Test Project

Skill

Industrial Robotics

The Test Project includes the following sections:

1. Forms of participation in the Test Project
2. Test Project
3. Project modules and time required
4. Assessment criteria
5. Required appendices

Time allotted to complete the project: 15h

1. FORMS OF PARTICIPATION IN THE COMPETITION

Individual participation

2. TEST PROJECT

The Test Project consists of 5 modules to be completed in turn. The participants are given instructions, pneumatic and electrical circuit diagrams, and the equipment layout.

The Test Project includes installing and commissioning of robot-assisted systems (RAS) based on the following modules:

1.) Robotized Welding
2.) Milling
3.) Machine loading/unloading
4.) Operation of automated lines
5.) Spot welding

The Test Project and Criteria may be changed only if the worksite cannot be completed and with the approval of the Skill Competition Manager.

If a competitor does not observe the OHSE requirements or exposes themselves and/or other competitors to danger, they may be removed from the competition.

The Test Project is to be completed in turn according to a random draw. The results are to be scored when the module is completed by the competitor.

3. PROJECT MODULES AND TIME REQUIRED

Modules and time are summarized in Table 1

Table 1. List of project modules

Item No.	Module name	Test Project completion time
1	Module 1: Robotized Welding	180 minutes
2	Module 2: Milling	180 minutes
3	Module 3: Machine loading/unloading	180 minutes
4	Module 4: Operation of automated lines	180 minutes
5	Module 5. Spot welding	180 minutes

See Table 2 for the sample site work plan

Table 2. Sample site work plan

Day	Working time	Site activity
C1	9 am – 12 noon	Test project performance by the Competitors
	12 noon – 2 pm	Assessment + lunch
	2–5 pm	Test project performance by the Competitors
	5–7 pm	Assessment + dinner
C2	9 am – 12 noon	Test project performance by the Competitors
	12 noon – 2 pm	Assessment + lunch
	2–5 pm	Test project performance by the Competitors
	5–7 pm	Assessment + dinner
C3	9 am – 12 noon	Test project performance by the Competitors
	12 noon – 2 pm	Assessment + lunch
	2–5 pm	locked

Module 1: Robotized Welding

The competitor should perform commissioning of a robotic welding cell.

The commissioning includes the following:

1.) Installation

2.) Switching on the equipment. Completing the installation.

3.) System configuration and function check.

4.) Putting the industrial robot into operation

5.) Writing a tool cleaning program.

6.) Writing a welding test program.

7.) Saving the image and backup of the configured robotic cell.

Original state of equipment:

- The electrical equipment to be operated by the Competitor must be prepared by the Workshop Manager or the Expert assigned to this module, in accordance with the inter-industry occupational safety rules in the operation of electrical equipment POT R M-016-2001, RD 153-34.0- 03.150-00 (Appendix B, at the end of the Test Project).

- The robot safety system has been fully configured and connected.

- The welding equipment is laid out on the table element by element, together with fasteners. The wire drawing device is fixed in place.

- The robot stands in the training cell; the power and data cables between the robot controller and the industrial robot are connected. The control unit of the industrial robot is also connected.

- The robot has been set in the installation position (the Home_arc program, which moves the industrial robot to its starting position suitable for installation, has been created in advance).

- The following parameters have been reset: additional loads on the robot axes, tool calibration data, tool weight and center of gravity, user coordinate system calibration data (base), robot I/O configurations; all the user programs except Home_arc have been removed.

- The signals from the tool cleaning station are not connected to the industrial robot control system. Signal names are not specified. The welding power source has been configured.

- ArcTechBasic, TouchSense, and KUKA.LoadDataDetermination technology packages have been installed in the industrial robot control system.

- Discrete I/O of the industrial robot are not configured. I/O and Universal welder signals are not configured. The Profibus IO device is configured.

- All the necessary documentation (technical descriptions, assembling manuals, pneumatic and electrical circuit diagrams, photographs) are located in the DataSheet and CircuitDiagrams folders on the laptop, respectively (the Welding Robot folder).

- The tool weight and center of gravity are determined and specified in the Competitor's Test Project using the KUKA.LoadDataDetermination technology package.

Item 1. Installation

The state of the equipment:

1.) Install the collision protection and the welding torch on the robot flange.

2.) Pull the armoring coil inside the armored conduit.

3.) Connect the hose to the wire drawing device and the welding torch.

4.) Connect the power and data cables from the welding machine to the wire drawing device.

5.) Connect the aerial circuit to the tool cleaning station as per the pneumatic circuit diagram.

6.) Connect the signals from the tool cleaning station to the industrial robot controller as per the electrical circuit diagram.

7.) Install and secure the part on the cell's work desk.

8.) Connect the ground cable from the welding machine to the welding jig.

9.) Connect the data cable from the welding machine to the robot controller.

The assembled robot-assisted system shall be checked by the Expert when the installation is complete. The Expert shall sign the "Report on Robot-Assisted System Assembly Check" to give authorization for powering up the RAS (see Appendix A at the end of the Test Project).

After the Report on the Robot-Assisted System Assembly Check has been signed, the Expert must disconnect the positive cable from the welding power source.

Item 2. Switching on the equipment. Completing the installation

1.) Switch on the industrial robot.

2.) Switch on the welding machine.

3.) Thread the wire in the wire drawing device.

4.) Lower the pinch rollers and set the sufficient force to draw the wire.

5.) Pushing the pinch rollers switch-on button, draw the wire until it protrudes out of the welding tip by approximately 30 mm.

6.) Switch on the compressor and set the outlet pressure to 6 bar.

Item 3. System configuration and function check

1.) Start the WorkVisual software.

2.) Upload the current project and save it in the WV sub-folder (in the Welding Robot folder) under the name "Welding _xxx", where "xxx" is the name of the Competitor in English.

3.) Configure the discrete I/O of the industrial robot according to Table 1-2.

4.) Configure the I/O and signals of the Universal welder device (Table 3-5).

5.) Upload the project to the robot control system.

6.) Sign the discrete signals in accordance with the table.

Table 1. Discrete Inputs

Signal name	EtherCAT coupler input No.	Robot input No.	Description
Collision_signal	16	501	Torch collision sensor signal. Signal =0 at collision
Torch_cleaner_OPEN	1	502	Torch_cleaner_OPEN signal from torch cleaner

Table 2. Discreet outputs

Signal name	EtherCAT coupler output No.	Robot output No.	Description
Torch_cleaner_START	1	533	Torch_cleaner_START signal to the torch cleaner
Torch_cleaner_CUT	2	534	Torch_cleaner_CUT signal to the torch cleaner to cut the wire

Table 3. Inputs. Data communicated by the welding power source to the robot

Name of the welding power source signals	Robot input No.	Description
Power source ready	309	Reads 1 when the welding power source is in working condition (ready for operation)
Main current	310	Reads 1 when there is an output from the main circuit inverter
Cell error	315	Reads 1, when the welding power source produces an error signal Welding machine operation stops
Weld process active	308	Returns the watchdog value

Table 4. Outputs. Data communicated by the robot to the welding power source

Name of the welding power source signals	Robot output No.	Description
Start welding	300	When the signal is 1, welding starts. Does not work if the wire feed forward or backward signal is already on
Gas active	303	When 1, the gas blowing is activated. Gas blowing is turned on during the welding start-up, regardless of whether the signal is on or off
Acknowledge power source	315	When 1, the power source stops working. When it switches to 0, errors and warnings are erased and the welding power source resumes operation
Wire feed forward	301	Welding wire feed forward/backward signals. If both are 1, nothing will be run. Are not active during welding

Table 5. Welding parameter setting signals

Name of the welding power source parameters	Robot outputs	Description
Synergy	364–364	When 1, voltage is set to SYNERGIC mode.
Welding current	372–378	Setting welding current, A.
Welding voltage synergy	420–435	Sets welding voltage. Setting unit is [0.1 V].

7.) Check the operation of the tool cleaning system (wire cutting, torch clamp, torch cleaning, torch lubrication) element by element. Check the wire feed from the robot control unit using the function keys. **Prior to the check, notify the expert thereof.**

8.) Cut the wire with manual wire cutters. Ensure the wire sticks out by 20 mm.

Item 4. Commissioning of the industrial robot

1.) Specify additional loads on axes A1–A3 of the industrial robot.
2.) Calibrate the welding torch. Use tool number 1 to save the tool calibration data. The tool name shall be "Welding_torch". The end of the welding wire with a 20 mm protrusion shall be taken as the TCP. The protrusion distance of the welding wire is measured from the end of the welding tip to the end of the wire. The tool calibration tolerance shall be within 0.4 mm.
3.) Calibrate the tool impact direction. The tool impact direction must be along the OX-axis.
4.) Specify the tool weight and center of gravity in relation to the robot flange according to Table 6.

Table 6. Tool load data

Weight					
M	3.84 kg				
Center of gravity		Orientation		Moment of inertia	
X	11.09 mm	A	176.19°	JX	0.05 kg*m^2
Y	−0.96 mm	B	−89.72°	JY	0.12 kg*m^2
Z	0.00 mm	C	93.83°	JZ	0.15 kg*m^2

5.) Calibrate Base 1 "MainBase" for the workpiece. Take the left corner of the workpiece closest to the robot as the origin point.
6.) Calibrate Base 2 "CleaningStation" for the tool cleaning station. Take the left corner of the tool cleaning station closest to the robot as the origin point.

Item 5. Writing a tool cleaning program
1.) It is necessary to write a tool cleaning program. The program name shall be "Torch_cleaner". Base 2 and Tool 1 shall be used when writing the program. The speed of approaching and moving away from the tool cleaning station to the endpoint shall be 0.3 m/s; the speed of approaching all the actuating elements of the cleaning station shall not exceed 0.15 m/s, and the speed of PTP motions shall not exceed 15%.

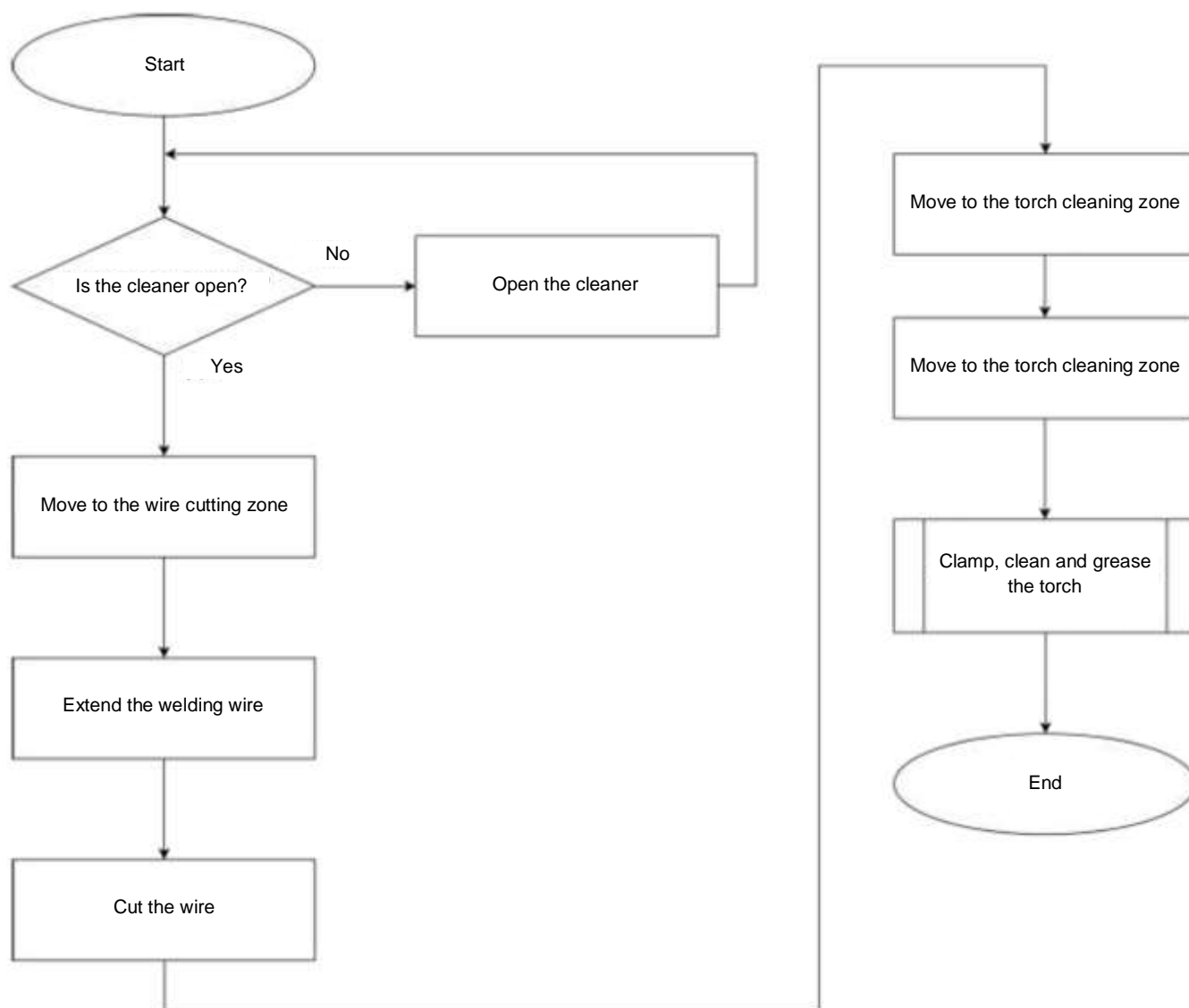See Figure 1 for the tool cleaning sequence.

Figure 1. Tool cleaning sequence

2.) The program shall be tested **in the presence of the expert** in T1 mode at a speed of 100%.

3.) **Upon approval by the Expert**, the program shall be tested in the presence of the Expert in T2 mode at a speed forcibly reduced to 50%.

4.) **Upon approval by the Expert**, the program shall be tested in the presence of the Expert in AUT mode at a speed forcibly reduced to 70%.
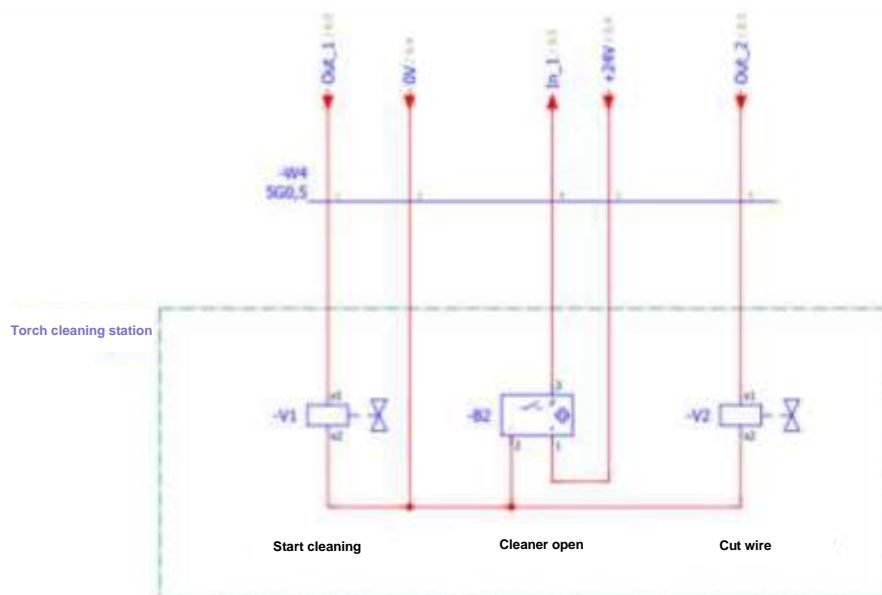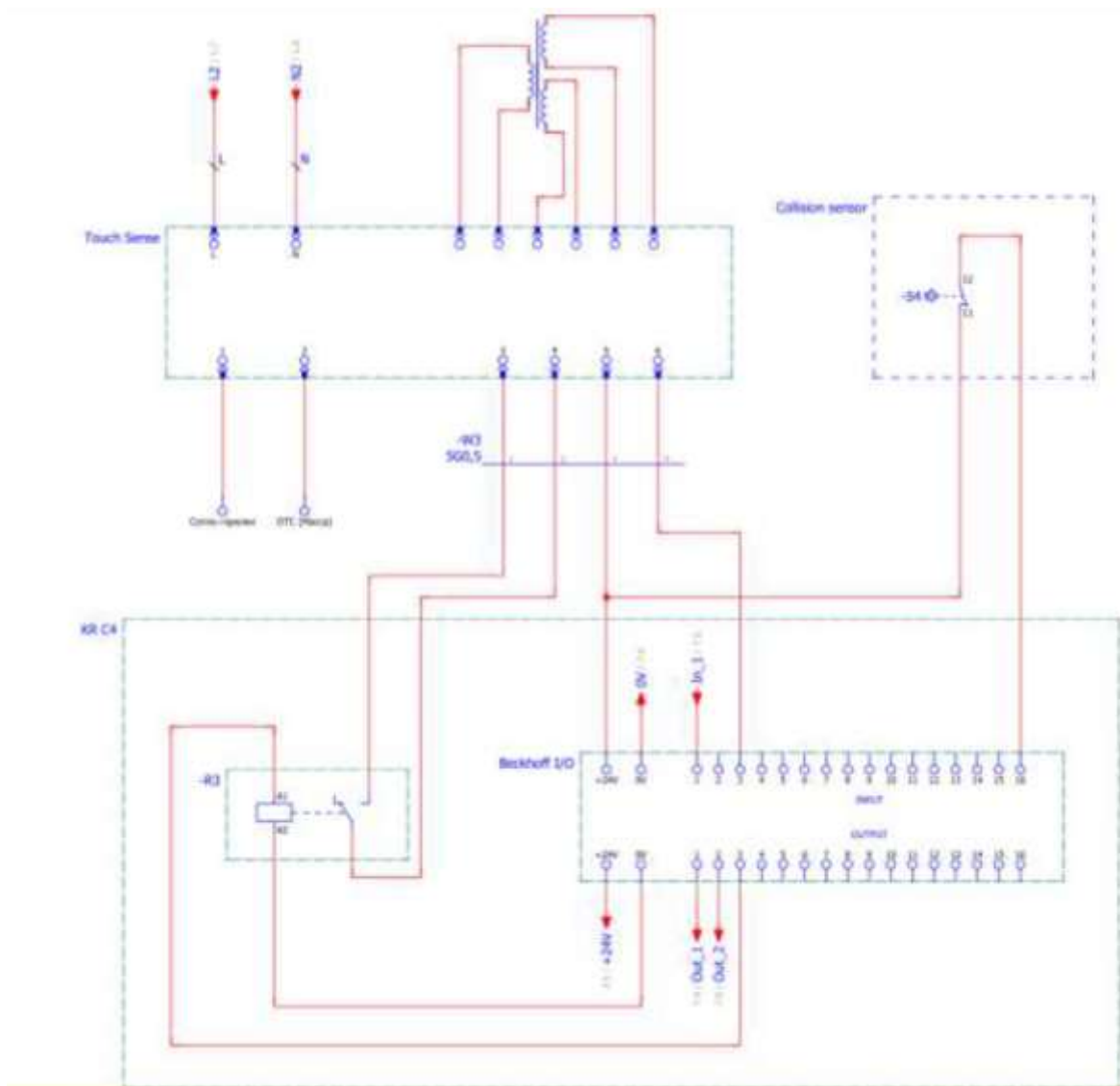
Item 6. Writing a welding test program
1.) Create "MyFirstWeld" program.
2.) Write a robot-assisted welding program according to the welding product presented.
3.) The speed at which the tool approaches and moves away from the part to the end point shall not exceed 0.3 m/s.
4.) The ArcTech Basic process package forms should be used when writing the welding motions. See Appendix 3 for welding parameters.
5.) The tool cleaning program shall be called up after the first motion in the test part welding program.
6.) The robot shall not collide with anything during operation.
7.) To test a written program, the program start mode should be selected without arc ignition.
8.) Write a part search program using TouchSense (2D) technology.
9.) The fully debugged program shall be tested in the **presence of the Expert** in T1 mode at a 100% speed.
10.) **Upon approval by the Expert**, the fully debugged program shall be tested in the presence of the Expert in T2 mode at a speed forcibly reduced to 50%.
11.) **Upon approval by the Expert**, the fully debugged program shall be tested in the presence of the Expert in AUT mode at a speed forcibly reduced to 70%.

Item 7. Saving the image and backup of the configured robotic cell
1.) Save the image and backup of the configured robotic cell using a special flash drive.
2.) To save the image, create an "IM xxx" folder in the "Welding Robot" folder (on the desktop), where the 'xxx' shall be replaced with the industrial robot number.
3.) To save the backup, create a "BackUp xxx" folder in the "Welding Robot" folder (on the desktop), where the 'xxx' shall be replaced with the industrial robot number.

Appendix 1. Example of a wiring diagram

Appendix 2. Example of a system pneumatic circuit diagram

MS4-EM1-1/4-S   MS4-LFR-1/4-D7-ERV-AS

Torch cleaning station

Compressor
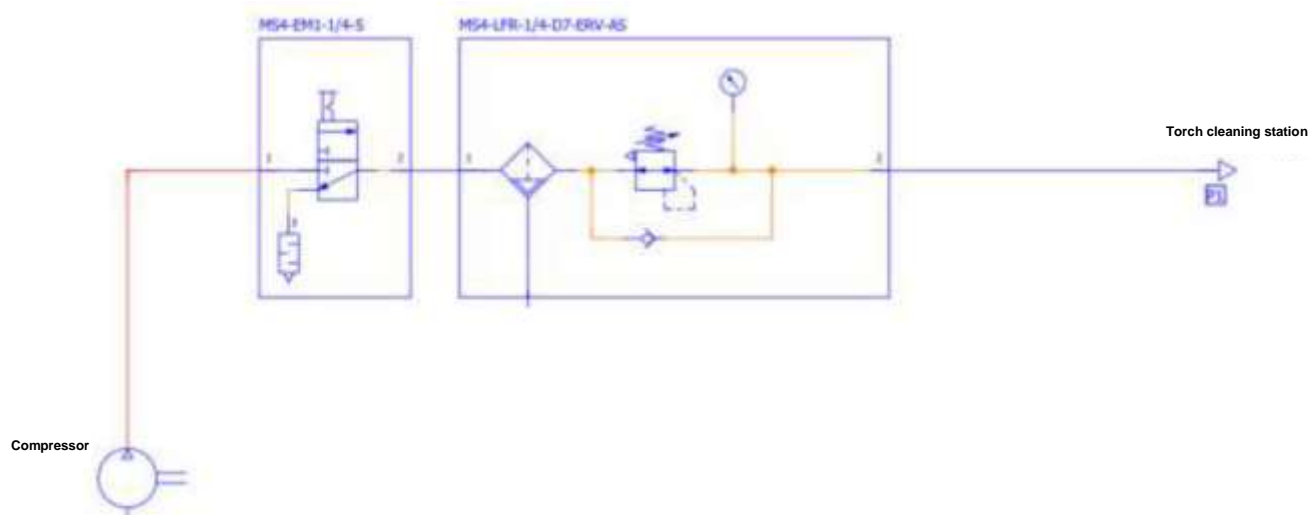
Appendix 3. Welding parameters (Example 1)

Horizontal bottom weld parameters (ArcOn):

Arc ignition parameters:

a.) Channel number: 5

b.) Preflow time: 0.3 s

c.) Wait time after ignition: 0.3 s

      Welding parameters:

            a. Channel number: 5

            b. Robot speed: 0.4 m/min

      Weaving parameters

            a. No weaving

Vertical weld parameters (ArcOn):

Arc ignition parameters:

a.) Channel number: 4

b.) Preflow time: 0.2 s

c.) Wait time after ignition: 0.3 s

      Welding parameters:

            a. Channel number: 4

            b. Robot speed: 0.35 m/min

      Weaving parameters

            a. Pattern: Triangle

            b. Length: 3 mm

            c. Deflection: 3 mm

            d. Angle: 0

Horizontal top weld parameters (ArcOn):

Arc ignition parameters:

a.) Channel number: 5

b.) Preflow time: 0.3 s

c.) Wait time after ignition: 0.3 s

      Welding parameters:

            a. Channel number: 5

            b. Robot speed: 0.4 m/min

      Weaving parameters

            a. Pattern: Triangle

            b. Length: 3.5 mm

            c. Deflection: 3.5 mm

            d. Angle: 0

Arc extinguishing parameters for all weld types (ArcOff):

<u>End crater parameters:</u>

       a. Channel number: 10

       b. End crater time: 0.2

       c. Postflow time: 0.2

Module 2: Milling

The competitor shall commission a robotic milling machine.

The commissioning includes the following:

1.) Installation.
2.) Switching on the equipment. Completing the installation.
3.) System configuration and function check.
4.) Commissioning of the industrial robot.
5.) Writing a spindle control test program.
6.) Running the CAM system.
7.) Starting a milling program.
8.) Saving the image and backup of the configured robotic cell.

Original state of equipment:

- The electrical equipment to be operated by the Competitor must be prepared by the Workshop Manager or the Expert assigned to this module, in accordance with the inter-industry occupational safety rules in the operation of electrical equipment POT R M-016-2001, RD 153-34.0- 03.150-00 (Appendix B, at the end of the Test Project).

- The robot safety system has been fully configured and connected.

- The equipment is laid out on the table element-by-element; the machine vice is fixed on the table.

- The robot stands in the training cell; the power and data cables between the robot controller and the industrial robot are connected. The control unit of the industrial robot is also connected.

- The robot has been set in the installation position (the Home_mill program, which moves the industrial robot to its starting position suitable for installation, has been created in advance).

- The following parameters have been reset: additional loads on the robot axes, tool calibration data, tool weight and center of gravity, user coordinate system calibration data, robot I/O configurations; all the user programs except Home_mill have been deleted.

- Inputs/outputs of the industrial robot have not been configured. The signals from the spindle control panel have not been connected to the industrial robot control system. Signal names are not specified. The frequency converter and the logic controller have been configured. A program for translating the spindle rotation frequency "Frequency" into binary code has been written in advance.

- A CAM system with a ready-made post-processor has been installed on the laptop. The 3D model of the parts to be fabricated can be found in the 'Detal' folder.

- All the necessary documentation (technical descriptions, assembling manuals, pneumatic and electrical circuit diagrams, photographs) are located in the DataSheet and CircuitDiagrams folders on the laptop, respectively.

Item 1. Installation

1.) Install the spindle on the robot flange according to the assembly instructions.
2.) Clamp a four-tooth end milling cutter of 8 mm diameter with a 30 mm offset into the spindle collet. The milling cutter's offset distance is measured from the end of the chuck to the end of the milling cutter.
3.) Connect the spindle to the spindle control panel using a cable that comes with the system.
4.) Fasten the cable to the industrial robot body, providing the necessary length margin to allow free running of the robot assemblies (the spare cable shall not interfere with the milling of the spindle).

5.) Connect the cables from the spindle control panel to the robot controller according to the electrical circuit diagram.

6.) Clamp the workpiece in the machine vice. Check the workpiece for firm seating.

The assembled robot-assisted system shall be checked by the Expert when the installation is complete. The Expert shall sign the "Report on Robot-Assisted System Assembly Check" to give authorization for powering up the RAS (see Appendix A at the end of the Test Project).

Item 2. Switching on the equipment. Completing the installation

1.) Switch on the industrial robot.

2.) Switch on the spindle control panel.

Item 3. System configuration and function check

1.) Start the WorkVisual software.

2.) Upload the current project and save it in the WV folder (in the Milling Robot folder) under the name "Milling _xxx", where "xxx" is the name of the Competitor in English.

3.) Configure the discrete I/O of the industrial robot according to Table 1.

4.) Upload the project to the robot control system.

5.) Sign the signals in accordance with the table.

Table 1. Discreet outputs

Signal name	EtherCAT coupler output No.	Robot output No.	Description
VEL_1	1	1	Transmitting the 0th bit for rotation frequency control
VEL_2	2	2	Transmitting the 1th bit for rotation frequency control
VEL_3	3	3	Transmitting the 2nd bit for rotation frequency control
Spindel_ON_CW	4	4	Signal to the frequency converter: clockwise rotation of the spindle
Spindel_ON_CCW	5	5	Signal to the frequency converter: counterclockwise rotation of the spindle

6.) Check the operation of the tool cleaning system (wire cutting, torch clamp, torch cleaning, torch lubrication) element by element. Check the wire feed from the robot control unit using the function keys. **Prior to the check, notify the expert thereof.**

7.) Cut the wire with manual wire cutters. Ensure the wire sticks out by 20 mm.

Item 4. Commissioning of the industrial robot

1.) Specify additional loads on axes A1–A3 of the industrial robot.

2.) Calibrate the milling tool. Use tool number 1 to save the tool calibration data. The tool name shall be "End_mill_d8". The center of the milling tool end is taken as the TCP. The tool calibration tolerance shall be within 0.4 mm.

3.) Calibrate the direction of the tool 1 impact direction.

4.) Specify the tool weight and center of gravity in relation to the robot flange according to Table 2.

Table 2. Tool load data

Weight					
M	3.84 kg				
Center of gravity		Orientation		Moment of inertia	
X	11.09 mm	A	176.19°	JX	0.05 kg*m^2
Y	−0.96 mm	B	−89.72°	JY	0.12 kg*m^2
Z	0.00 mm	C	93.83°	JZ	0.15 kg*m^2

5.) Calibrate Base 1 "Workpiece" for the workpiece. Take the left corner of the workpiece closest to the robot as the origin point.

Item 5. Writing a spindle control test program

1.) Create the "SpindelTest" program consisting of the following commands:
   - Moving to the initial position by PTP motions, the axes in this position must be equal: axis 1: [0], axis 2: [−90], axis 3: [70], axis 4: [0], axis 5: [10], axis 6: [0].
   - Switching on the spindle with a rotation frequency of 4,000 rpm clockwise.
   - 10-second hold.
   - Rotation frequency of 4,000 rpm clockwise.
   - 10-second hold.
   - Rotation frequency of 12,000 rpm clockwise.
   - Switching off the spindle.
2.) Use the previously configured output to switch on the spindle.
   The rotation frequency is set using the "Frequency" variable in the program text.
3.) The program shall be tested in T1 mode in the **presence of the Expert**.

Item 6. Running the CAM system

1.) Start SprutCAM and select the appropriate industrial robot from the library.
2.) Import the 3D model of the part (Figure 1).
3.) Add the workpiece with its actual dimensions to the CAM system.
4.) Configure the tool and workpiece coordinate system (it is recommended to use the actual values that were previously obtained during the calibration on the robot).
5.) Create a milling path with the following parameters:
   - Tool: end mill with a diameter of 8 mm (the length and the working length are indicated after measurement);
   - Step: 30% of the tool diameter;
   - Cutting depth: 3 mm;
   - Spindle rotation speed: 8,000 rpm;
   - Working feed: 2,000 mm/min;
   - Cutting-in feed: 500 mm/min;
   - Accelerated feed: 4,000 mm/min;
6.) Calculate the resulting path and check for collisions by launching the simulation process.

7.) Make sure that there are no collisions and unload the First_milling control program by selecting the appropriate postprocessor of the robot manufacturer.

8.) Save the CAM system project to the Milling Robot folder.

Item 7. Starting a milling program

1.) Transfer the First_milling control program from the flash drive to the robot controller.

2.) Ensure that tool 1 and base 2 are selected in the control program.

3.) Taking safety precautions, check the control program in T1 mode, preliminarily notifying the Expert. To ensure safety, it is necessary to: raise the user's coordinate system in the Z-axis by 150 mm, or start the check without the workpiece clamped in the vice.

4.) Upon obtaining permission from the monitoring expert, start the processing program in AUT mode at a speed forcibly reduced to 70%.

5.) Be ready to reduce or increase the execution speed of the program, depending on the recommendations of the monitoring expert.

6.) Tidy up the workstation after the work.

Item 8. Saving the image and backup of the configured robotic cell

1.) Save the image and backup of the configured robotic cell using a special flash drive.

2.) To save the image, create an "IM xxx" folder in the "Milling Robot" folder (on the desktop), where the 'xxx' shall be replaced with the industrial robot number.

3.) To save the backup, create a "BackUp xxx" folder in the "Milling Robot" folder (on the desktop), where the 'xxx' shall be replaced with the industrial robot number.

Appendix 1. Example of a wiring diagram
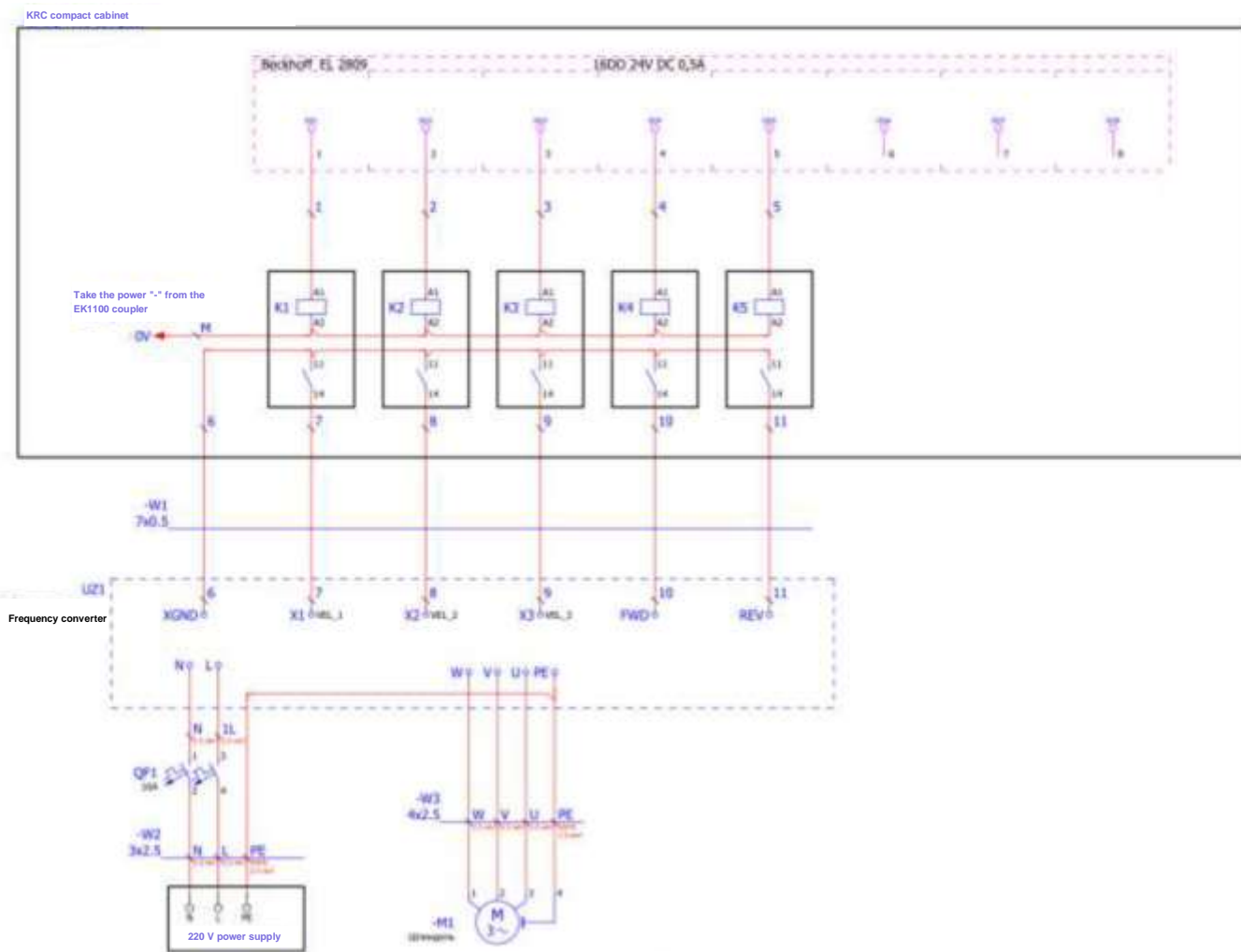
Module 3: Machine loading/unloading

The competitor has to commission a robotic cell that operates a machine tool.

The commissioning includes the following:

1.) Installation.
2.) Switching on the equipment. Completing the installation.
3.) System configuration and function check.
4.) Running the offline programming system.
5.) RAS commissioning.
6.) Adjusting the program.
7.) Saving the image and backup of the configured robotic cell.

Original state of equipment:

- The electrical equipment to be operated by the Competitor must be prepared by the Workshop Manager or the Expert assigned to this module, in accordance with the inter-industry occupational safety rules in the operation of electrical equipment POT R M-016-2001, RD 153-34.0- 03.150-00 (Appendix B, at the end of the Test Project).

- The robot safety system has been fully configured and connected.

- The equipment has been installed and fixed in the industrial robot cell.

- The robot stands in the training cell; the power and data cables between the robot controller and the industrial robot are connected. The control unit of the industrial robot is also connected.

- The robot has been set to the starting position (the Home_CNC program, which moves the industrial robot to its starting position, has been created in advance).

- The following parameters have been reset: additional loads on the robot axes, tool calibration data, tool weight and center of gravity, user coordinate system calibration data, robot I/O configurations; all the programs except Home_CNC have been deleted.

- Inputs/outputs of the industrial robot have not been configured. The signals from the I/O modules of the industrial logic controller (PLC) are not connected to the sensors and actuators of the system. The names of the signals in the robot control system have not been specified.

- The CNC rack and operator panel have been configured. Programs are written on the rack in advance: programs for processing, transmitting signals from the CNC rack to the robot; transmitting data on the number of workpieces for processing from the operator panel to the robot; notifying the operator of the filling of the finished part storage; turning on the light column.

- The laptop has the Kuka Sim.Pro, an offline programming system with ready 3D models of the entire system. 3D models can be found in folders on the desktop.

- All the necessary documentation (technical descriptions, assembling manuals, pneumatic and electrical circuit diagrams, photographs) are located in the DataSheet and CircuitDiagrams folders on the laptop, respectively.

Item 1. Installation
1.) Make the electrical connections according to the electrical circuit diagrams.
2.) Connect the pneumatic lines according to the pneumatic circuit diagram.

The assembled robot-assisted system shall be checked by the Expert when the installation is complete. The Expert shall sign the "Report on Robot-Assisted System Assembly Check" to give authorization for powering up the RAS (see Appendix A at the end of the Test Project).

Item 2. Switching on the equipment. Completing the installation

1.) Switch on the industrial robot.
2.) Switch on the control cabinet.
3.) Turn on the compressor and set the outlet pressure to 4 bar.

Item 3. System configuration and function check

1.) Start the WorkVisual software.
2.) Upload the current project and save it in the WV folder (in the CNC Robot folder) under the name "CNC _xxx", where "xxx" is the name of the Competitor in English.
3.) Configure the discrete I/O of the industrial robot according to Table 1-2.
4.) Upload the project to the robot control system.
5.) Sign the discrete signals in accordance with the table.
6.) Run element-by-element functional test of the cell. **Prior to the check, notify the expert thereof.**

Table 1. Robot input signal configuration table

Signal name	EtherCAT coupler input No.	Robot input No.	Description
WP_storage1	1	1	Signal to the industrial robot on a workpiece in Cell 1
WP_storage2	2	2	Signal to the industrial robot on a workpiece in Cell 2
WP_storage3	3	3	Signal to the industrial robot on a workpiece in Cell 3
WP_storage4	4	4	Signal to the industrial robot on a workpiece in Cell 4
WP_storage5	5	5	Signal to the industrial robot on a workpiece in Cell 5
WP_storage6	6	6	Signal to the industrial robot on a workpiece in Cell 6
WP_storage7	7	7	Signal to the industrial robot on a workpiece in Cell 7
WP_storage8	8	8	Signal to the industrial robot on a workpiece in Cell 8
WP_storage9	9	9	Signal to the industrial robot on a workpiece in Cell 9
Product_storage1	10	10	Signal to the industrial robot on a part in Cell 1
Product_storage2	11	11	Signal to the industrial robot on a part in Cell 2
Product_storage3	12	12	Signal to the industrial robot on a part in Cell 3
Product_storage4	13	13	Signal to the industrial robot on a part in Cell 4
Product_storage5	14	14	Signal to the industrial robot on a part in Cell 5
Product_storage6	15	15	Signal to the industrial robot on the availability of a part in Cell 6
Product_storage7	16	16	Signal to the industrial robot on the availability of a part in Cell 7
Product_storage8	17	17	Signal to the industrial robot on a part in Cell 8
Product_storage9	18	18	Signal to the industrial robot on a part in Cell 9
Door_open	19	19	Signal to the industrial robot that the machine door is open
Door_close	20	20	Signal to the industrial robot that the machine door is closed
Chuck open	21	21	Signal to the industrial robot that the chuck is open
Chuck close	22	22	Signal to the industrial robot that the chuck is closed
Gripper open	23	23	Signal to the industrial robot that the gripper is open
Gripper close	24	24	Signal to the industrial robot that the gripper is closed
Milling_started	25	25	Signal to the industrial robot that the milling started

Milling_finish	26	26	Signal to the industrial robot that the milling is finished
	30–32	30–32	Available signals

Table 2. Output configuration table for the robot with EM8905-1001 I/O-Modul

Signal name	EM8905-1001 I/O-Modul input No.	Robot input No.	Description
Open_gripper	7	1	Signal from the robot to open the gripper
Close_gripper	10	2	Signal from the robot to close the gripper

Table 3. Output configuration table for the robot with EtherCAT coupler

Signal name	EtherCAT coupler input No.	Robot input No.	Description
Open door	1	3	Signal from the robot to open the door
Open chuck	2	4	Signal from the robot to open the chuck
Robot in neutral	3	5	The robot is in neutral position
Storage error	4	6	"Storage is full" message to the operator
	4–16	6–18	Available signals

Item 4. Running the offline programming system

1.) Start the Kuka Sim.Pro system and create a new project.

2.) Lay out the robotic cell according to the **actual dimensions** of the robot-assisted system. Add to the project:
- a table and an adapter plate;
- an industrial robot;
- a gripper;
- CNC milling machine;
- a workpiece storage;
- a finished product storage.

3D models of cell components are in the CNC Robot folder.

3.) Calibrate Tool 1 named "Gripper". The tool center point (TCP) should be assumed as the central point between two gripper fingers.

4.) Calibrate the user coordinate system for the workpiece storage (WP_storage), finished products storage (Product_storage), and machine (CNC_machine).

5.) Link the input and output signals of the industrial robot with the gripper:
- open the Program tab;
- activate the Signals parameters in the Show menu;
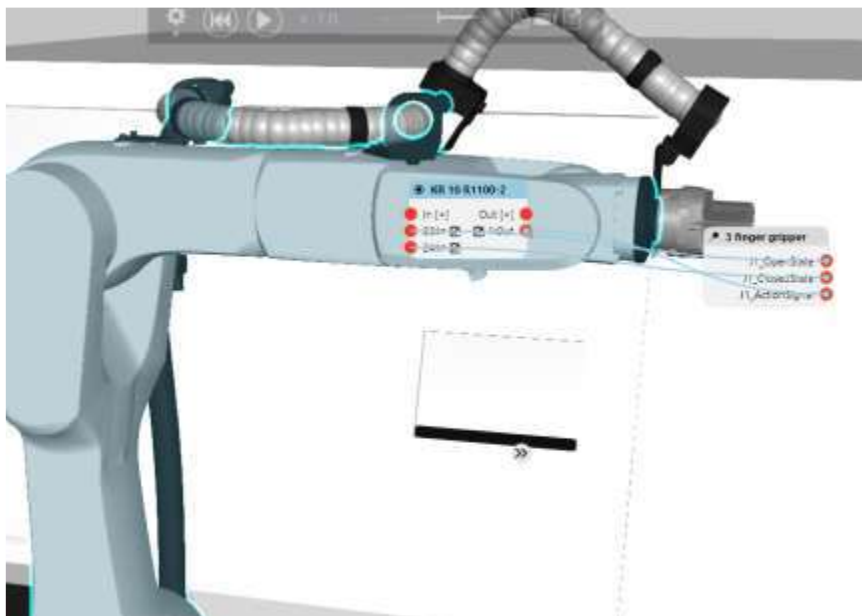- click on the robot and link the signals (Figure 1);

Figure 1. Example of signal linking in Kuka Sim.Pro

6.) Similarly to Item 5, link the door opening and chuck clamping signals between the CNC machine and industrial robot.

7.) Write a program called "Handling" to load the workpieces on the machine with the industrial robot and unload the finished products to the part storage according to the algorithm (Appendix 8).

8.) Consider the following aspects when writing the program:

- Workpieces at the workpiece storage can be arranged in a random order.
- Finished products can already be at the finished product storage.
- The number of workpieces necessary for processing is set on the operator's panel (the Product_count robot variable).
- The machine will start processing a workpiece only if the following conditions are met:

    A) The robot is in the neutral position "Robot_in_neutral" (a signal to the CNC machine from the robot).

    B) The machine door is closed (a signal from the CNC machine).

- Any motions related to workpiece storage should be performed with the "WP_storage" base. Similar conditions shall be met for the finished products storage ("Product_storage") and machine ("CNC_machine").
- The tool weight shall vary depending on the presence or absence of a workpiece/part in the robot gripper.
- The speed of PTP motions must not exceed 10%.
- The speed of linear motions over a distance of 100 mm between any obstacle and elements of the robot may not exceed 0.4 m/s and may be optimized, without stopping the robot at a programmed point (motion smoothing).
- The speed of linear motions at a distance less than 100 mm between any obstacle and elements of the robot may not exceed 0.15 m/s.

9.) Download and copy the "Handling" master program to a flash drive.

10.) Save the project to the desktop.

Item 5. RAS commissioning

1.) Specify additional loads on the axis of the industrial robot.
2.) Calibrate Tool 1 named "Gripper". Data for calibration shall be taken from the offline programming system.
3.) Specify the tool weight and center of gravity in relation to the robot flange according to Table 4.

Table 4. Tool loading data

Weight					
M	3.84 kg				
Center of gravity		Orientation		Moment of inertia	
X	11.09 mm	A	176.19°	JX	0.05 kg*m^2
Y	−0.96 mm	B	−89.72°	JY	0.12 kg*m^2
Z	0.00 mm	C	93.83°	JZ	0.15 kg*m^2

4.) Calibrate the user coordinate system (BASE) for the workpiece storage ("WP_storage"), finished products storage ("Product_storage"), and machine ("CNC_machine"). Data for calibration shall be taken from the offline programming system.

Item 6. Adjusting the program

1.) Copy the "Handling" control program from the flash drive to the robot controller.
2.) Start the control program in the T1 mode and check it for errors and collisions.
3.) If collisions or errors are detected, eliminate them.
4.) Supplement the program with required logical elements, if necessary.
5.) The fully debugged program shall be tested in the **presence of the Expert** in T1 mode at a 100% speed.
6.) **Upon approval by the Expert,** the fully debugged program shall be tested in the presence of the Expert in the T2 mode at a speed forcibly reduced to 50%.
7.) **Upon approval by the Expert**, the fully debugged program shall be tested in the presence of the Expert in AUT mode at a speed forcibly reduced to 70%.

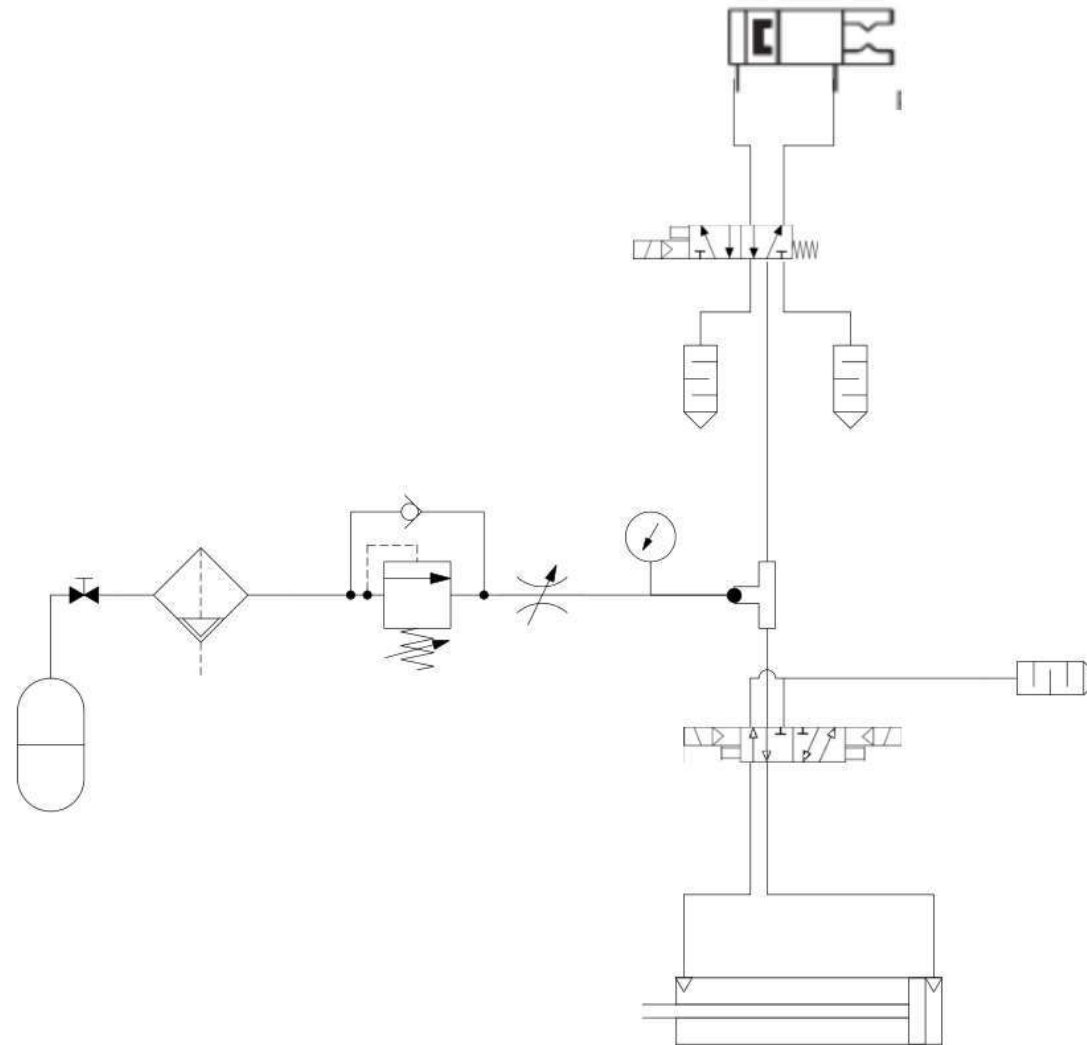**Item 7.** Saving the image and backup of the configured robotic cell

Save the image and backup of the configured robotic cell using a special flash drive

1.) To save the image, create an "IM xxx" folder in the "CNC Robot" folder (on the desktop), where the 'xxx' shall be replaced with the industrial robot number.
2.) To save the backup, create a "BackUp xxx" folder in the "CNC Robot" folder (on the desktop), where the 'xxx' shall be replaced with the industrial robot number.
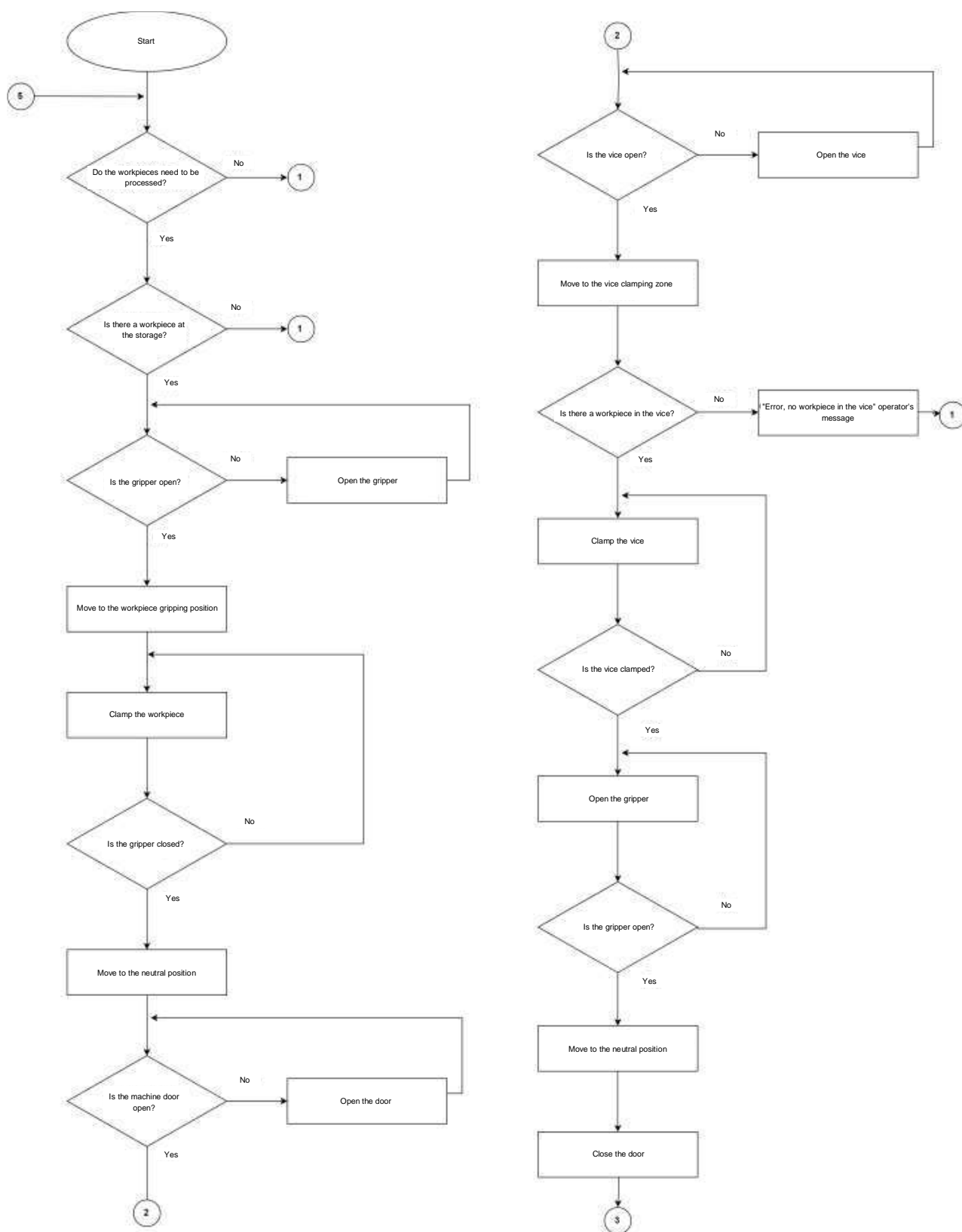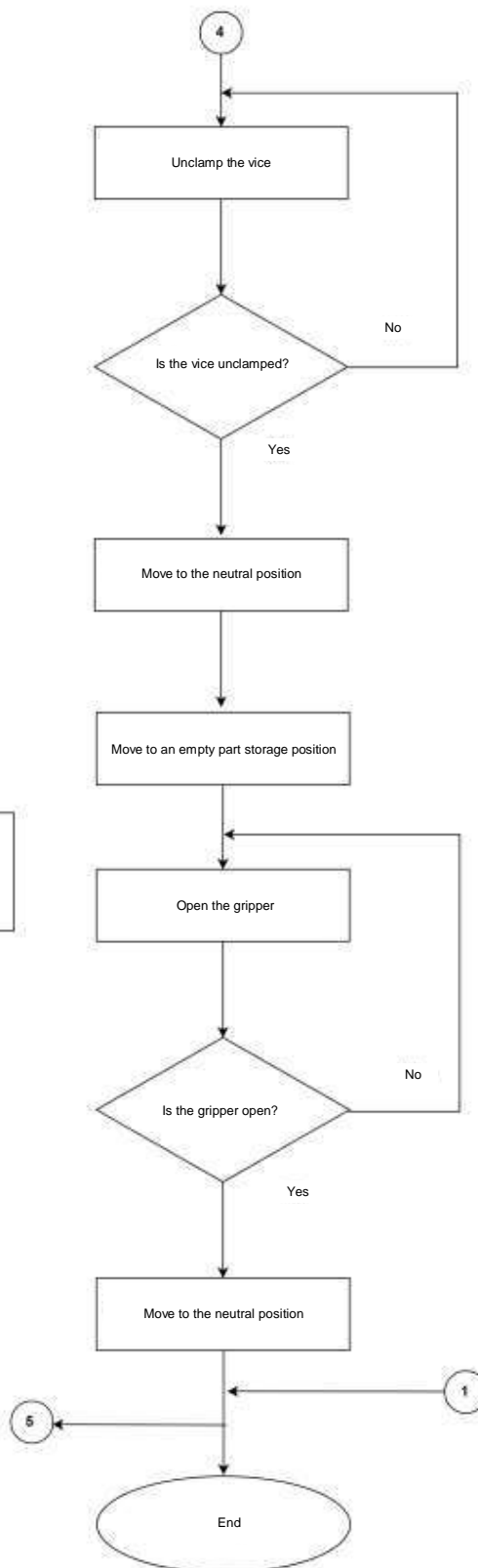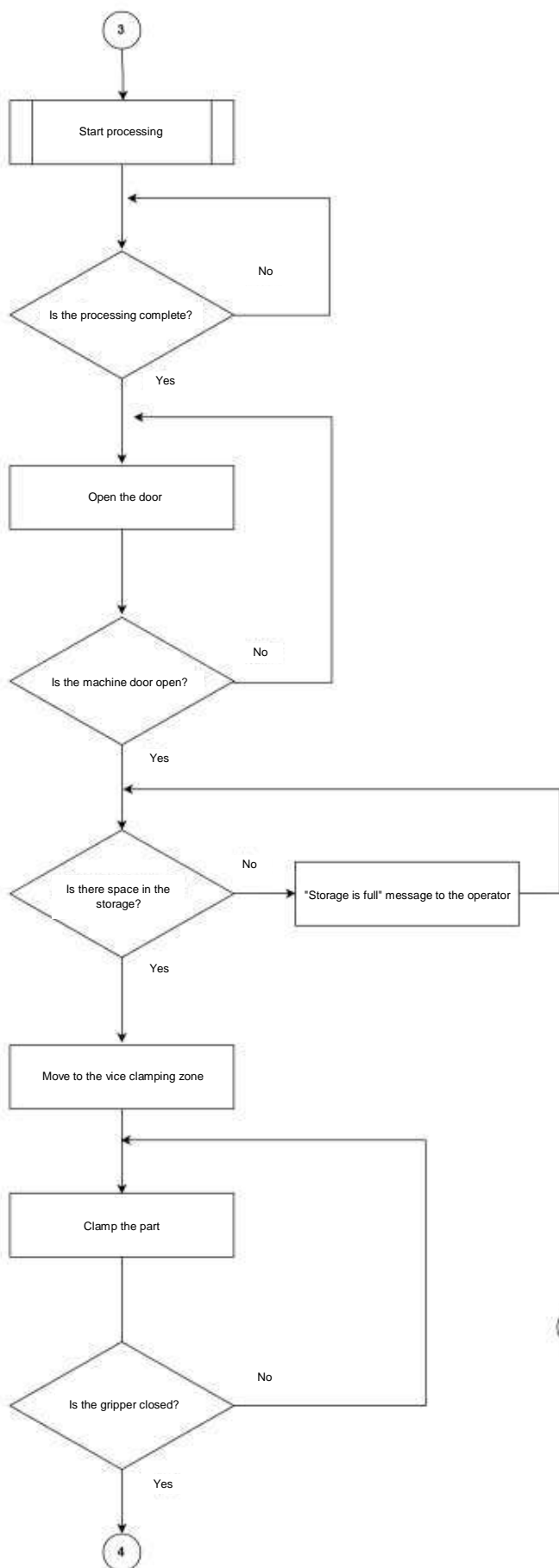
Appendix 1. Example of a pneumatic system
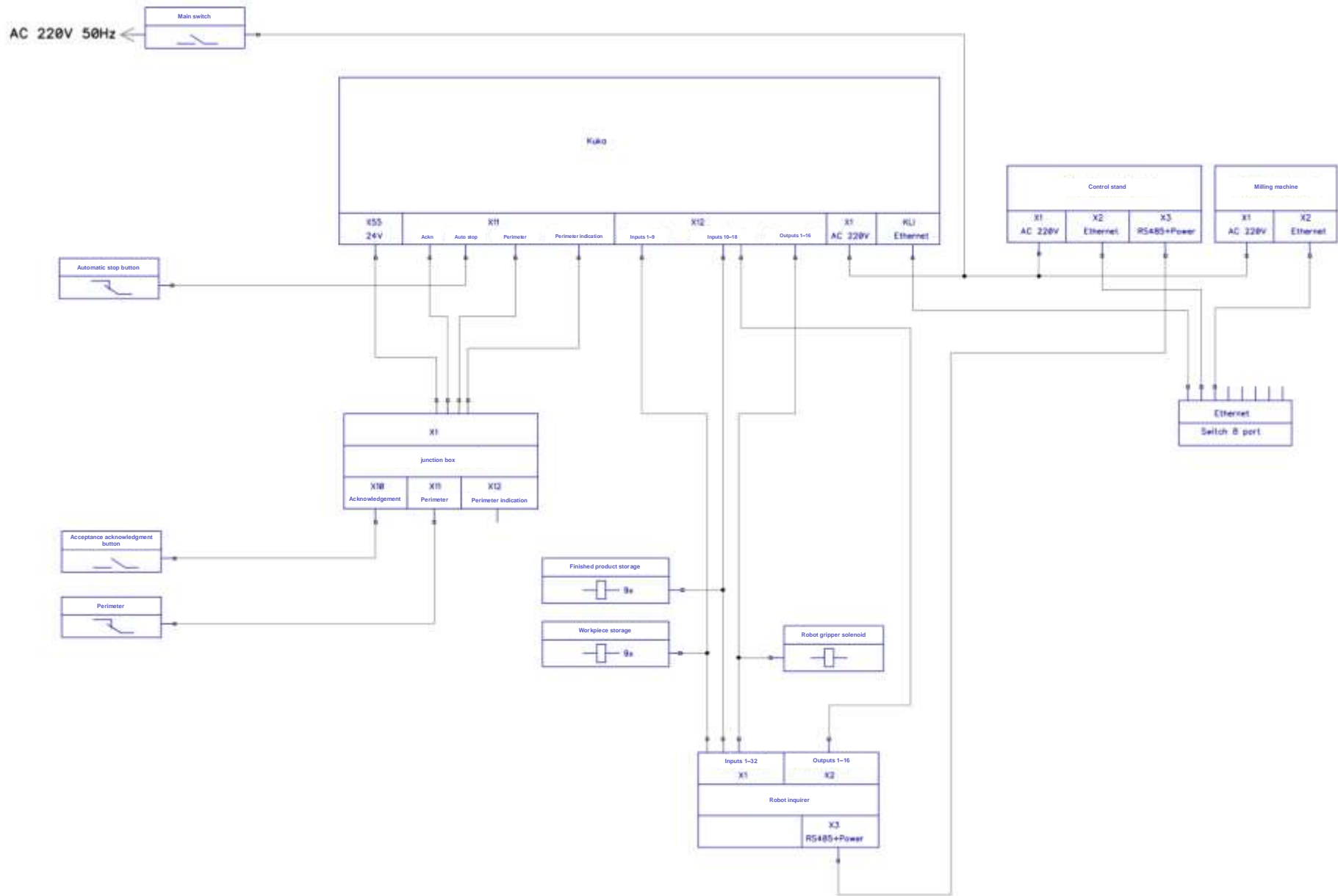
Appendix 2. Example of a pneumatic system

Appendix 3. Example of the machine loading/unloading sequence

Left column:

(Start)

(5) →

Do the workpieces need to be processed? — No → (1)

Yes ↓

Is there a workpiece at the storage? — No → (1)

Yes ↓

Is the gripper open? — No → Open the gripper

Yes ↓

Move to the workpiece gripping position

↓

Clamp the workpiece

↓

Is the gripper closed? — No

Yes ↓

Move to the neutral position

↓

Is the machine door open? — No → Open the door

Yes ↓

(2)

Right column:

(2)

↓

Is the vice open? — No → Open the vice

Yes ↓

Move to the vice clamping zone

↓

Is there a workpiece in the vice? — No → "Error, no workpiece in the vice" operator's message → (1)

Yes ↓

Clamp the vice

↓

Is the vice clamped? — No

Yes ↓

Open the gripper

↓

Is the gripper open? — No

Yes ↓

Move to the neutral position

↓

Close the door

↓

(3)

(3)

Start processing

Is the processing complete? — No

Yes

Open the door

Is the machine door open? — No

Yes

Is there space in the storage? — No → "Storage is full" message to the operator

Yes

Move to the vice clamping zone

Clamp the part

Is the gripper closed? — No

Yes

(4)

---

(4)

Unclamp the vice

Is the vice unclamped? — No

Yes

Move to the neutral position

Move to an empty part storage position

Open the gripper

Is the gripper open? — No

Yes

Move to the neutral position

(1)

(5)

End

Module 4: Operation of automated lines

The competitor shall commission a robotic cell that performs the toy car assembly process. The assembly line consists of (Figure 1): two industrial robots (1, 2) jointly participating in the assembly process. A car is assembled from three components stored in the magazine storage unit (3) and on the storage tables (4, 5). The conveyor sends assembled cars to the storage (6)

The assembly line is controlled from the operator's panel. The MES system is responsible for production scheduling and industrial robot job assignments.
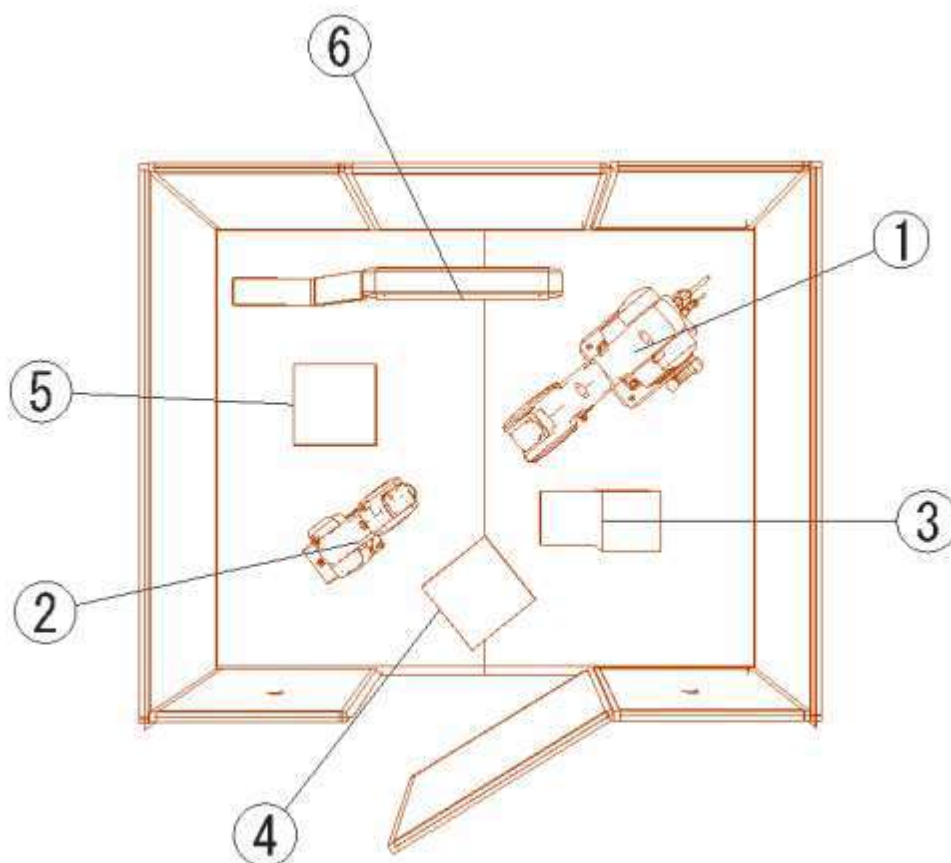

Figure 1. Car assembly line

The commissioning includes the following:
1.) Switching on the equipment.
2.) System configuration and function check.
3.) RAS commissioning.
4.) Writing assembly programs.
5.) Writing programs for external automation mode.
6.) Saving images and backups of the configured robotic cell.

Original state of equipment:

-       The electrical equipment to be operated by the Competitor must be prepared by the Workshop Manager or the Expert assigned to this module, in accordance with the inter-industry occupational safety rules in the operation of electrical equipment POT R M-016-2001, RD 153-34.0- 03.150-00 (Appendix B, at the end of the Test Project).

- The robot safety system has been fully configured and connected.
- The cell is completely assembled.
- The robot stands in the training cell; the power and data cables between the robot controller and the industrial robot are connected. The control unit of the industrial robot is also connected.
- The MES system, PLC, and HMI are set up and configured; all connections are made (Figure 2).
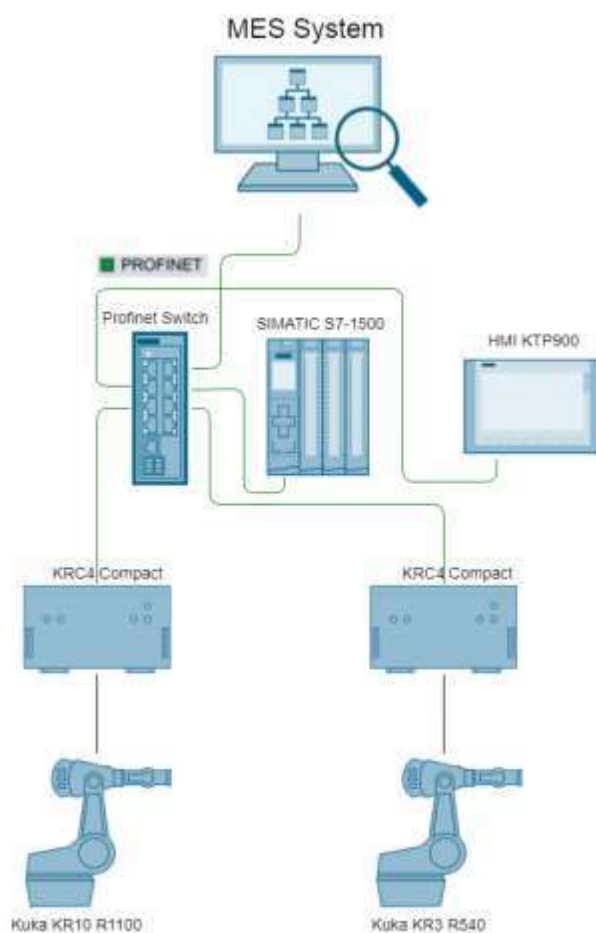

Figure 2. Structural diagram of the assembly line APCS

- The robots are set in the initial position (with previously written Home_Line programs moving the industrial robots to the initial position).
- The following parameters have been reset: additional loads on the robot axes, tool calibration data, tool weight and center of gravity, user coordinate system calibration data, robot I/O configurations; all the programs except "Home_Line" have been deleted.
- Inputs/outputs of the industrial robot have not been configured. The signals from the I/O modules of the industrial logic controller (PLC) are not connected to the sensors and actuators of the system. The names of the signals in the robot control system have not been specified.
- All the necessary documentation (technical descriptions, assembling manuals, pneumatic and electrical circuit diagrams, photographs) are located in the DataSheet and CircuitDiagrams folders on the laptop, respectively.

Item 1. Switching on the equipment
1.) Switch on the industrial robots.
2.) Switch on the compressor and set the outlet pressure to 3 bar.

Item 2. System configuration and function check.

1.) Start the WorkVisual software.
2.) Download the current project from the Kuka KR 10 R1100 robot and save it in the WV folder (in the Assembly Line folder) under the name "Assembly_KR10_xxx", where "xxx" is the name of the Competitor in English.
3.) Configure the digital I/Os of the industrial robot according to Table 1-4.
4.) Run element-by-element functional test of the cell. **Prior to the check, notify the expert thereof.**
5.) Perform Items 1–4 for the Kuka KR 3 R540 robot (Table 5-8).

Table 1. Input configuration table for Kuka KR 10 R1100 robot with EM8905-1001 I/O-Modul

Signal name	Output No. EM8905-1001 I/O-Modul	Robot output No.	Description
Open_gripper	8	1	Signal from the robot to open the gripper
Close_gripper	11	2	Signal from the robot to close the gripper

Table 2. Input configuration table for Kuka KR 10 R1100 robot with an EtherCAT coupler

Signal name	Input No. EtherCAT coupler	Robot input No.	Description
Gripper_open	1	1	Signal to the industrial robot that the gripper is open
Gripper_close	2	2	Signal to the industrial robot that the gripper is closed

Table 3. Input configuration table for the Kuka KR 10 R1100 robot with PROFINET IO

Signal name	Input No. PROFINET IO	Robot input No.	Description
Component- 1_on	1	2000	Signal to the industrial robot that component 1 is in the discharge area of the spring magazine
Component_magazine_on	2	2001	"Rod extended" signal to the industrial robot on the magazine's pneumatic cylinder condition
Component_magazine_off	3	2002	"Rod retracted" signal to the industrial robot on the magazine's pneumatic cylinder condition
Car_in_position_1	4	2003	The conveyor signals to the industrial robot that the assembled car is in Zone 1 (start of the conveyor)
Car_in_position_2	5	2004	The conveyor signals to the industrial robot that the assembled car is in Zone 2 (end of the conveyor)
Collision_zone_free	6	2005	Signal to the industrial robot on the assembly zone status. Signal = 1, the zone is free, Signal = 0, the zone is busy
Conveyor_zone_free	7	2006	Signal to the industrial robot on conveyor status. Signal = 1, the conveyor is free, Signal = 0, the conveyor is busy
	8–256	2007–2255	Available input signals

Table 4. Input configuration table for the Kuka KR 10 R1100 robot with PROFINET IO

Signal name	Output No. PROFINET IO	Robot output No.	Description
Components_magazine_on	1	2000	Signal to feed the first component for the magazine

Conveyor on	2	2001	Signal to switch on the conveyor
Take_collision_zone	3	2002	Industrial robot signals of taking the assembly zone
Component_1	4	2003	The robot signals the MES that it has installed the 1st component
Car	5	2004	The robot signals the MES that it has mounted the assembled machine on the conveyor
	6–256	2005–2255	Available output signals

Table 5. Output configuration table for the Kuka KR 6 R1100 robot with an EtherCAT coupler

Signal name	Output No. EtherCAT coupler	Robot output No.	Description
Open_gripper	1	1	Signal from the robot to open the gripper
Close_gripper	2	2	Signal from the robot to close the gripper

Table 6. Input configuration table for the Kuka KR 6 R1100 robot with an EtherCAT coupler

Signal name	Input No. EtherCAT coupler	Robot input No.	Description
Gripper_open	1	1	Signal to the industrial robot that the gripper is open
Gripper_close	2	2	Signal to the industrial robot that the gripper is closed

Table 7. Input configuration table for the Kuka KR3 R540 robot with PROFINET IO

Signal name	Input No. PROFINET IO	Robot input No.	Description
Collision_zone_free	1	2000	Signal to the industrial robot on the assembly zone status. Signal = 1, the zone is free, Signal = 0, the zone is busy
	2–256	2001–2255	Available input signals

Table 8. Output configuration table for the Kuka KR3 R540 robot with PROFINET IO

Signal name	Output No. PROFINET IO	Robot output No.	Description
Take_collision_zone	1	2000	Industrial robot signals of taking the assembly zone
Component_2	2	2001	The robot signals the MES that it has installed the 2nd component
Component_3	3	2002	The robot signals the MES that it has installed the 3rd component
	4–256	2003–2255	Available output signals

Item 3. Commissioning of the industrial robot

1.) Specify additional axial loads on Industrial Robot 1 (Kuka KR10 R1100).
2.) Calibrate the gripper Use tool number 1 to save the tool calibration data. The tool name should be "Gripper". The tool calibration tolerance shall be within 0.3 mm.
3.) Calibrate the direction of the tool 1 impact direction.
4.) Specify the tool weight and center of gravity in relation to the robot flange according to Table 4.

Table 9. Tool loading data

Weight					
M	3.84 kg				
Center of gravity		Orientation		Moment of inertia	
X	11.09 mm	A	176.19°	JX	0.05 kg*m^2
Y	−0.96 mm	B	−89.72°	JY	0.12 kg*m^2
Z	0.00 mm	C	93.83°	JZ	0.15 kg*m^2

5.) Use Tool 1 to calibrate the user coordinate system for: Components_magazine, Assembly_position, and Conveyor.

6.) Repeat steps 1 to 3 for Industrial Robot 2 (Kuka KR R540).

7.) Specify the tool weight and center of gravity in relation to the robot flange according to Table 4.

Table 9. Tool loading data

Weight					
M	3.84 kg				
Center of gravity		Orientation		Moment of inertia	
X	11.09 mm	A	176.19°	JX	0.05 kg*m^2
Y	−0.96 mm	B	−89.72°	JY	0.12 kg*m^2
Z	0.00 mm	C	93.83°	JZ	0.15 kg*m^2

8.) Use Tool 1 to calibrate the user coordinate system for: Body_pallet, Cabin_pallet, and Assembly_position

Item 4. Writing assembly programs.

For Industrial Robot 1 (Kuka KR10 R1100), write an assembly program for toy trucks:

1.) Create a **Chassis program** for the robot to move the chassis from the components magazine to the assembly zone as follows:

A.) Check if chassis is retrievable from the components magazine. If not, request chassis release (Components_magazine_on output).

B.) Make sure the pneumatic cylinder piston which feeds the chassis is drawn out and the chassis can be retrieved, then grip it.

C.) Set the chassis in the assembly position and return to the neutral position.

Consider the following aspects when writing the program:
- Before gripping the chassis, check the gripper status: open it, if closed.
- After the device has been commanded to close, wait until the gripper closes before proceeding.
- Any motions related to the components magazine should be performed with the Components_magazine base. The same applies to Assembly_position.
- The speed of PTP motions must not exceed 10%.

- The speed of linear motions over a distance of 100 mm between any obstacle and elements of the robot may not exceed 0.25 m/s and may be optimized, without the robot stopping in the programmed point (motion smoothing).
- The speed of linear motions at a distance less than 100 mm between any obstacle and elements of the robot may not exceed 0.1 m/s.

2.) Create a **Car program** for the robot to move the newly assembled car from the assembly zone onto the conveyor:

A.) Place the car on the conveyor and return to the neutral position.

B.) Command the conveyor to start.

Consider the following aspects when writing the program:
- Before gripping the car, check the gripper status: open it, if closed.
- After the device has been commanded to close, wait until the gripper closes before proceeding.
- The conveyor will stop automatically when the car crosses the final segment (Conveyor Position 2).
- Any motions related to the assembly position should be performed with the Assembly_position base. The same applies to Conveyor.
- The speed of PTP motions must not exceed 10%.
- The speed of linear motions over a distance of 100 mm between any obstacle and elements of the robot may not exceed 0.25 m/s and may be optimized, without the robot stopping in the programmed point (motion smoothing).
- The speed of linear motions at a distance less than 100 mm between any obstacle and elements of the robot may not exceed 0.1 m/s.

For Industrial Robot 2 (Kuka KR3 R540), write an assembly program for toy trucks:

3.) Create a **Body_type1 program**, for the robot to move the body (type 1) from the body pallet to the assembly zone as follows:

A.) Place the body (type 1) onto the chassis, which must already be in the assembly position. Return to the neutral position.

B.) Recalculate the coordinates for gripping the second body.

Consider the following aspects when writing the program:
- Before gripping the chassis, check the gripper status: open it, if closed.
- After the device has been commanded to close, wait until the gripper closes before proceeding.
- Any motions related to the body pallet should be performed with the Body_pallet base. The same applies to Assembly_position.
- The speed of PTP motions must not exceed 10%.
- The speed of linear motions over a distance of 100 mm between any obstacle and elements of the robot may not exceed 0.25 m/s and may be optimized, without the robot stopping in the programmed point (motion smoothing).
- The speed of linear motions at a distance less than 100 mm between any obstacle and elements of the robot may not exceed 0.1 m/s.

4.) Create **Body_type2 program** for the robot to move the body (type 2) from the body pallet to the assembly zone as follows: When coding the program, consider what was done specifically for **Body_type1**.

1.) Create **Cabin_type1 program** for the robot to move the cabin (type 1) from the body pallet to the assembly zone as follows:

A.) Place the cabin (type 1) onto the chassis, which must already be in the assembly position. Return to the neutral position.

B.) Recalculate the coordinates for gripping the second cabin.

Consider the following aspects when writing the program:
- Before gripping the cabin, check the gripper status: open it, if closed.
- After the device has been commanded to close, wait until the gripper closes before proceeding.
- Any motions related to the cabin pallet should be performed with the Cabin_pallet base. The same applies to Assembly_position.
- The speed of PTP motions must not exceed 10%.
- The speed of linear motions over a distance of 100 mm between any obstacle and elements of the robot may not exceed 0.25 m/s and may be optimized, without the robot stopping in the programmed point (motion smoothing).
- The speed of linear motions at a distance less than 100 mm between any obstacle and elements of the robot may not exceed 0.1 m/s.

5.) Create a **Cabin_type2 program** for the robot to move the cabin (type 2) from the body pallet to the assembly zone as follows: When coding the program, consider what was done specifically for **Cabin_type1**.

6.) **The fully debugged programs shall be tested** in the presence of the Expert in T1 mode at a 100% speed.

7.) Upon approval by the Expert, the fully debugged programs shall be tested in the presence of the Expert in T2 mode at a speed forcibly reduced to 50%.

8.) Upon approval by the Expert, the fully debugged programs shall be tested in the presence of the Expert in AUT mode at a speed forcibly reduced to 70%.

Item 5. Writing programs for external automation mode

For Industrial Robot 1 (Kuka KR10 R1100), write an external automation program:

1.) Run CELL in R1\System.

2.) Edit SWITCH-CASE for CASE 1:

A.) Replace ";EXAMPLE1" with "Chassis".

B.) Run Chassis ONLY if the assembly zone is free.

C.) Upon confirming that the assembly zone is free, Take_collision_zone.

D.) Upon completing Chassis, the robot must signal the MES it has set the chassis in the assembly position (Component_1).

The complex management system should run the following sequence to check the zone:

If none of the robots have taken the assembly zone (Figure 3), both report $OUT[2002]=FALSE. The PLC sends $IN[2005]=TRUE to both.
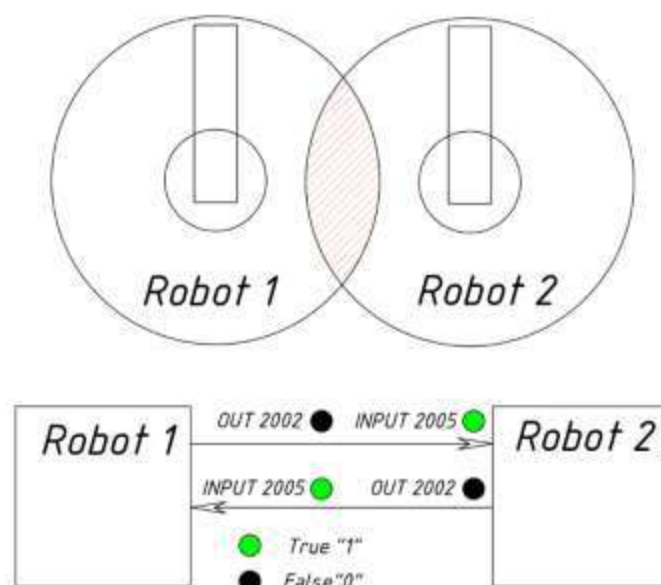
Figure 3. I/O status when none of the robots have taken the assembly zone

If Robot 1 is to take the assembly zone (Figure 4), first check if it is not taken ($IN[2005]=TRUE); then Robot 1 takes the zone $OUT[2002]= TRUE. The PLC reports to Robot 2 that the zone is taken $IN[2005]=FALSE.
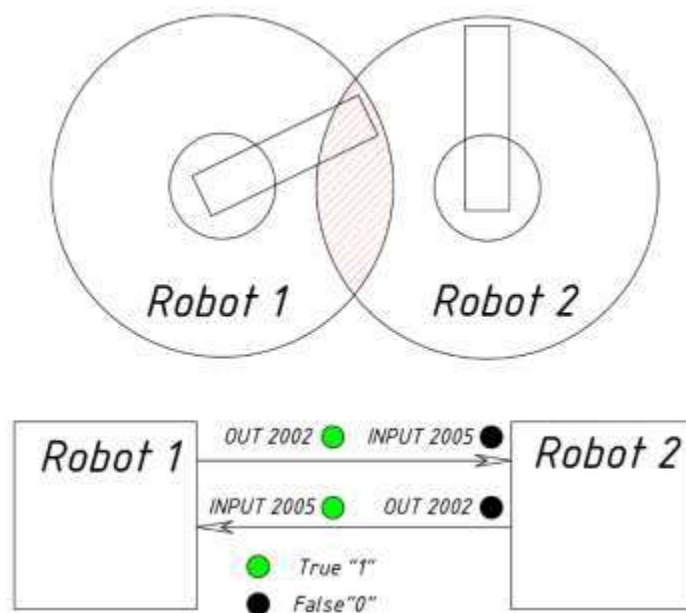

Figure 4. I/O status when Robot 1 has taken the assembly zone

If Robot 2 is to take the assembly zone (Figure 4), first check if it is not taken ($IN[2005]=TRUE); then Robot 2 takes the zone $OUT[2002]= TRUE. The PLC reports to Robot 1 that the zone is taken $IN[2005]=FALSE.
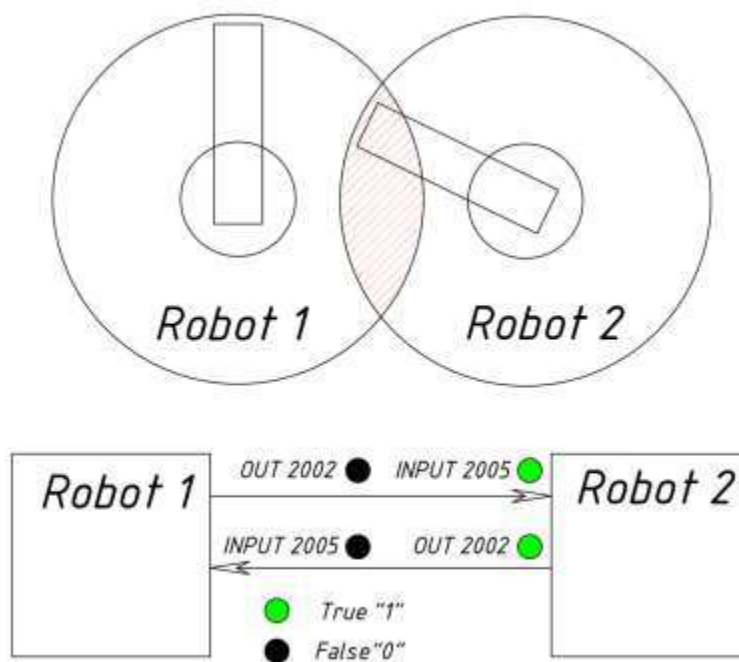
Figure 5. I/O status when Robot 2 has taken the assembly zone

3.) Similarly to CASE 1, follow the sequence (Figure 6) to edit the SWITCH- CASE for CASE 2.
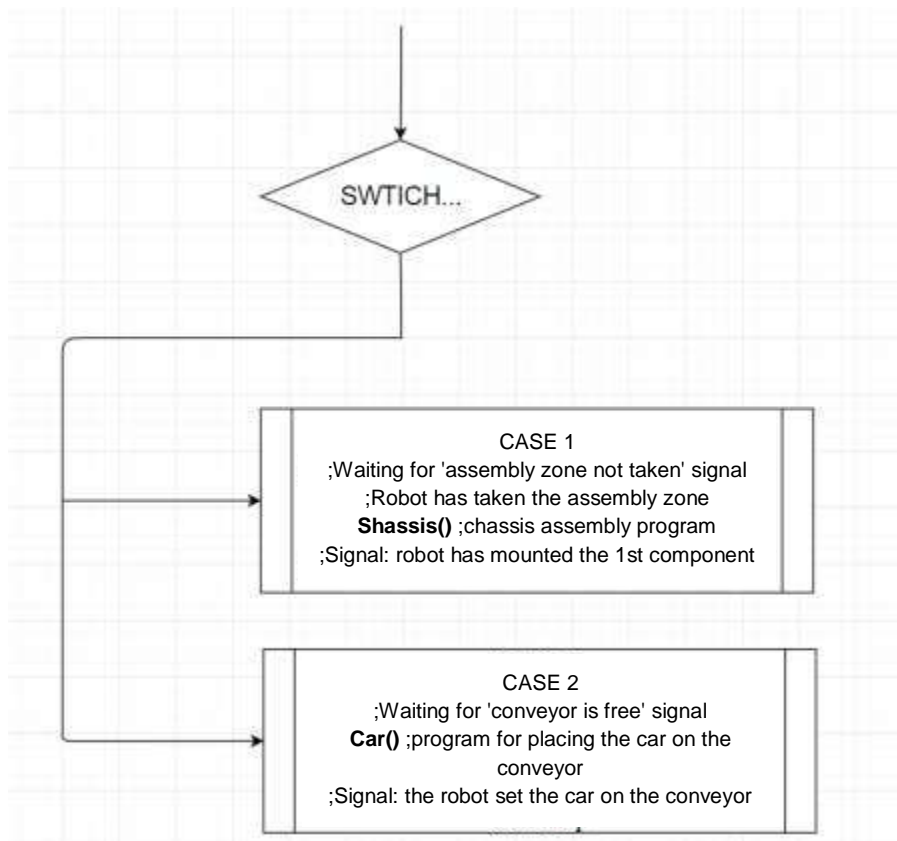

Figure 6. CELL switch-case sequence, Robot 1

4.) <u>For Industrial Robot 2 (Kuka KR3 R540)</u>, write an external automation program external (Figure 7) similarly to Steps 1 to 3.
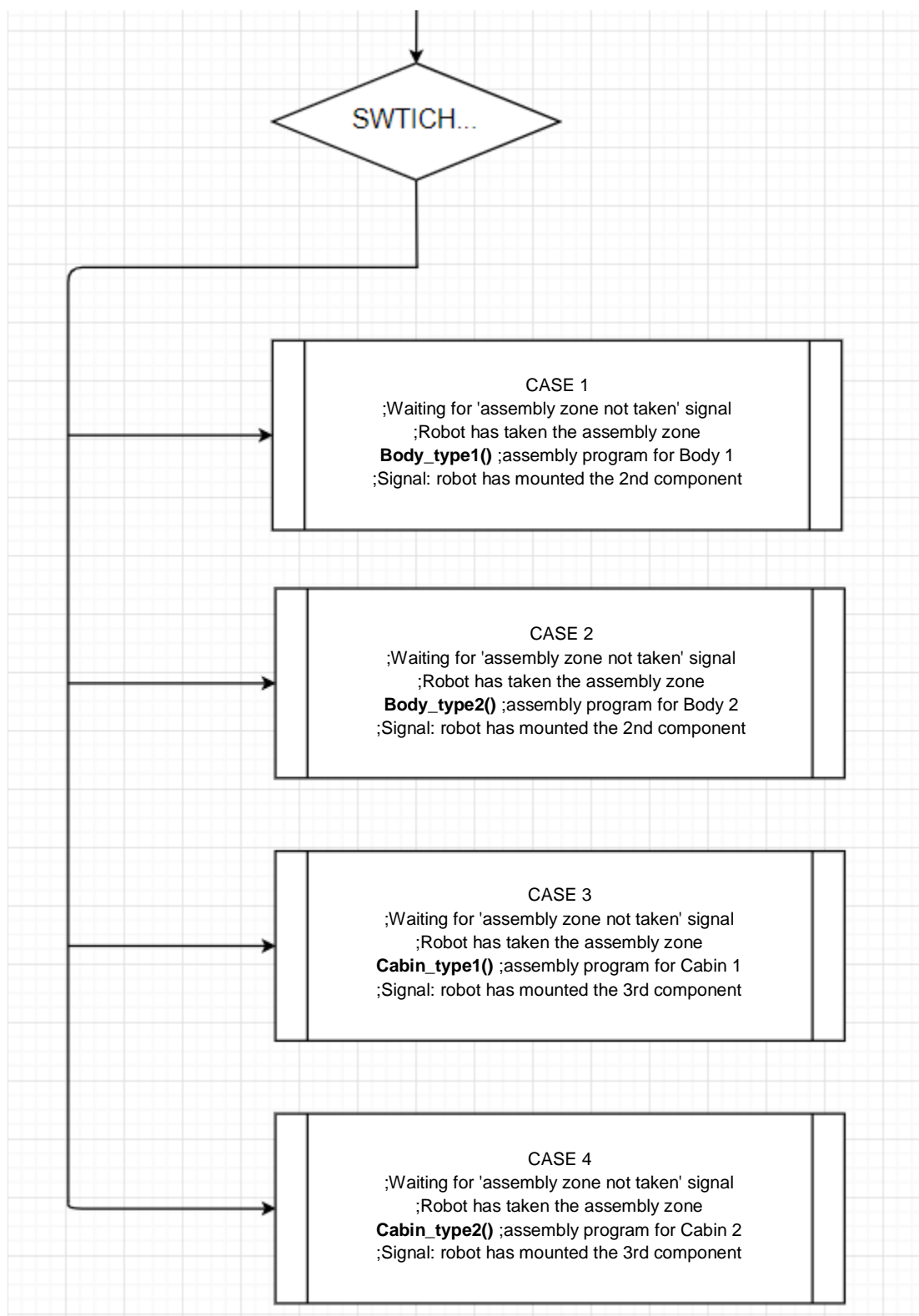

Figure 7 — Figure 6 — CELL switch-case sequence, Robot 2

5.) **The fully debugged programs** shall be tested in the presence of the Expert in EXT mode at a 30% speed at max.

Item 6. Saving images and backups of the configured robotic cell

Save the image and backup of the configured robotic cell using a special flash drive.

1.) To save the image, create an "IM xxx" folder in the "Assembly Line" folder (on the desktop), where the 'xxx' shall be replaced with the industrial robot number.

2.) To save the backup, create a "BackUp xxx" folder in the "Assembly Line" folder (on the desktop), where the 'xxx' shall be replaced with the industrial robot number.

Module 5. Spot welding

The competitor shall commission a robotic cell that performs an automated spot-welding operation on the article.

The commissioning includes the following:

1.) Installation.
2.) Switching on the equipment. Completing the installation.
3.) System configuration and function check.
4.) Running the offline programming system.
5.) RAS commissioning.
6.) Adjusting the program.
7.) Saving the image and backup of the configured robotic cell.

Original state of equipment:

- The electrical equipment to be operated by the Competitor must be prepared by the Workshop Manager or the Expert assigned to this module, in accordance with the inter-industry occupational safety rules in the operation of electrical equipment POT R M-016-2001, RD 153-34.0- 03.150-00 (Appendix B, at the end of the Test Project).

- The robot safety system has been fully configured and connected.

- The equipment is laid out on the desktop element by element.

- The robot and the transformer are in the training cell; the power and data cables between the robot controller and the industrial robot are connected. The control unit of the industrial robot is also connected.

- The robot has been moved to the initial position (the Home_Spot program, which moves the industrial robot to its starting position, has been created in advance).

- The following parameters have been reset: additional loads on the robot axes, tool calibration data, tool weight and center of gravity, user coordinate system calibration data, robot I/O configurations; all the user programs except Home_Spot have been deleted.

- Inputs/outputs of the industrial robot have not been configured. The signals from the I/O modules of the industrial logic controller (PLC) are not connected to the sensors and actuators of the system. The names of the signals in the robot control system have not been specified.

- The laptop has an offline programming system with ready-made 3D models of the entire system. 3D models are in folders on the desktop.

- All the necessary documentation (technical descriptions, assembling manuals, pneumatic and electrical circuit diagrams, photographs) are located in the DataSheet and CircuitDiagrams folders on the laptop, respectively.

Item 1. Installation

1.) Mount the welding gun on the flange of the industrial robot.
2.) Mount electrode holders on the gun.
3.) Mount electrodes on the holders.
4.) Lay and attach the hose on the housing; ensure the extra length for the robot assemblies to move freely.
5.) Connect gun power cables to the transformer.
6.) Connect coolant hoses.
7.) Make the electrical connections according to the electrical circuit diagrams.

8.) Connect the pneumatic lines according to the pneumatic circuit diagram.

9.) Mount the welding tooling in the robot cell as shown in the complex diagram. Fasten it.

The assembled robot-assisted system shall be checked by the Expert when the installation is complete. The Expert shall sign the "Report on Robot-Assisted System Assembly Check" to give authorization for powering up the RAS (see Appendix A at the end of the Test Project).

Item 2. Voltage supply. Completing the installation

1.) Switch on the industrial robot.

2.) Power on the transformer.

3.) Switch on the compressor and set the outlet pressure to 6 bar.

Item 3. System configuration and function check

1.) Install the necessary software on the robot.

2.) Configure the industrial robot I/O and sign them per Tables 1 to 3.

3.) Test the functionality of system elements one by one. Prior to the check, notify the expert thereof.

Table 1. Output configuration table for a robot with Robot I/O-Modul

Signal name	Output No. Robot I/O-Modul	Robot output No.	Description
Open_gripper	7	1	Signal from the robot to open the welding gun
Close_gripper	10	2	Signal from the robot to close the welding gun

Table 3. Input configuration table for PLC-equipped robot

Signal name	PLC Input No.	Robot input No.	Description
Air_on	1	1	Signal to the industrial robot: air pressure is on-line
Water_on	2	2	Signal to the industrial robot: coolant is on-line
Gun_open	3	3	Signal to the industrial robot: gun is open
Gun_close	4	4	Signal to the industrial robot: gun is close
	5–16	5–16	Available input signals

Table 4. Output configuration table for PLC-equipped robot

Signal name	PLC Output No.	Robot output No.	Description
Weld on	1	3	Signal from the industrial robot to begin welding
Cooling on	2	4	Signal from the industrial robot to switch on cooling
Dress_on	3	5	Signal from the industrial robot to start electrode cleaning
	4–16	6–18	Available output signals

Item 4. Running the offline programming system

1.) Launch the offline programming system.

2.) Arrange the robotic cell per the documentation (cell component documents and 3D models are stored in a folder on the desktop).

3.) Calibrate Tool 1 (Servo_gun). The tool center point (TCP) is the central point of the immobile electrode.

4.) Calibrate the user coordinate system for Clamp_table, Dress_station.

5.) Write a Tip_dress program to dress electrodes following the sequence:

A) Check the gun status, open if closed.

B) Move to the dressing position.

C) Close the gun.

D) Turn on the dressing mechanism for 1.5 seconds, then turn off.

E) Return to home position.

Consider the following aspects when writing the program:

- Any motions related to, or taken in the vicinity of, the electrode dress station must use the Dress_station user coordinate system.

- Axial motion speed must not exceed 10%.

- The speed of linear motions over a distance of 100 mm between any obstacle and elements of the robot may not exceed 0.4 m/s and may be optimized, without stopping the robot at a programmed point (motion smoothing).

- The speed of linear motions at a distance less than 100 mm between any obstacle and elements of the robot may not exceed 0.15 m/s.

6.) Write Spot_Welding program using the following sequence:

A) Check if air is on-line ('Air_on' signal).

B) Turn on the cooling system, check if coolant is on-line ('Water_on' signal).

C) Check the gun status: open it, if closed.

D) Move to Welding Point 1.

E) Close the gun.

F) Weld.

G) Open the welding gun.

H) Move to the next point.

Consider the following aspects when writing the program:

- Any motions related to, or taken in the vicinity of, the clamp table must use the Clamp_table user coordinate system.

- Axial motion speed must not exceed 10%.

- The speed of linear motions over a distance of 100 mm between any obstacle and elements of the robot may not exceed 0.4 m/s and may be optimized, without stopping the robot at a programmed point (motion smoothing).

- The speed of linear motions at a distance less than 100 mm between any obstacle and elements of the robot may not exceed 0.10 m/s.

- The welding position point names must match those in the process flow charts (Figure 1).

- The program must count the welded points; after each 10 welded points, run Tip_dress.

Figure 1. Example segment of the process flow chart

7.) Unload the resulting control programs to a flash storage device.

8.) Save the project to the desktop.

Item 5. RAS commissioning
1.) Specify additional loads on the axis of the industrial robot.
2.) Calibrate Tool 1 (Servo_gun). Data for calibration shall be taken from the offline programming system.
3.) Specify the tool weight and center of gravity in relation to the robot flange.
4.) Calibrate the Clamp_table user coordinate system. Data for calibration shall be taken from the offline programming system.
5.) Calibrate the Dress_station user coordinate system. Axial directions and coordinate system numbers must match those in the offline programming system.

Item 6. Adjusting the program

1.) Move the Tip_dress and Spot_Welding control programs from the Flash storage to the robot controller.
2.) Start the control program in the T1 mode and check it for errors and collisions.
3.) If collisions or errors are detected, eliminate them.
4.) Supplement the program with required logical elements, if necessary.
5.) The fully debugged program shall be tested in the presence of the Expert in T1 mode at a 100% speed.
6.) Upon approval by the Expert, the fully debugged program shall be tested in the presence of the Expert in T2 mode at a speed forcibly reduced to 50%.
7.) Upon approval by the Expert, the fully debugged program shall be tested in the presence of the Expert in AUT mode at a speed forcibly reduced to 70%.

Item 7. Saving the image and backup of the configured robotic cell
1.) Save the image and backup of the configured robotic cell using a special flash drive.
2.) To save the image, create an "IM xxx" folder in the "Milling Robot" folder (on the desktop), where the 'xxx' shall be replaced with the industrial robot number.
3.) To save the backup, create a "BackUp xxx" folder in the "Milling Robot" folder (on the desktop), where the 'xxx' shall be replaced with the industrial robot number.

4. ASSESSMENT CRITERIA

This section defines the assessment criteria and the number of allotted points (judgment and measurement aspects), as given in Table 2. The total number of project/module points for all Assessment Criteria is 100.

Table 2

Section	Criterion	of Assessment		
		Judgment	Measurement	Total
A	Robotized Welding	0	20	20
B	Milling	0	20	20
C	Machine loading/unloading	0	20	20
D	Operation of automated lines	0	20	20
E	Spot welding	0	20	20
Total =		0	100	100

5. APPENDICES TO THE TEST PROJECT

Appendix A. Report on Robot-Assisted System Assembly Check

<div align="right">Appendix 1.</div>

Report on Robot-Assisted System Assembly Check.

Workstation No./Full name	_____/ _____

I hereby confirm that the electrical installation is ready for connection to the voltage supply and further operation. All elements of the system are connected in accordance with the wiring diagrams as well as the electrical and pneumatic circuit diagrams.

Attempt 1	Attempt 2	Attempt 3

Expert / Full Name / Signature	Expert / Full Name / Signature	Expert / Full Name / Signature

Appendix B. Excerpt from INTER-INDUSTRY OCCUPATIONAL HEALTH AND SAFETY RULES in operation of electrical equipment

CHAPTER 3. VOLTAGE REMOVAL SAFETY MEASURES

To prepare the workplace and remove voltage, do the following:

3.1.1. Switch off and disconnect:

any conductive parts to be involved in operation;

non-insulated conductive parts that people, mechanisms, and handling machinery might accidentally approach.

3.1.3. After circuit-breakers, disconnectors, and manual load breakers are switched off, check visually whether they are actually off and whether there are no shunting jumpers.

3.1.5. In electrical machines rated under 1,000 V, remove voltage from any conductive part by disconnecting the manual switches (automatic circuit breakers in the cabinet); if there are fuses, remove them. If there are no fuses, lock the cabinet, cover the buttons, place insulating pads between switch contacts, etc. to prevent undesirable switching. When removing voltage by a remote-controlled switch, first break the secondary circuit of the closing coil.

An optional alternative is to isolate buses or disconnect the cable and wires from the switch or from the equipment to be involved in work.

Additionally, hang warning posters.

3.1.6. In case the contacts of a switch rated under 1,000 V cannot be checked visually, whether the switch is off can be checked by reading the voltage on its clamps or outgoing buses or on the wires and clamps of the equipment these switches operate.

3.2.1. To prevent voltage from being connected to the workplace, the handles of manually controlled switches (circuit breakers, disconnectors, manual load breakers, automatic circuit breakers, cutout switches) must carry warning posters, Do Not Switch On! Space is Manned (Figure 1)

Figure 1. Do Not Switch On! Space is Manned poster

The posters must be visible on the circuit breakers and buttons, whether remotely or locally controlled, as well as on the automatic circuit breakers and in the locations of removed switch-drive control and power circuit fuses.

3.3.1. To check whether voltage is on or off, use a voltage indicator pre-tested by specially designed instrumentation or by proximity to conductive parts known to be carrying voltage.

3.3.2. Switchgear voltage can be checked by a Cat. IV operative if the electrical equipment is rated above 1,000 V, a Cat. III operative if it is rated under 1,000 V.

3.3.4. When checking the voltage of a 6 to 20-kV OPL by a capacitance (non-pulsing) current-based indicator from a wooden/reinforced-concrete or telescopic support, make sure the indicator is sufficiently sensitive. To that end, its tip must be grounded.

3.3.6. In electrical equipment rated under 1,000 V with a grounded neutral, use a two-pole indicator to check both the inter-phase voltage and the voltage between each phase and the grounded housing/protective conductor. A pre-verified voltmeter can also be used. Test lamps may not be used.

3.3.7. Any device signaling that the device is off, any blocker, any continuous voltmeter, etc. is only an additional tool that confirms the voltage is off; such devices alone are not enough to conclude that voltage is off.