions.
   (X2-X1) / (setdown positions-1) = _____
7. Address the pre-position B1 for the setdown manually.
   Note the Y value. The point can be selected freely, but should be located centrally between the plate of the tool rack and the setdown position.
   Y3: _____
8. Calculate the distance between the setdown position and the pre-position B1 for the setdown.
   Y2-Y3: _____ (guide value: approx. 7 cm)

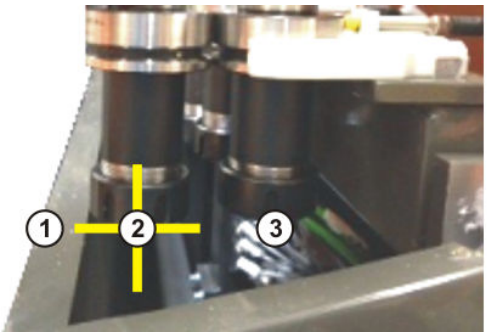


Fig. 8-9: Pre-position

1 Plate of tool rack
2 Pre-position B1
3 Setdown position

9. Calculate the remaining positions with the determined values.
   Each setdown position requires 4 points:
   - Position beneath the pre-position for setdown (A1)
     (>>> *8.10.3.2 "A1 values for 10 setdown positions" Page 97*)
   - Pre-position for setdown (B1)
     (>>> *8.10.3.1 "B1 values for 10 setdown positions" Page 97*)
   - Setdown position (SP)
     (>>> *8.10.3.3 "SP values for 10 setdown positions" Page 98*)
   - Position for pickup above the setdown position (D1)
     (>>> *8.10.3.4 "D1 values for 10 setdown positions" Page 99*)
10. Enter the calculated values in the data list.

```
DECL POS A1_ToolChanger[10] ;Position above and in front
of storage position
A1_ToolChanger[1]={X -22.93,Y -50.0,Z 63.0,A 88.98,B
0.45,C -179.930,S 22,T 50}
; ...
A1_ToolChanger[10]={X 743.93,Y -50.0,Z 63.0,A 88.98,B
0.45,C -179.930,S 22,T 50}

DECL POS B1_ToolChanger[10] ;Position in front of
storage position
B1_ToolChanger[1]={X -22.93,Y -50.0,Z 28.0,A 88.98,B
0.45,C -179.930,S 22,T 50}
; ...
B1_ToolChanger[10]={X 743.93,Y -50.0,Z 28.0,A 88.98,B
0.45,C -179.930,S 22,T 50}

DECL POS SP_ToolChanger[10] ;Storage Position
SP_ToolChanger[1]={X -22.93,Y 18.54,Z 28.0,A 88.98,B
0.45,C -179.930,S 22,T 50}
; ...
SP_ToolChanger[10]={X 743.93,Y 18.54,Z 28.0,A 88.98,B
0.45,C -179.930,S 22,T 50}

DECL POS D1_ToolChanger[10] ;Position above storage
position
D1_ToolChanger[1]={X -22.93,Y 18.54,Z 63.0,A 88.98,B
0.45,C -179.930,S 22,T 50}
; ...
```

```
D1_ToolChanger[10]={X 743.93,Y 18.54,Z 63.0,A 88.98,B
0.45,C -179.930,S 22,T 50}
```

11. Execute the positions with the test program.
    (>>> *8.10.4 "Checking the tool change" Page 100*)

8.10.3.1 B1 values for 10 setdown positions

The orientation values (A, B and C), as well as status and turn, must be the same for all positions.

Description

- Save the calculated SP values.
- Reduce Y values by the distance calculated.

(>>> *8.10.3 "Calculating positions for the tool change" Page 94*)

Calculation example

Item	B1_ToolChanger
[1]	{X X1_____, Y Y1-distance_____, Z Z1_____, A _____, B _____, C _____}
[2]	{X X1+1xdistance__, Y Y1-distance_____, Z Z1_____, A _____, B _____, C _____}
[3]	
[4]	{X X1+2xdistance__, Y Y1-distance_____, Z Z1_____, A _____, B _____, C _____}
	etc.

Calculated values

Item	B1_ToolChanger
[1]	{X _____, Y _____, Z _____, A _____, B _____, C _____}
[2]	{X _____, Y _____, Z _____, A _____, B _____, C _____}
[3]	{X _____, Y _____, Z _____, A _____, B _____, C _____}
[4]	{X _____, Y _____, Z _____, A _____, B _____, C _____}
[5]	{X _____, Y _____, Z _____, A _____, B _____, C _____}
[6]	{X _____, Y _____, Z _____, A _____, B _____, C _____}
[7]	{X _____, Y _____, Z _____, A _____, B _____, C _____}
[8]	{X _____, Y _____, Z _____, A _____, B _____, C _____}
[9]	{X _____, Y _____, Z _____, A _____, B _____, C _____}
[10]	{X _____, Y _____, Z _____, A _____, B _____, C _____}

8.10.3.2 A1 values for 10 setdown positions

The orientation values (A, B and C), as well as status and turn, must be the same for all positions.

Description

- Save the calculated B1 values.
- Increase Z values by the length of the longest tool plus a slight margin. Example: 50 mm

(>>> *8.10.3.1 "B1 values for 10 setdown positions" Page 97*)

Calculation example

Item	A1_ToolChanger
[1]	{X X1_____, Y Y1-distance_____, Z Z1+50_____, A ____, B ____, C ____}
[2]	{X X1+1xdistance____, Y Y1-distance_____, Z Z1+50_____, A ____, B ____, C ____}
[3]	
[4]	{X X1+2xdistance____, Y Y1-distance_____, Z Z1+50_____, A ____, B ____, C ____}
	etc.

Calculated values

Item	A1_ToolChanger
[1]	{X _____, Y _____, Z _____, A _____, B _____, C _____}
[2]	{X _____, Y _____, Z _____, A _____, B _____, C _____}
[3]	{X _____, Y _____, Z _____, A _____, B _____, C _____}
[4]	{X _____, Y _____, Z _____, A _____, B _____, C _____}
[5]	{X _____, Y _____, Z _____, A _____, B _____, C _____}
[6]	{X _____, Y _____, Z _____, A _____, B _____, C _____}
[7]	{X _____, Y _____, Z _____, A _____, B _____, C _____}
[8]	{X _____, Y _____, Z _____, A _____, B _____, C _____}
[9]	{X _____, Y _____, Z _____, A _____, B _____, C _____}
[10]	{X _____, Y _____, Z _____, A _____, B _____, C _____}

8.10.3.3 SP values for 10 setdown positions

The orientation values (A, B and C), as well as status and turn, must be the same for all positions.

Description

- Enter X1, Y1, Z1 under X, Y, Z of SP_ToolChanger[1].
- Transfer Y, Z from SP_ToolChanger[1] to SP_ToolChanger[2]-[x].
- The X value increases each time by the distance calculated.

(>>> *8.10.3 "Calculating positions for the tool change" Page 94*)

Calculation example

Item	SP_ToolChanger
[1]	{X X1_____, Y Y1 _____, Z Z1_____, A _____, B _____, C _____}
[2]	{X X1+1xdistance___, Y Y1 _____, Z Z1_____, A _____, B _____,_ C _____}
[3]	{X X1+2xdistance___, Y Y1 _____, Z Z1_____, A _____, B _____, _C _____}
[4]	etc.

Calculated values

Item	SP_ToolChanger
[1]	{X _____, Y _____, Z _____, A _____, B _____, C _____}
[2]	{X _____, Y _____, Z _____, A _____, B _____, C _____}
[3]	{X _____, Y _____, Z _____, A _____, B _____, C _____}
[4]	{X _____, Y _____, Z _____, A _____, B _____, C _____}
[5]	{X _____, Y _____, Z _____, A _____, B _____, C _____}
[6]	{X _____, Y _____, Z _____, A _____, B _____, C _____}
[7]	{X _____, Y _____, Z _____, A _____, B _____, C _____}
[8]	{X _____, Y _____, Z _____, A _____, B _____, C _____}
[9]	{X _____, Y _____, Z _____, A _____, B _____, C _____}
[10]	{X _____, Y _____, Z _____, A _____, B _____, C _____}

8.10.3.4 D1 values for 10 setdown positions

The orientation values (A, B and C), as well as status and turn, must be the same for all positions.

Description

- Save the calculated SP values.
- Increase Z values by the length of the longest tool plus a slight margin. Example: 50 mm

(>>> *8.10.3.3 "SP values for 10 setdown positions" Page 98*)

Calculation example

Item	D1_ToolChanger
[1]	{X X1_____, Y Y1_____, Z Z1+50_____, A ____, B ____, C ____}
[2]	{X X1+1xdistance___, Y Y1_____, Z Z1+50_____, A ____, B ____, C ____}
[3]	{X X1+2xdistance___, Y Y1_____, Z Z1+50_____, A ____, B ____, C ____}
[4]	etc.

Calculated values

Item	D1_ToolChanger
[1]	{X _____, Y _____, Z _____, A _____, B _____, C _____}
[2]	{X _____, Y _____, Z _____, A _____, B _____, C _____}
[3]	{X _____, Y _____, Z _____, A _____, B _____, C _____}
[4]	{X _____, Y _____, Z _____, A _____, B _____, C _____}
[5]	{X _____, Y _____, Z _____, A _____, B _____, C _____}
[6]	{X _____, Y _____, Z _____, A _____, B _____, C _____}
[7]	{X _____, Y _____, Z _____, A _____, B _____, C _____}
[8]	{X _____, Y _____, Z _____, A _____, B _____, C _____}
[9]	{X _____, Y _____, Z _____, A _____, B _____, C _____}
[10]	{X _____, Y _____, Z _____, A _____, B _____, C _____}

8.10.4 Checking the tool change

Description

The programmed tool change must be checked before start-up to ensure that it is collision-free.

For this, a test program must be created using the supplied inline forms in which the tool change is selected once at each setdown position.

(>>> *10.1 "Overview of the inline forms" Page 105*)

In order for the inline form for the tool change to work, the following inline forms must first be integrated into the program:

- (>>> *10.1.1 "Main air on/off" Page 105*)
- (>>> *10.1.3 "Switch chiller on/off" Page 106*)
- (>>> *10.1.4.1 "Spindle enable" Page 107*)

8.11 Switching the milling robot system off

Procedure

1. Perform safe retraction of the robot in operating mode T1.
2. Remove tool from the electrically-driven spindle.
3. Turn the main switch on the robot controller to OFF.
4. Turn the main switch on the milling controller to OFF.
5. Deactivate the compressed air.
6. Switch the mode selector switch to External and remove the key.

NOTICE

If the milling robot system is switched on by unauthorized persons, damage to property may occur. To prevent the milling robot system from being switched on by unauthorized persons, the mode selector switch must be switched to External and the key must be removed.

9 Installation

The software is already pre-installed on delivery. If reinstallation should be required, however, the necessary procedure is described in the following sections.

9.1 System requirements for KUKA.MillTech 1.0

Hardware

- KR C4 robot controller

Software

Robot controller:

- KUKA System Software 8.6
  - KUKA.UserTech 4.0
  - KUKA.ProfiNet MS 5.0
  - KUKA.HMI zenon7.60 Plugin 512 RT 4.1

Laptop/PC:

- WorkVisual 6.0

9.2 System requirements for KUKA.MillTech CNC 1.0

Hardware

- KR C4 robot controller

Software

Robot controller:

- KUKA System Software 8.6
  - KUKA.UserTech 4.0
  - KUKA.ProfiNet MS 5.0
  - KUKA.CNC 3.0
  - KUKA.ProConOS 4-1 5.0
  - KUKA.HMI zenon7.60 Plugin 512 RT 4.1

Laptop/PC:

- WorkVisual 6.0

9.3 Installing or updating an option package

Description

The option package is installed in WorkVisual and added to the project. During project deployment, the option package is automatically installed on the robot controller.

It is advisable to archive all relevant data before updating a software package.

Precondition

- User group “Expert”

- T1 or T2 mode
- No program is selected.
- Network connection to the robot controller
- The option package is available as a KOP file.

Procedure

1. Install the option package in WorkVisual.
2. Load the active project from the robot controller.
3. Insert the option package into the project.
4. Deploy the project from WorkVisual to the robot controller and activate it.
5. The request for confirmation *Do you want to activate the project […]?* is displayed on the smartHMI. The active project is overwritten during activation. If no relevant project will be overwritten: Answer the query with **Yes**.
6. An overview with the changes and a request for confirmation are displayed on the smartHMI. Answer this with **Yes**. The option package is installed and the robot controller carries out a reboot.

Information about procedures in WorkVisual is contained in the WorkVisual documentation.

LOG file

A LOG file is created under C:\KRC\ROBOTER\LOG.

9.4 Uninstalling the option package

Description

The option package can be uninstalled via WorkVisual.

It is advisable to archive all relevant data before uninstalling a software package.

Precondition

- User group “Expert”
- T1 or T2 mode
- No program is selected.
- Network connection to the robot controller

Procedure

1. Load the project from the robot controller.
2. Remove the option package from the project. A window with modifications is displayed.
3. Deploy the project from WorkVisual to the robot controller and activate it.
4. Answer the request for confirmation *Do you want to activate the project […]?* on the smartHMI with **Yes**.
5. An overview with the changes and a request for confirmation are displayed on the smartHMI. Answer this with **Yes**. The option package is uninstalled and the robot controller carries out a reboot.

Information about procedures in WorkVisual is contained in the WorkVisual documentation.

LOG file

A LOG file is created under C:\KRC\ROBOTER\LOG.

10 Programming

10.1 Overview of the inline forms

Inline form	Description
MillTech > Main air	Switch main air on/off (>>> *10.1.1 "Main air on/off" Page 105*)
MillTech > Tool cleaning air	Switch tool cleaning air on/off (>>> *10.1.2 "Blow air on/off" Page 106*)
MillTech > Spindle cooling	Switch chiller on/off (>>> *10.1.3 "Switch chiller on/off" Page 106*)
MillTech > Spindle functions	Spindle functions for spindle operation (>>> *10.1.4 "Spindle functions for spindle operation" Page 107*)
MillTech > Spindle clamp	Release/clamp spindle (>>> *10.1.5 "Release/clamp spindle" Page 112*)
MillTech > Tool changer	Tool changer functions (>>> *10.1.6 "Tool changer" Page 112*)

10.1.1 Main air on/off

Description

The instruction can be used to switch the main air on and off. The main air must be switched on before the spindle is enabled.

Precondition

- User rights: Function group **General KRL program changes**
- Program is selected or open.

Procedure

1. Select the menu sequence **Commands** > **MillTech** > **Main air** and **ON** or **OFF**.
2. Press **Cmd OK** to save the instruction.

Inline form

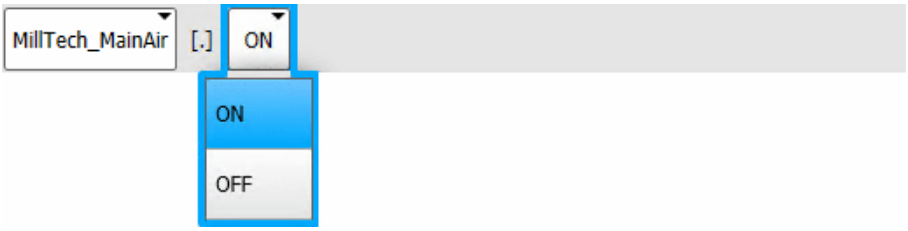


Fig. 10-1: Inline form “MillTech_MainAir”

10.1.2 Blow air on/off

Description

The instruction can be used to switch the tool cleaning air on and off. The tool cleaning air must be switched on before the spindle is enabled.

Precondition

- User rights: Function group **General KRL program changes**
- Program is selected or open.

Procedure

1. Select the menu sequence **Commands** > **MillTech** > **Tool cleaning air** and **ON** or **OFF**.
2. Press **Cmd OK** to save the instruction.

Inline form

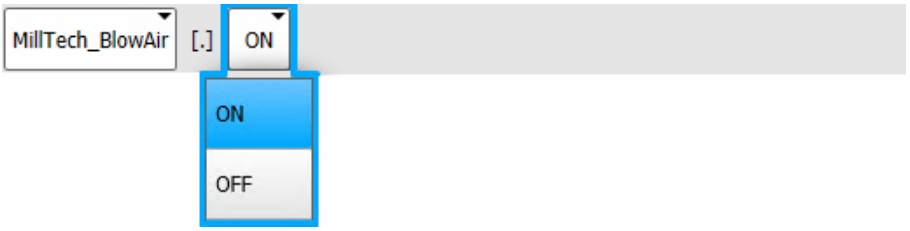


Fig. 10-2: Inline form “MillTech_BlowAir”

10.1.3 Switch chiller on/off

Description

The instruction can be used to switch the chiller on and off. The chiller must be switched on before the spindle is enabled. The chiller is permanently supplied with power, i.e. when switched off the chiller is in standby mode.

Precondition

- User rights: Function group **General KRL program changes**
- Program is selected or open.

Procedure

1. Select the menu sequence **Commands** > **MillTech** > **Spindle cooling** and **ON** or **OFF**.
2. Press **Cmd OK** to save the instruction.

Inline form

Fig. 10-3: Inline form “MillTech_Chiller”

10.1.4 Spindle functions for spindle operation

Description

MillTech can be used to program the following spindle functions for spindle operation:

10.1.4.1 Spindle enable

Description

The instruction can be used to enable control of the spindle via the KRL program. A check is automatically made to see whether the spindle is ready. The instruction must be programmed before the spindle is switched on.

Precondition

- User rights: Function group **General KRL program changes**
- Program is selected or open.

Procedure

1. Select the menu sequence **Commands** > **MillTech** > **Spindle functions** > **Spindle enable**.
2. Set the parameters as required in the inline form.
3. Press **Cmd OK** to save the instruction.

Inline form

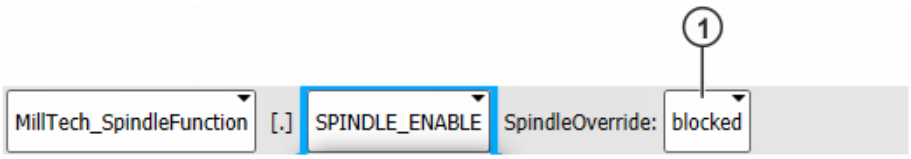


Fig. 10-4: Inline form "MillTech_SpindleFunction.SPINDLE_ENABLE"

Item	Description
1	Spindle override • **blocked** The spindle override cannot be influenced via the HMI Milling user interface. • **allowed** The spindle override can be influenced via the HMI Milling user interface.

10.1.4.2 Spindle disable

Description

The instruction can be used to disable control of the spindle via the KRL program.

Use:

- No spindle operation required for a prolonged period.
- Spindle is to be controlled using the HMI Milling user interface or KUKA.CNC.

Precondition

- User rights: Function group **General KRL program changes**
- Program is selected or open.

Procedure

1. Select the menu sequence **Commands** > **MillTech** > **Spindle functions** > **Spindle disable**.
2. Press **Cmd OK** to save the instruction.

Inline form

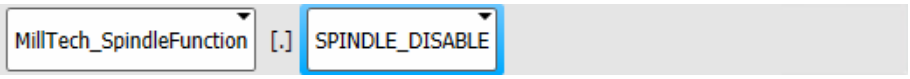


Fig. 10-5: Inline form “MillTech_SpindleFunction.SPINDLE_DISABLE”

10.1.4.3 Start/stop spindle

Description

The instruction can be used to start and stop the spindle. The instruction can be executed in parallel with the robot motion following the instruction or independently of the following motion.

For execution of the instruction in parallel with the robot motion, the following triggers are available in the inline form:

- TRIGGER WHEN PATH

  The trigger refers to the end point of the motion or, if the end point is approximated, to the end of the approximate positioning arc.
- TRIGGER WHEN DISTANCE

  The trigger refers to the start point of the motion or, if the end point is approximated, to the end of the approximate positioning arc.

TRIGGER WHEN PATH cannot be used for PTP motions.

Further information about trigger programming and the reference points for approximate positioning can be found in the operating and programming instructions of the KUKA System Software for system integrators.

Precondition

- User rights: Function group **General KRL program changes**
- Program is selected or open.

Procedure

1. Select the menu sequence **Commands** > **MillTech** > **Spindle functions** and **ON** or **OFF**.
2. Set the parameters as required in the inline form.
3. Press **Cmd OK** to save the instruction.

Inline form

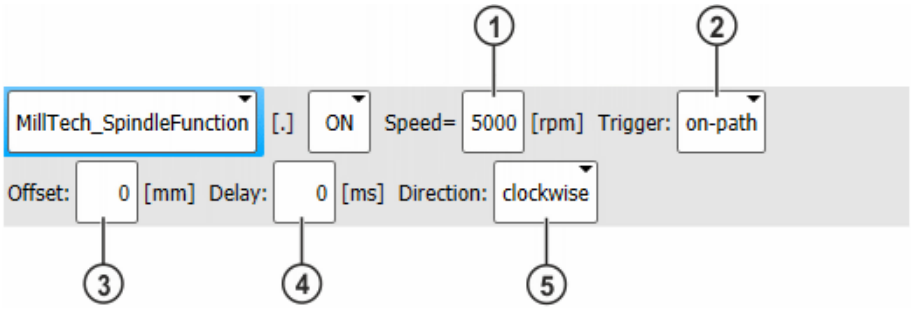


Fig. 10-6: Inline form “MillTech_SpindleFunction.ON”

Item	Description
1	Spindle speed in rpm
2	Trigger for spindle start • **on-path** Spindle start with TRIGGER WHEN PATH • **on-distance** Spindle start with TRIGGER WHEN DISTANCE Without monitoring of “actual speed = setpoint speed” • **none** Spindle start at current position with settable **Delay** With monitoring of “actual speed = setpoint speed” • **cont** Immediate spindle start
3	Spatial offset of trigger point in mm Only relevant for TRIGGER WHEN PATH: • **on-path**: Offsets the trigger point *x* mm relative to the end point – <0: towards start of motion – >0: towards end of motion
4	Delay of trigger point in ms Relevant for the following triggers: • **on-path**: Delays the trigger point *x* ms relative to the **offset** end point. • **on-distance**: Shifts the trigger point by *x* ms towards the end of the motion. A negative delay before the start point of the motion is not possible. • **none**: Time in ms that the system waits before (>=0) or after (<0) the spindle is started.
5	Direction of spindle rotation • **clockwise** Clockwise • **counterclockwise** Counterclockwise

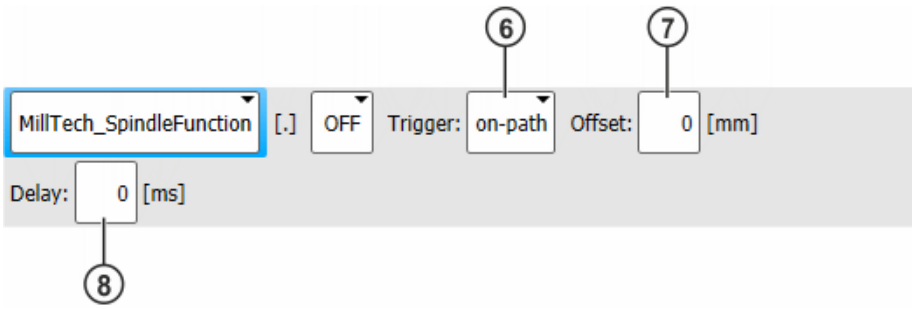


Fig. 10-7: Inline form “MillTech_SpindleFunction.OFF”

Item	Description
6	Trigger for spindle stop • **on-path** Spindle stop with TRIGGER WHEN PATH • **on-distance** Spindle stop with TRIGGER WHEN DISTANCE Without monitoring of “actual speed = setpoint speed” • **none** Spindle stop at current position with settable **Delay** With monitoring of “actual speed = setpoint speed” • **cont** Immediate spindle stop
7	Spatial offset of trigger point in mm Only relevant for TRIGGER WHEN PATH: • **on-path**: Offsets the trigger point *x* mm relative to the end point – <0: towards start of motion – >0: towards end of motion
8	Delay of trigger point in ms Relevant for the following triggers: • **on-path**: Delays the trigger point *x* ms relative to the **offset** end point. • **on-distance**: Shifts the trigger point by *x* ms towards the end of the motion. A negative delay before the start point of the motion is not possible. • **none**: Time in ms that the system waits before (>=0) or after (<0) the spindle is stopped.

10.1.4.4 Checking spindle readiness

Description

The instruction can be used to check whether the spindle is ready.

Use:

- When the spindle is enabled, the system automatically checks whether the spindle is ready.
  (>>> *10.1.4.1 "Spindle enable" Page 107*)

- The instruction can be used after spindle enabling, e.g. after a tool change or before the next machining step.

Precondition

- User rights: Function group **General KRL program changes**
- Program is selected or open.

Procedure

1. Select the menu sequence **Commands** > **MillTech** > **Check spindle ready**.
2. Press **Cmd OK** to save the instruction.

Inline form

Fig. 10-8: Inline form “MillTech_SpindleFunction.CHECK_READY”

10.1.4.5 Program example for spindle operation

```
 1 INI
 2
 3 Set System Ready
 4 PTP HOME Vel= 100% DEFAULT
 5
 6 MillTech_Chiller.ON
 7 MillTech_MainAir.ON
 8 MillTech_BlowAir.ON
 9 MillTech_SpindleFunction.SPINDLE_ENABLE SpindleOverride:
   allowed
10 MillTech_SpindleFunction.ON Speed= 200 rpm, Trigger:
   none, Offset: 0 mm, Delay: 0 ms, Direction: clockwise
11 WAIT_SEC 4
12 $VEL.CP = 0.005
13 LIN_REL {Z 10}#TOOL
14 MillTech_SpindleFunction.OFF Trigger: none, Offset: 0mm,
   Delay: 0 ms
15 WAIT_SEC 4
16 MillTech_SpindleFunction.ON Speed= 200 rpm, Trigger:
   none, Offset: 0 mm, Delay: 0 ms,Direction:
   counterclockwise
17 WAIT_SEC 4
18 $VEL.CP = 0.005
19 LIN_REL {Z -10}#TOOL
20 MillTech_SpindleFunction.OFF Trigger none,Offset: 0 mm,
   Delay: 0 ms
21 HALT
22 PTP HOME Vel=100 % DEFAULT
23 ;gcodeexecute("test_kuka.nc")
24
25 PTP HOME Vel=100 % DEFAULT
26
27 MillTech_Chiller.OFF
28 MillTech_BlowAir.OFF
29 MillTech_MainAir.OFF
30 END
```

10.1.5 Release/clamp spindle

Description

The instruction can be used to program the following spindle functions:

- **Release**
  Advance the spindle piston and release the spindle.
- **Clamp**
  Retract the spindle piston and clamp the spindle. No monitoring of whether the tool is present.
- **Clamp with tool**
  Retract the spindle piston and clamp the spindle. With monitoring of whether the tool is present and clamped.

Precondition

- User rights: Function group **General KRL program changes**
- Program is selected or open.

Procedure

1. Select the menu sequence **Commands** > **MillTech** > **Spindle clamp** and select the desired function.
2. Press **Cmd OK** to save the instruction.

Inline form

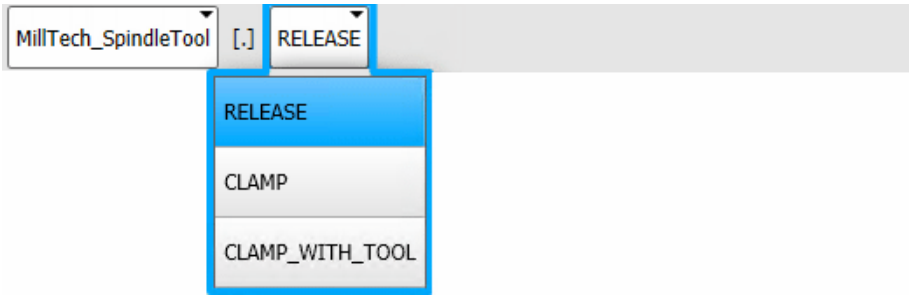


Fig. 10-9: Inline form “MillTech_SpindleTool”

10.1.6 Tool changer

Description

MillTech can be used to program the following tool changer functions:

10.1.6.1 Opening/closing the tool cover

Description

The instruction can be used to open and close the tool cover.

Precondition

- User rights: Function group **General KRL program changes**
- Program is selected or open.

Procedure

1. Select the menu sequence **Commands** > **MillTech** > **Tool changer** and **Open cover** or **Close cover**.
2. Set the parameters as required in the inline form.
3. Press **Cmd OK** to save the instruction.

Inline form

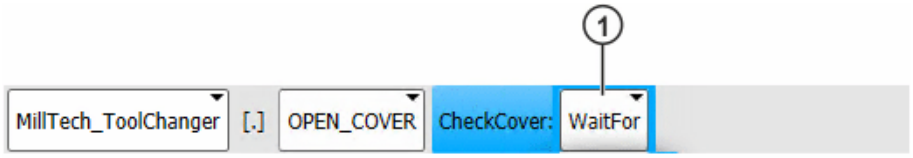


Fig. 10-10: Inline form “MillTech_ToolChanger.OPEN_COVER”

Item	Description
1	Tool cover check on opening • **WaitFor** The system waits until the tool cover is open. Program execution is then resumed. • **DontWaitFor** The system does not wait until the tool cover is open. The program is continued immediately.

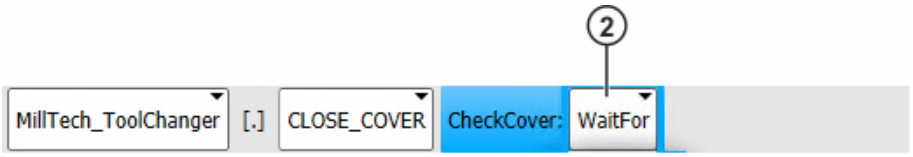


Fig. 10-11: Inline form “MillTech_ToolChanger.CLOSE_COVER”

Item	Description
2	Check of the tool cover on closing • **WaitFor** The system waits until the tool cover is closed. Program execution is then resumed. • **DontWaitFor** The system does not wait until the tool cover is closed. The program is continued immediately.

10.1.6.2 Change tool

Description

This instruction can be used to change the tool.

Precondition

- User rights: Function group **General KRL program changes**
- Program is selected or open.

Procedure

1. Select the menu sequence **Commands** > **MillTech** > **Tool changer** > **Change tool**.
2. Set the parameters as required in the inline form.
3. Press **Cmd OK** to save the instruction.

Inline form

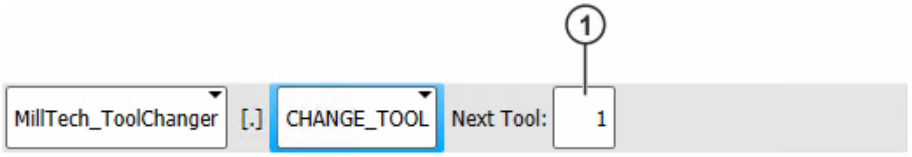


Fig. 10-12: Inline form “MillTech_ToolChanger.CHANGE_TOOL”

Item	Description
1	Number of the position in the tool rack where the next required tool is located

10.2 Kinematic coupling of external axes (optional)

Description

In the case of kinematic coupling, the robot calculates its motion path in relation to the position of the kinematic system. If the kinematic system moves, the robot follows it with the TCP so that the position of the TCP remains constant relative to the moving base of the kinematic system.

The mathematical coupling can be activated for BASE kinematic systems. In the case of BASE kinematic systems, a kinematic coupling is active in the TOOL or BASE coordinate system.

The most recently active base in KRL is applied in the CNC environment when the EMI interface is activated (in cncmotion.src).

After a tool change has been carried out, the previously active base is set again as standard, but in static mode. To prevent this, the kinematic coupling must be activated.

The kinematic coupling can be activated using the following command:

Example:

```
$BASE=EK(MACHINE_DEF[2].ROOT,MACHINE_DEF[2].MECH_TYPE,BASE_DA
TA[20])
```

In this example, the second external kinematic system is selected. The number of the dynamic base to be used must be inserted in BASE_DATA. In the example, it is the dynamic base with the number 20.

Example

```
DEF cncDoToolChange(cncNewTool : IN)

INT cncNewTool
INT cncLastBase
DECL E6AXIS cncLastAxPos

; save the last cnc position into a temorary variable
cncLastAxPos = $AXIS_ACT
; save the last base number
```

```
cncLastBase = $ACT_BASE
$BASE = $NULLFRAME
 IF (gnSpindleactTool <> cncNewTool) THEN
  ; unload the old tool first
  SWITCH cncnewTool
   CASE 0
    MillTech_MainAir.ON
    MillTech_ToolChanger.OPEN_COVER CheckCover: WaitFor
    MillTech_ToolChanger.CHANGE_TOOL Next Tool: 0
    MillTech_ToolChanger.CLOSE_COVER CheckCover: WaitFor
   CASE 1

    MillTech_MainAir.ON
    MillTech_ToolChanger.OPEN_COVER CheckCover: WaitFor
    MillTech_ToolChanger.CHANGE_TOOL Next Tool: 1
    MillTech_ToolChanger.CLOSE_COVER CheckCover: WaitFor
  ; ...
   CASE 10

    MillTech_MainAir.ON
    MillTech_ToolChanger.OPEN_COVER CheckCover: WaitFor
    MillTech_ToolChanger.CHANGE_TOOL Next Tool: 10
    MillTech_ToolChanger.CLOSE_COVER CheckCover: WaitFor

   DEFAULT
    LOOP
     HALT
    ENDLOOP

  ENDSWITCH
 ENDIF
 ; Here, the point at which the CNC was left must be
addressed.

 $BASE =
EK(MACHINE_DEF[2].ROOT,MACHINE_DEF[2].MECH_TYPE,BASE_DATA[17]
)
 bas(#tool,cncreferencetool)
 $ACT_TOOL = cncreferencetool
 ; move to the last cnc position
 PTP cncLastAxPos
END
```

11 Maintenance

11.1 Maintenance symbols

Maintenance symbols

The overview may contain maintenance symbols that are not relevant for the maintenance work on this product. The maintenance illustrations provide an overview of the relevant maintenance work.

Oil change

Lubricate with grease gun

Lubricate with brush

Lubricate with spray grease

Tighten screw/nut

Check component, visual inspection

Clean component

Exchange battery

Exchange component

Check toothed belt tension

11.2 Robot system maintenance

Description

Maintenance work must be performed at the specified maintenance intervals after commissioning at the customer's plant.

Precondition

- Robot has been moved into its home position.
- The robot controller and technology cabinet are switched off and secured to prevent unauthorized persons from switching them on again.
- In the case of work on the technology cabinet: discharging time of capacitors has elapsed.

Further information about the capacitors can be found in the operating instructions of the frequency converter.

- The power cables are deenergized.

WARNING

Risk of fatal injury from mains voltage
Cables routed from power supply connection X1 (robot controller) and XS1 (technology cabinet) to the main switch are energized even when the main switch is switched off. Death, severe injuries or damage to property may result.

– Before starting work, deenergize the incoming power cable.
– Before starting work, ensure that the system is deenergized.

- Tool and workpiece have been removed.
- Main air is shut off and the connecting line to the main air is disconnected (compressed air system is vented).
- Pneumatic connections to customer equipment are disconnected and the system depressurized.
- Observe the ESD guidelines.

The diagram (>>> *Fig. 11-1*) shows the maintenance points for the 8 kW milling robot system as an example.

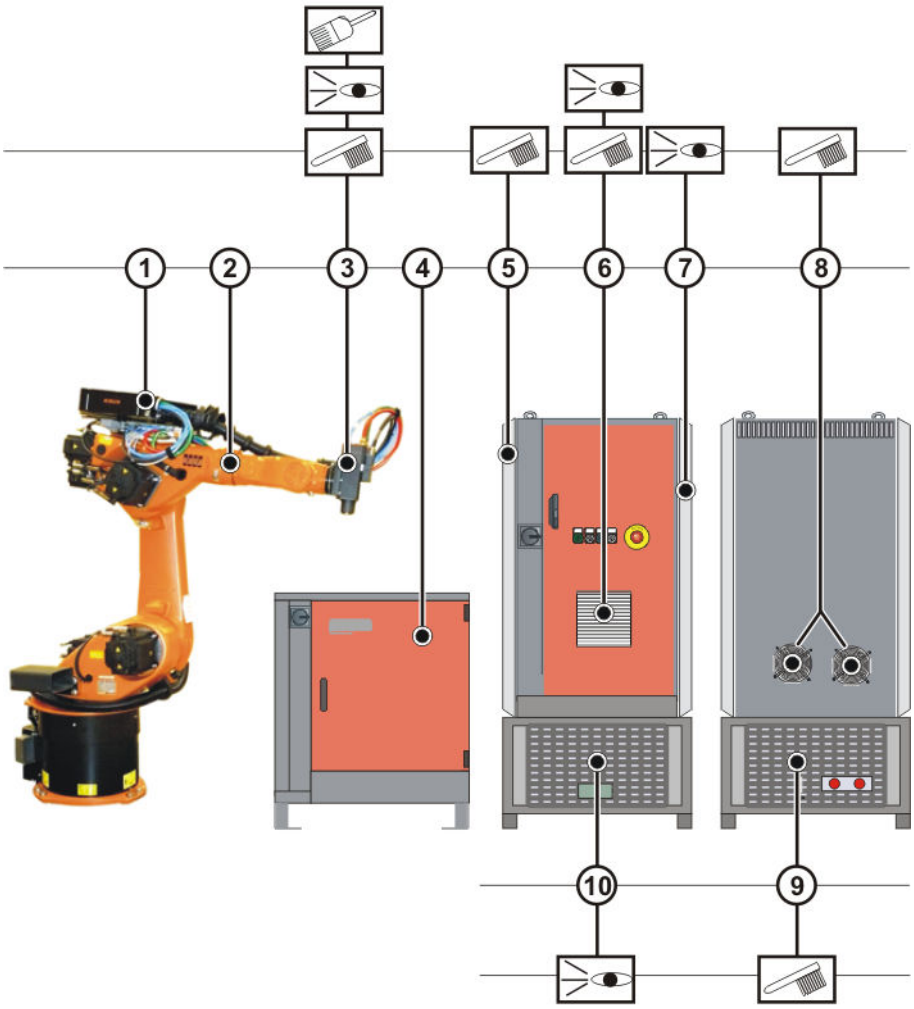


Fig. 11-1: Maintenance points

Interval	Item	Activity
Daily, before putting the system into operation	1	Check the energy supply system. Detailed information about maintenance can be found in the energy supply system documentation.
Daily, before putting the system into operation	2	Manipulator Detailed information about maintenance can be found in the manipulator documentation.
Daily, before putting the system into operation	3	Electrically-driven spindle Visual inspection: The contact surfaces between the tool holder and its location must be kept clean in order to ensure safe coupling. Clean if necessary. Detailed information can be found in the assembly instructions of the electrically-driven spindle.
Daily, before putting the system into operation	4	Robot controller Detailed information about maintenance can be found in the robot controller documentation.
Daily, before putting the system into operation	-	Check all hoses for leaks and damage. Also check whether the hoses are kinked or pinched.
Daily, before putting the system into operation	-	Visually inspect all electrical cabling and connections for damage. Also check whether the cables are kinked or pinched.
Daily, before putting the system into operation	-	Check that all covers are in place.
Daily, before putting the system into operation	-	Check the internal pressurization: Check whether the air that is blown in exits through the openings of the front labyrinth seal by the spindle nose.
Weekly	3	Check that the electrically-driven spindle is fitted securely.
Weekly	10	Check the coolant level on the recooling system. Detailed information is contained in the assembly, installation and operating instructions of the recooling system.
2 weeks	3	Clean the contact surfaces of the tool holder with a soft, clean cloth soaked in ethanol. Detailed information can be found in the assembly instructions of the electrically-driven spindle.

Interval	Item	Activity
Monthly	3	Lubricate HSK gripper on the electrically-driven spindle. Detailed information can be found in the assembly instructions of the electrically-driven spindle.
Monthly	10	Recooling system • Check the coolant in the recooling system for dirt and solid particles, e.g. swarf, etc. • Check the recooling system for leaks by means of a visual inspection. Detailed information is contained in the assembly, installation and operating instructions of the recooling system.
2 months	9	Clean the fins of the condenser on the recooling system with compressed air or a brush.
Annually	10	Change the coolant on the recooling system.
Annually	-	Measure the loop impedance/system impedance (≤ 200 mΩ) in accordance with EN 60204.
2 years	8	Depending on installation conditions and degree of fouling, clean the external fans with a brush.
If filter mat becomes discolored	6	Check the filter mat of the door fan and, depending on the degree of clogging, clean or exchange.
Filter cartridges, depending on the degree of fouling	7	Exchange filter cartridges, depending on the degree of fouling. (>>> *11.4 "Exchanging the filter cartridges of the compressed air filter combination" Page 122*)

Information about maintenance work on all the components in this system is contained in the manufacturer documentation.

11.3 Tool rack maintenance

Description

Maintenance work must be performed at the specified maintenance intervals after commissioning at the customer's plant.

Precondition

- Robot has been moved into its home position.
- The robot controller and technology cabinet are switched off and secured to prevent unauthorized persons from switching them on again.
- The power cable is deenergized.
- Tool and workpiece have been removed.
- Compressed air is shut off and system is vented.
- Pneumatic connections to customer equipment are disconnected and the system depressurized.
- Observe the ESD guidelines.

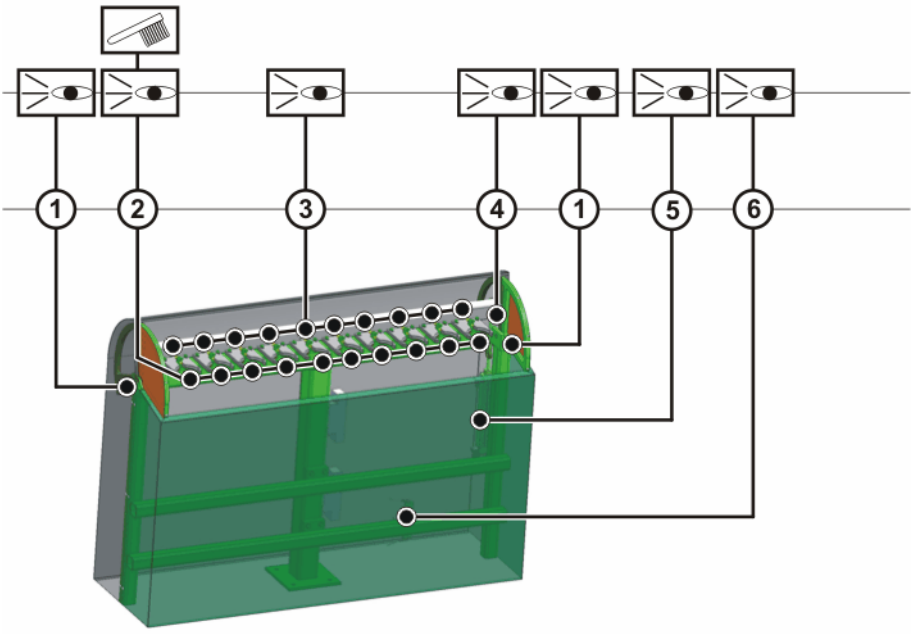


Fig. 11-2: Maintenance points on the tool rack

Interval	Item	Activity
Daily, before putting the system into operation	1	Check the hinges of the tool cover for wear, failure, damage and function.
	2	Visual inspection of the grippers for wear, failure and damage
		Clean the grippers.
	3	Function test of the “Gripper” sensors.
	4	Function test of the “Tool cover open” sensor.
	5	Function test of the valve of the tool cover
	6	Function test of the pneumatic cylinder of the tool cover
	-	Visually inspect all electrical cabling and connections for damage. Also check whether the cables are kinked or pinched.
	-	Check the mounting of the tool rack.
	-	Depending on installation conditions and degree of fouling, clean the sensors.
Annually	-	Check that the tool rack is securely fastened to the foundation and that it is stable. Tightening torque of the hexagon nuts: 50 Nm

Tools

The functioning and wear of the tools used must be checked at regular intervals. The test cycles for the tools are specified in the documentation from the tool manufacturers.

11.4 Exchanging the filter cartridges of the compressed air filter combination

Description

Exchange filter cartridges at regular intervals in accordance with the degree of contamination of the compressed air.

Precondition

- Robot has been moved into its home position.
- The milling controller is switched off and secured to prevent unauthorized persons from switching it on again.
- The power cable is deenergized.
- Compressed air is shut off and vented.
- Pneumatic connections to customer equipment are disconnected and the system is depressurized.

Procedure

1. Open the side door of the milling controller.
2. Exchange the filter cartridges.
3. Close the side door of the milling controller.

11.5 Maintenance of recooling system and cooling water

CAUTION

Risk of injury due to contact with cooling water
Glycol is added to the cooling water to prevent build-up of bacteria and viruses. Contact with cooling water or cooling water mist can cause injury.

- Wear personal protective equipment (hand protection, eye protection, etc.).
- In the case of unintentional contact with eyes, flush the eyes immediately with clean water.
- In the case of unintentional contact with skin, wash thoroughly with plenty of soap and water.

Procedure

- Check water hoses for leaks and damage.

Detailed information about maintenance can be found in the assembly, installation and operating instructions of the recooling system.

11.6 Cleaning the milling robot system

Precondition

- Robot has been moved into its home position.
- The robot controller and technology cabinet are switched off and secured to prevent unauthorized persons from switching them on again.
- In the case of work on the technology cabinet: discharging time of capacitors has elapsed.

Further information about the capacitors can be found in the operating instructions of the frequency converter.

- The power cables are deenergized.

WARNING

Risk of fatal injury from mains voltage
Cables routed from power supply connection X1 (robot controller) and XS1 (technology cabinet) to the main switch are energized even when the main switch is switched off. Death, severe injuries or damage to property may result.

– Before starting work, deenergize the incoming power cable.
– Before starting work, ensure that the system is deenergized.

- Tool and workpiece have been removed.
- Main air is shut off and the connecting line to the main air is disconnected (compressed air system is vented).
- Pneumatic connections to customer equipment are disconnected and the system depressurized.
- Observe the ESD guidelines.

Work regulations

- The manufacturer's instructions must be observed when using cleaning agents for cleaning work.
- It must be ensured that no cleaning agents enter electrical components.
- Do not use compressed air during cleaning work.
- Do not spray with water.

Procedure

1. Check that the tool and workpiece have been removed.
2. Check that the robot controller and milling controller have been switched off and secured against being switched on again.
3. Loosen and vacuum up any dust deposits.
4. Clean robot controller and milling controller with a cloth soaked with a mild cleaning agent.
5. Clean cables, plastic parts and hoses with a solvent-free cleaning agent.
6. Replace damaged, illegible or missing identifications, labels and plates.
7. Regularly remove milling and drilling swarf.

12 Repair

12.1 Exchanging a tool in the tool rack

Description

The following is a description of the procedure for exchanging tools manually in the tool rack.

Procedure

1. Stop and cancel the milling program.
2. Set down the tool that is in the electrically-driven spindle in the specified position in the tool rack.
3. Move robot to a safe position.
4. Set T1 mode on the smartPAD.
5. Manually open the tool cover of the tool rack.

DANGER

Hazards when working on the milling robot system
If it is necessary to enter the cell with the robot controller and milling controller switched on in order to work on the milling robot system, suitable safety measures must be implemented. Death or severe injuries may otherwise result.

- Secure the open safety gate, e.g. with a padlock, against being closed unintentionally.
- The user is responsible for defining additional safety measures to ensure safe protection of personnel.

6. Request entry to the cell. Deactivate and activate operator safety.
(>>> *7.1.2 "Deactivating and activating operator safety" Page 71*)
7. Shut off the compressed air supply of the tool rack, vent it and secure it against being switched back on.

CAUTION

Risk of burns due to hot tool or workpiece
During operation, the tool and workpiece can reach temperatures which can cause burns.

- Avoid contact.
- If the tool is changed manually, take appropriate safety precautions and wear personal protective equipment, e.g. protective gloves, safety footwear and long, closely fitting clothing.

CAUTION

Risk of injury due to sharp-edged tool or workpiece
The tool and workpiece may have sharp edges that can cause cutting injuries.

- Avoid contact.
- If the tool is changed manually, take appropriate safety precautions and wear personal protective equipment, e.g. protective gloves, safety footwear and long, closely fitting clothing.

8. Enter the cell, check the tools in the tool rack and, if necessary, clean or replace.
9. Clear milling swarf, drilling swarf and dirt out of the tool stations.

10. Check that the “Tool present” sensors are functioning. If tools are loaded, the corresponding sensor signals must be “TRUE”; if tools are missing, the corresponding signals must be “FALSE”.
11. Ensure that the tool rack is correctly filled in accordance with the specifications. All tools must be loaded into the tool rack in the configured position.
12. Leave the cell and reactivate operator safety.
    (>>> *7.1.2 "Deactivating and activating operator safety" Page 71*)
13. Restore compressed air supply to the tool rack.
14. Manually close the tool cover of the tool rack.
15. Put the system back into operation.

13 Decommissioning, storage and disposal

13.1 Decommissioning

Precondition

- The system is deenergized.
- The system is depressurized.

Procedure

Information about decommissioning is contained in the documentation of the individual components.

13.2 Storage

Precondition

If the milling robot system is to be put into long-term storage, the following points must be observed:

- The place of storage must be as dry and dust-free as possible. Do not store product outside.
- Avoid temperature fluctuations.
- Avoid wind and drafts.
- Avoid condensation.
- Use appropriate coverings that cannot detach themselves and which can withstand the expected environmental conditions.
- Do not leave any loose parts on the transport system, especially ones that might knock against other parts.
- Do not leave the milling robot system exposed to direct sunlight while in storage.
- Observe and comply with the permissible temperature ranges for storage.
- Select a storage location in which the packaging materials cannot be damaged.

Procedure

1. Clean the milling robot system. No dirt may remain on or in the milling robot system.
2. Inspect the milling robot system, both internally and externally.
3. Empty the coolant tank in accordance with the assembly, installation and operating instructions for the recooling system.
4. Remove any foreign bodies.
5. Remove any corrosion expertly.
6. Attach all covers to the milling robot system and check that the seals are correctly in place.
7. Unplug electrical connections and seal them with suitable covers.
8. Seal hose connections by suitable means.
9. Cover the milling robot system with plastic sheeting and seal it at the base frame against dust.

   If necessary, add a desiccant beneath the plastic sheeting.

13.3 Disposal

When the robot system reaches the end of its useful life, it can be dismantled, and the materials can be disposed of properly by type.

The following table provides an overview of the materials used in the robot system. Some of the plastic components are marked with a material designation and must be disposed of accordingly.

As the end user, the customer is legally required to return depleted batteries. Used batteries can be returned to the vendor or brought to the designated collection points (e.g. in communal refuse collection facilities or commercial centers) free of charge. The batteries can also be sent to the vendor by post.
The following symbols can be found on the batteries:

- Crossed-out garbage can: battery must not be disposed of with ordinary household refuse.

- Pb: battery contains more than 0.004 lead by weight.
- Cd: battery contains more than 0.002 cadmium by weight.
- Hg: battery contains more than 0.0005 mercury by weight.

Lubricants, hydraulic oil, coolants and cleaning agents that are harmful to the environment must not be allowed to enter the ground or drainage system. These substances must be stored, transported and collected in suitable containers and disposed of in accordance with the applicable national laws, regulations and standards.

Material, designation	Subassembly, component	Note
Cast steel	Hydraulic motors, gear unit housings, wheels, hydraulic pump	
Steel	Frames, base frame, gear units, screws and washers	
	Motors	Dispose of motors without dismantling them.
PUR	Cable sheaths	
ETFE	Flexible tube	
Copper	Cables, wires	
PU	Hoses	
PA	Hinged clamps	
NBR	O-rings, shaft seals	
EPDM	Seals and covers	
PTFE	Sealing rings	
Electrical components	Sensor, boards	Dispose of as electrical scrap without disassembling
Cooling water with glycol		

14 Messages

14.1 Operating messages

HMI message	Cause	Remedy
Emergency Stop	EMERGENCY STOP device triggered.	Release all EMERGENCY STOP devices. Acknowledge the fault on the HMI or with the “Acknowledge” button.
	EMERGENCY STOP jumper plug removed (if no additional EMERGENCY STOP device has been connected).	Check and re-insert the jumper plug. Acknowledge the fault on the HMI or with the “Acknowledge” button.
	Safety PLC fault	Check the Safety PLC in the technology cabinet for red LEDs. If any red LEDs are lit up, restart the milling robot system. If the error message is still displayed after a restart, contact KUKA Support.
SafePLC error	Safety PLC fault	Restart the milling robot system.
	The PROFINET connecting cable between the robot controller and the technology cabinet has been removed.	Reconnect the PROFINET connecting cable between the robot controller and the technology cabinet. Acknowledge the fault on the HMI or with the “Acknowledge” button.
Standstill monitor error	Standstill monitor fault	Acknowledge the fault on the HMI or with the “Acknowledge” button.
Robot error	Robot controller fault	Minimize the Milling HMI and continue the troubleshooting on the robot HMI. See robot error description.
Milling system error	Milling robot system fault	Check the component tabs on the HMI. Continue the troubleshooting according to the faults indicated.
Chiller error	Recooling system fault	Check the error code (LED display) on the recooling system and correct the fault according to the recooling system fault documentation. Acknowledge the fault on the HMI or with the “Acknowledge” button.

HMI message	Cause	Remedy
Air pressure error	Air pressure is missing on the milling robot system.	Check compressed air and reconnect if necessary. Acknowledge the fault on the HMI or with the “Acknowledge” button.
	Pneumatic hoses leaking	Check lines for leaks and replace if necessary. Acknowledge the fault on the HMI or with the “Acknowledge” button.
UserSafety	Safety gate open	Close the safety gate. Acknowledge the fault on the HMI or with the “Acknowledge” button.
	Connection interrupted between the technology cabinet and the gate lock	Check connecting cable and reconnect if necessary. Acknowledge the fault on the HMI or with the “Acknowledge” button.
	Gate lock error	Read the error code on the gate lock (see gate lock documentation) and rectify accordingly. Acknowledge the fault on the HMI or with the “Acknowledge” button.
	Gate lock not taught	Teach the gate lock according to the documentation.
Flowrate error on the Chiller/Air Pressure tab	Chiller cooling circuit interrupted or leaking	Check the chiller cooling circuit for leaks and continuity and rectify the fault. Acknowledge the fault on the HMI or with the “Acknowledge” button.
Temperature error on the Chiller/Air Pressure tab	The temperature of the cooling system has exceeded the defined maximum level.	Diagnose and eliminate the cause of the temperature rise. Allow the system to cool. Acknowledge the fault on the HMI or with the “Acknowledge” button.
Main Air Fault error on the Chiller/Air Pressure tab	Air supply interrupted. Defective pneumatic connecting line.	Error in the air supply or in the connecting lines to the robot and the tool rack (optional). Check the connecting lines and rectify the fault. Acknowledge the fault on the HMI or with the “Acknowledge” button.
Regulator Release error on the Spindle tab	Tool clamping system fault	Contact KUKA Support.
Frequency Converter Error fault on the Spindle tab	Spindle drive fault	Contact KUKA Support.

HMI message	Cause	Remedy
Electrically-driven spindle does not start.	Conditions for operation of the electrically-driven spindle not fulfilled	Check the required connections in the process sequence on the Spindle tab of the Milling HMI and rectify the fault.
Tool rack (optional) cannot be opened.	Conditions not fulfilled for operation of the tool rack	Check the required connections in the process sequence on the Tool Rack tab of the Milling HMI and rectify the fault.
Main air cannot be switched on.	Conditions for pneumatic system not fulfilled	Check the required connections in the process sequence on the Chiller, Main Air and Tool Cleaning Air tab of the Milling HMI and rectify the fault.
Recooling system cannot be switched on.	Conditions for operation of the recooling system not fulfilled	Check the required connections in the process sequence on the Chiller, Main Air and Tool Cleaning Air tab of the Milling HMI and rectify the fault.
Electrically-driven spindle cannot be started via the robot program	Conditions for operation of the electrically-driven spindle not fulfilled	Check that the correct sequence of the inline forms for operation of the electrically-driven spindle has been observed.

15 Appendix

15.1 Automatic External interface I/Os

Inputs

Value	Name	Designation
33	PGNO_FBIT	First bit of the program number
41	PGNO_PARITY	Parity bit
42	PGNO_VALID	Program number valid
12	$EXT_START	External program start
13	$MOVE_ENABLE	Motion enable
14	$CONF_MESS	Error acknowledgement
16	$DRIVES_OFF	Drives off (inverse)
15	$DRIVES_ON	Drives on
11	$I_O_ACT	Activate Automatic External interface

Outputs

Value	Name	Designation
Start conditions		
10	$RC_RDY1	Robot controller ready
1015	$SPOC_MOTION_ENABLE	Motion enable signal issued by safety controller
1030	$ALARM_STOP	EMERGENCY STOP circuit closed
1031	$USER_SAF	Operator safety closed
11	$PERI_RDY	Drives ready
31	$ROB_CAL	Robot mastered
15	$I_O_ACTCONF	Automatic External interface active
12	$STOPMESS	Stop message active
999	PGNO_FBIT_REFL	First bit of the mirrored program number
1032	$ALARM_STOP_INT	Internal EMERGENCY STOP
Program status		
16	$PRO_ACT	Program active
33	PGNO_REQ	Program number request
34	APPL_RUN	Application running
17	$PRO_MOVE	Program motion active
Robot position		
14	$IN_HOME	In HOME position
26	$IN_HOME1	In HOME position 1
27	$IN_HOME2	In HOME position 2
28	$IN_HOME3	In HOME position 3
29	$IN_HOME4	In HOME position 4

Value	Name	Designation
30	$IN_HOME5	In HOME position 5
24	$ON_PATH	Robot on path
18	$NEAR_POSRET	Robot near path
19	$ROB_STOPPED	Robot stopped
Operating mode		
20	$T1	Test mode T1
21	$T2	Test mode T2
22	$AUT	Automatic mode
23	$EXT	Automatic External mode

Further information about the Automatic External interface can be found in the operating and programming instructions for the KUKA System Software.

15.2 Standards and regulations

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
2014/68/EU:2014	**Pressure Equipment Directive**: Directive 2014/68/EU of the European Parliament and of the Council dated 15 May 2014 on the approximation of the laws of the Member States concerning pressure equipment (Only applicable for robots with hydropneumatic counterbalancing system.)
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 13850:2015	**Safety of machinery:** Emergency stop - Principles for design
EN ISO 10218-2:2011	**Industrial robots – Safety requirements:** Part 2: Robot systems and integration

EN 60204-1:2018	**Safety of machinery:** Electrical equipment of machines – Part 1: General requirements
EN 614-1:2006+A1:2009	**Safety of machinery:** Ergonomic design principles - Part 1: Terms and general principles
EN 12417:2001+A2:2009	Machine tools - Safety - Machining centres
EN 13128:2001+A2:2009	**Safety of machine tools and milling machines:** Milling machines (including drillig/milling machines)
EN ISO 14120:2015	**Safety of machinery:** Guards - General requirements for the design and construction of fixed and movable guards

16 KUKA Service

16.1 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

16.2 KUKA Customer Support

The contact details of the local subsidiaries can be found at:
www.kuka.com/customer-service-contacts

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