
**Physical device control — Interfaces
for automated machine tending —**

**Part 2:
Safety and control interface**

*Ensemble de commande pour les équipements — Interfaces pour le
chargement automatisé des machines —*

Partie 2: Interface de sécurité et de commande

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 184, *Automation systems and integration*, Subcommittee SC 1, *Physical device control*.

A list of all parts in the ISO 21919 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The ISO 21919 series describes interfaces for automated machine tending of at least one computer numerically controlled (CNC) machine by using a machine tending system. These interfaces are the link between automated machine tending systems and machines used for production. The automated machine tending is initiated by either the machine tending system or by the machine.

ISO 21919-1 gives an overview and defines the fundamental principles on how the interfaces are set up. It defines the necessary vocabulary and sets the syntax for the structure of signals. It distinguishes between the safety interface, the control interface and project specific extensions.

Automated machine tending refers to the automatic loading or unloading of one or more machines by using a machine tending system.

EXAMPLE Examples for machines are machine tools, typically computer numerically controlled (CNC), metrology co-ordinate measuring machines (CMM), 3D structured light scanner (3DSL), and X-ray machines. Examples for machine tending systems are robots, handling systems, gantrys, autonomous intelligent vehicles (AIV), and automated guided vehicles (AGV).

Automated machine tending is a substantial element in highly productive industrial environments. It is a complex endeavour. Necessary devices are complex systems by itself, are oftentimes provided by different suppliers and encounter each other at the production site first time. For a trouble-free collaboration of all units a clear definition of the interfaces is indispensable. For manufacturing systems such standardized interfaces at an international level haven't been defined yet.

Therefore, the definition of the interfaces often is project-specific from the scratch or each supplier tries to establish its in-house standards. These procedures cause great efforts, are prone to failure and hence take a lot of time and manpower. As each interface is built individually and testing beforehand is often not possible, commissioning times exceed the planned ones. Machine builders, system integrators and production plant operators report these issues being substantial obstacles for such automation projects.

Standardized interfaces lead to lean coordination processes, give higher planning reliability, shorten times for commissioning and are less error-prone.

On the other hand, automated machine tending systems can be very complex systems and standards need to be flexible enough to allow an adaption to the requirements of individual projects.

Applications are ranging from simple parts removal to material flow dedicated complex production lines. It is noteworthy that the processing technologies of the machines are independent to the interface and a majority of machine technologies can be integrated with the same standard.

[Figure 1](#) and [Figure 2](#) display the range of complexity of machine tending systems covered by the ISO 21919 series. [Figure 1](#) shows an example of a simple automated machine tending system, consisting of a machine tool loaded by a conveyor.

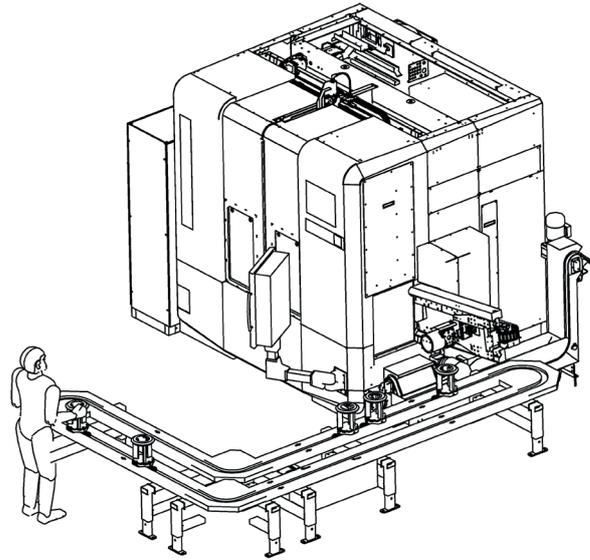


Figure 1 — Example of a simple automated machine tending system

[Figure 2](#) shows an example of a complex production line with five computer numerically controlled machine tools tended by a loading gantry.

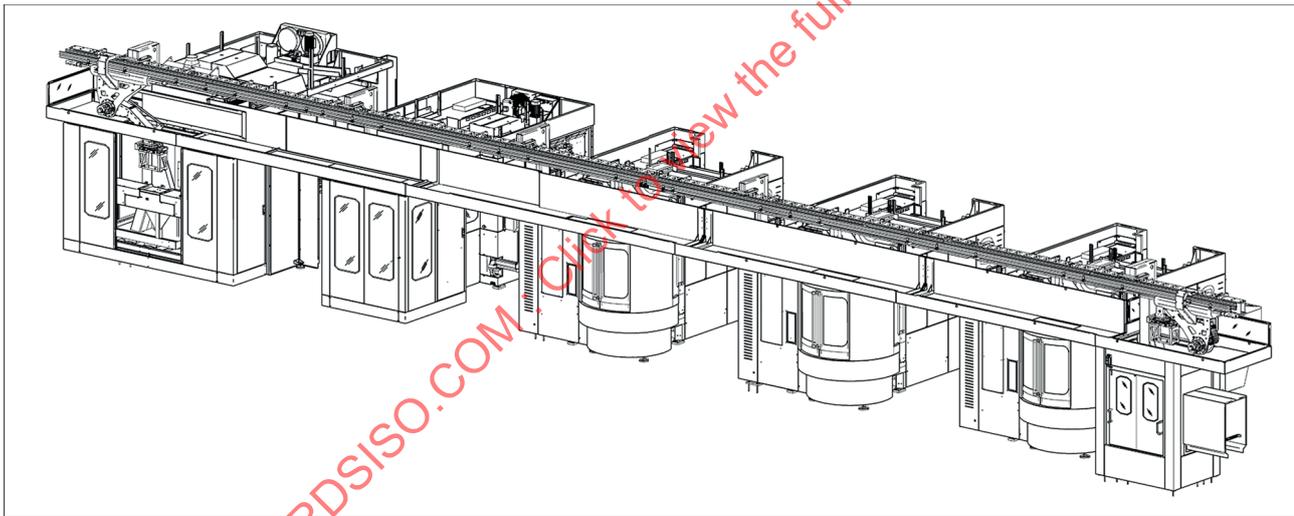


Figure 2 — Example of a complex production line loaded by a gantry

In general, the interfaces for automated machine tending are composed of:

- mechanical;
- control-related; and
- safety-related connections.

Physical device control — Interfaces for automated machine tending —

Part 2: Safety and control interface

1 Scope

This document deals with the safety interface and control interface. It allocates signals to a conformance class and/or conformance option. It describes the detailed functions of each signal, describes and displays the timing interactions between signals in flow charts and shows examples for safety matrices and safety-related functional relationships.

This document defines three conformance classes and dedicated conformance options. Classes and options consist of a number of signals to:

- allow a flexible adaptation of the interface(s) to a project-specific scope of functions and simultaneously;
- tie sets of signals tight enough to avoid unnecessary coordination efforts between suppliers of the machine tending systems and machines.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 13849-1, *Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design*

ISO 21919-1, *Automation systems and integration — Interfaces for automated machine tending — Part 1: Overview and fundamental principles*

IEC 62061, *Safety of machinery – Functional safety of safety-related electrical, electronic and programmable electronic control systems*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 21919-1 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

3.1

emergency stop

function which is intended to

- avert arising or reduce existing hazards to persons, damage to machinery or to work in progress, and

- be initiated by a single human action

Note 1 to entry: ISO 13850 gives detailed provisions.

[SOURCE: ISO 12100:2010, 3.40]

3.2

guard

physical barrier, designed as part of a functional unit to provide protection

[SOURCE: ISO 12100:2010, 3.27, modified — In the definition, "the machine" has been changed to "a functional unit". Notes 1 to 3 to entry have been removed.]

3.3

part family

all parts that a machine accepts for processing without a new set up

Note 1 to entry: A part family consists at least of one part.

4 Description of the interfaces

4.1 General

For an extensive description of the interfaces for automated machine tending, the following interfaces shall be defined:

- safety interface;
- control interface.

[Figure 3](#) shows the principle setup of the interfaces for automated machine tending.

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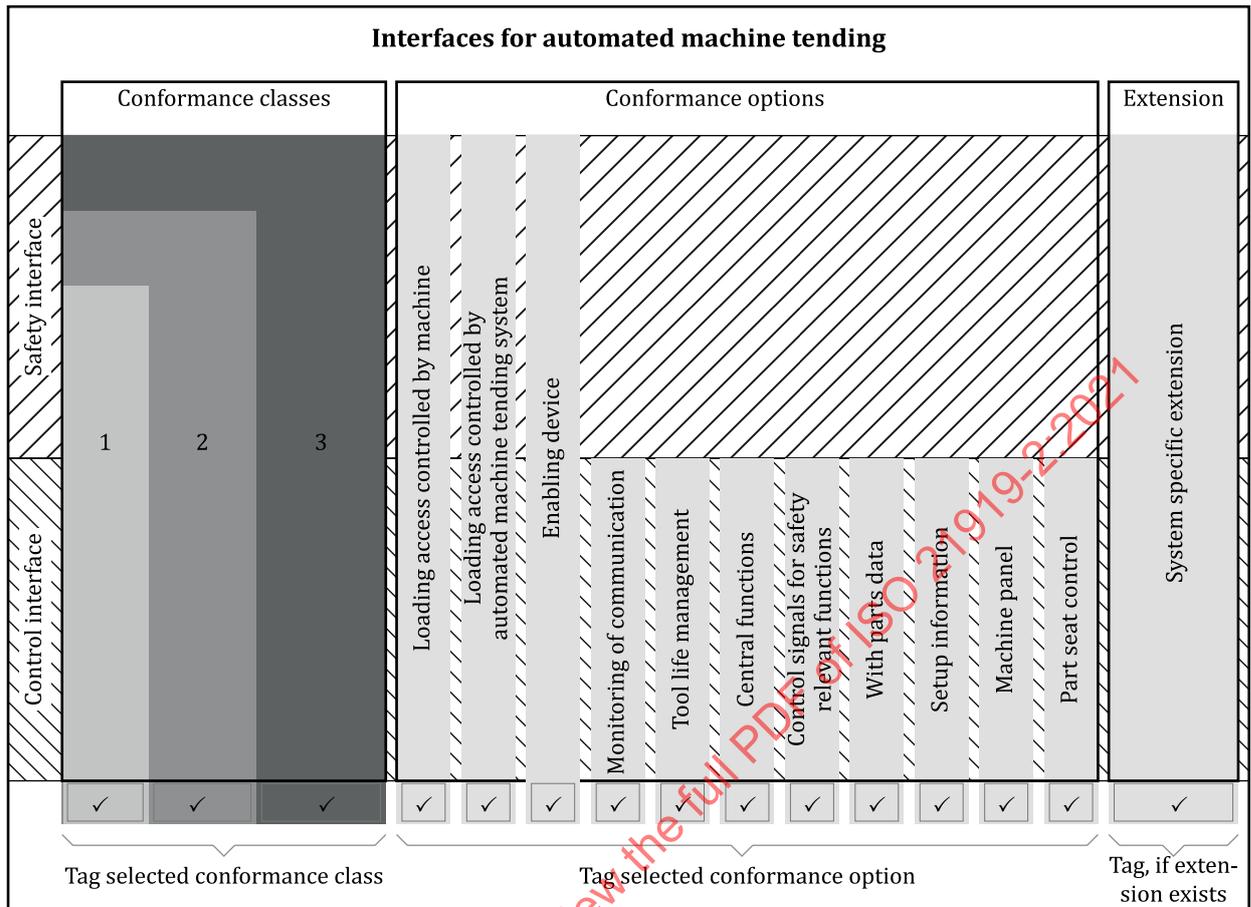


Figure 3 — Principle setup of the interface

4.2 Characteristics of the interface

4.2.1 General

The signals are grouped in conformance classes and conformance options for a flexible adaptation of the interface to the project-specific sets of functions. Grouping allows individual characterization of the interface while simultaneously meeting the requirements of this document.

For the application of this document, one conformance class shall be selected, all desired conformance options can be selected, and a project specific extension can be defined.

The signals assigned to the relevant conformance class or the relevant conformance option shall be made available at the interface if the characteristics on this conformance class/conformance option are selected.

When realizing the interface, the signals shall correlate in the way shown in the relevant flow charts in [Annex C](#).

4.2.2 Conformance class

4.2.2.1 General

With the selection of a conformance class a basic set of signals is selected in order to fulfil the task of automated machine tending.

The following conformance classes are available. Only one conformance class shall be selected.

- Conformance class 1: Minimum set of signals.
- Conformance class 2: Extended set of signals.
- Conformance class 3: Extended set of signals with process optimization.

4.2.2.2 Conformance class 1: Minimum set of signals

4.2.2.2.1 General

At conformance class 1, the following functions can be realized:

- safety of people;
- simple unloading;
- simple loading;
- simple combined unloading and loading.

The word "simple" indicates that there is no distinction between coherent and non-coherent transfer and that clamping functions are not handled via the interface.

Conformance class 1 is not applicable for machines that need coherent transfer.

4.2.2.2.2 Simple unloading

The function "simple unloading" serves the requirement to unload one part from the machine.

See the corresponding flow chart in [Figure C.1](#).

4.2.2.2.3 Simple loading

The function "simple loading" serves the requirement to load one part to the machine.

See the corresponding flow chart in [Figure C.2](#).

4.2.2.2.4 Simple combined unloading and loading

The function "simple combined unloading and loading" serves the requirement to unload one part from the machine and then load another part after that. The time period between unloading and subsequent loading is not defined.

However, the restriction applies that there shall be no machine movements required in the interference area during the loading and unloading process. In this case, the automated machine tending system can remain within the interference area.

See the corresponding flow chart in [Figure C.3](#).

4.2.2.3 Conformance class 2: Extended set of signals

4.2.2.3.1 General

At conformance class 2, all functions of conformance class 1 and the following can be realized:

- unloading with non-coherent transfer, with/without clamping function;
- unloading with coherent transfer;

- loading with non-coherent transfer, with/without clamping function;
- loading with coherent transfer;
- combined unloading and loading with non-coherent transfer, with/without clamping function;
- combined unloading and loading with coherent transfer;
- preparation of a part;
- emptying;
- functions of guard doors;
- further status information.

NOTE Conformance class 2 and conformance class 3 are typically implemented as bus interface as many signals are handled.

4.2.2.3.2 Unloading with non-coherent transfer, with/without clamping function

Function "Unloading with non-coherent transfer, with/without clamping function" serves the requirement to unload a part from the machine at non-coherent transfer.

See the corresponding flow chart in [Figure C.4](#).

4.2.2.3.3 Unloading with coherent transfer

Function "Unloading with non-coherent transfer, with clamping function" serves the requirement to unload a part from the machine at coherent transfer.

See the corresponding flow chart in [Figure C.5](#).

4.2.2.3.4 Loading with non-coherent transfer, with/without clamping function

Function "Loading with non-coherent transfer, with/without clamping function" serves the requirement to load a part from the machine at non-coherent transfer.

See the corresponding flow chart in [Figure C.6](#).

4.2.2.3.5 Loading with coherent transfer

Function "Loading with coherent transfer" serves the requirement to load a part from the machine at fixed transfer.

See the corresponding flow chart in [Figure C.7](#).

4.2.2.3.6 Combined unloading and loading with non-coherent transfer, with/without clamping function

Function "Combined unloading and loading with non-coherent transfer, with/without clamping function" serves the requirement to unload a part from the machine at not fixed transfer and then load another part to the machine. The time period between unloading and subsequent loading is not defined.

See the corresponding flow chart in [Figure C.8](#).

4.2.2.3.7 Combined unloading and loading with coherent transfer

Function "Combined unloading and loading with coherent transfer, with/without clamping function" serves the requirement to unload a part from the machine at coherent transfer and then load another part to the machine. The time period between unloading and subsequent loading is not defined.

See the corresponding flow chart in [Figure C.9](#).

4.2.2.3.8 Preparation of a part

Function "Preparation of a part" is used to inform the automated machine tending system at an early stage that there is no part at the loading space of the machine or that the machine will complete processing shortly.

4.2.2.3.9 Emptying

Function "Emptying" serves the requirement to unload all parts from the machine.

Emptying can be requested from the automated machine tending system to the machine, e.g. if there are no new raw parts.

If the machine needs to have all parts unloaded, it shall send a request to the automated machine tending system. Automated machine tending system decides when the machine can be unloaded and acknowledges the request by setting its request for emptying. Up to this point, the machine shall request loading cycles.

See the corresponding flow chart in [Figure C.10](#).

4.2.2.3.10 Function of guard doors

The functions of the guard doors serve the requirement to unlock the guard door(s), if necessary. Here, distinction shall be made whether the guard door is assigned to the automated machine tending system or to the machine. It can also be differentiated if a request for unlocking the guard door remains until the guard door has actually been unlocked or if the request has prematurely been withdrawn.

[Figure C.11](#) differentiates between the two cases and shows the corresponding flow charts.

4.2.2.3.11 Further status functions

Conformance class 2 contains further signals which provide information at the interface.

4.2.2.4 Conformance class 3: Extended set of signals with process optimization

4.2.2.4.1 General

At conformance class 3, all functions of conformance class 2 and the following can be realized:

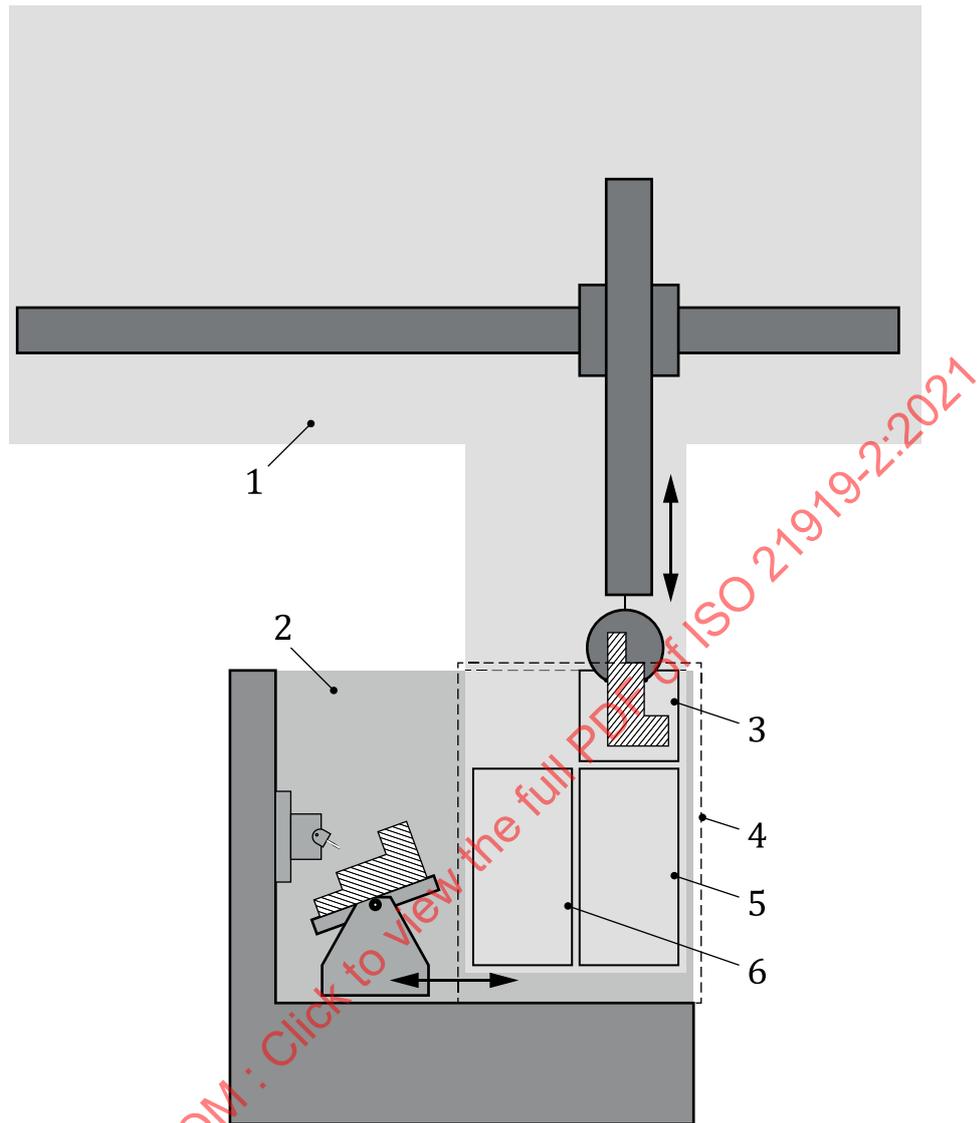
- process optimizations at the combined unloading and loading with coherent transfer;
- process optimizations at the combined unloading and loading with non-coherent transfer, with/without clamping function;
- process optimizations, if pre-positioning by the machine;
- process optimizations, if clamping and releasing is executed in more than one step.

4.2.2.4.2 Process optimizations at combined unloading and loading

4.2.2.4.2.1 General

Description of pre-positioning by the automated machine tending system.

[Figure 4](#) displays the principle coherence of different typical areas of machine and automated machine tending system and its interactions.

**Key**

- 1 range of automated machine tending system
- 2 range of machine
- 3 interference area preposition automated machine tending system
- 4 interference area
- 5 location of transfer station
- 6 interference area preposition machine

Figure 4 — Interference area at pre-positioning by automated machine tending system

Involved signals are AM_ENA_InIntfrArea, AM_STA_OutIntfrArea, AM_STA_OutIntfrAreaFixt, MA_ENA_InIntfrArea, MA_ENA_InIntfrAreaPrePos, and MA_STA_OutIntfrArea. For definition of these signals, see [Annex A](#).

4.2.2.4.2.2 With coherent transfer

The process optimizations at the combined unloading and loading with coherent transfer function unloads a part from the machine at coherent transfer and then load another part to the machine. The time period between unloading and subsequent loading is not defined.

In addition to conformance class 2, process optimizations (optimization of cycle time) are carried out concerning:

- pre-positionings;
- preparation of unloading part(s).

See the corresponding flow chart in [Figure C.13](#).

4.2.2.4.2.3 With non-coherent transfer, with/without clamping function

Function "Combined unloading and loading with non-coherent transfer, with/without clamping function" serves the requirement to unload apart from the machine at non-coherent transfer and then load another part to the machine. The time period between unloading and subsequent loading is not defined.

In addition to conformance class 2, process optimizations (optimization of cycle time) are carried out concerning:

- pre-positionings;
- preparation of unloading part(s).

See the corresponding flow chart in [Figure C.12](#).

4.2.2.4.3 Process optimizations, if pre-positioning by machine

In conformance class 3, signals are provided for process optimizations which require a pre-positioning of the machine. A process description shall be coordinated specifically to the project and depending on the mechanical design.

4.2.2.4.4 Process optimizations, if clamping and releasing is executed in more than one step

In conformance class 3, signals are provided for process optimizations which require clamping and releasing in more than one step. A process description shall be coordinated specifically to the project and depending on the mechanical design.

4.2.3 Conformance options

4.2.3.1 General

The selection of a conformance option allows adding an additional scope of functions to the selected conformance class. The set of signals allocated to a conformance option is intended to fulfil a specific task.

The following conformance options are available. Any desired conformance option can be selected.

- loading access controlled by machine;
- loading access controlled by automated machine tending system;
- enabling device;
- monitoring of communication;
- tool life management;
- central functions;
- control signals for safety-relevant functions;

- with parts data;
- setup information;
- machine panel;
- part seat control.

[Table 1](#) shows if a conformance option contains safety-relevant and/or control-relevant signals.

Table 1 — Allocation of safety-relevant and control-relevant signals to conformance options

Conformance option	Safety-relevant signals	Control-relevant signals
Loading access controlled by machine	✓	✓
Loading access controlled by automated machine tending system	✓	✓
Enabling device	✓	✓
Monitoring of communication		✓
Tool life management		✓
Central functions		✓
Control signals for safety-relevant functions		✓
With parts data		✓
Setup information		✓
Machine panel		✓
Part seat control		✓

4.2.3.2 Conformance option: Loading access controlled by machine

The signals assigned to the conformance option "Loading access controlled by machine" in [Annex A](#) shall be provided at the interface.

The conformance option "Loading access controlled by machine" includes signals with the belonging functions required if a loading access is controlled by the machine.

Handling the signals is analogous to the description and diagrams of the guard doors.

4.2.3.3 Conformance option: Loading access controlled by automated machine tending system

The signals assigned to the conformance option "Loading access controlled by automated machine tending system" in [Annex A](#) shall be provided at the interface.

The conformance option "Loading access controlled by automated machine tending system" includes signals with the belonging functions which are required if a loading access is controlled by the automated machine tending system.

Handling the signals is analogous to the description and diagrams of the guard doors.

4.2.3.4 Conformance option: Enabling device

The signals assigned to the conformance option "Enabling device" in [Annex A](#) shall be provided at the interface.

The conformance option "Enabling device" includes signals with the belonging functions which are necessary for operating the system in enabling mode.

4.2.3.5 Conformance option: Monitoring of communication

The signals assigned to the conformance option "Monitoring of communication" in [Annex A](#) shall be provided at the interface.

The conformance option "Monitoring of communication" includes signals with the belonging functions which are necessary for the monitoring of communication. Each functional unit sends a binary signal to the interface with a pulse of 1 Hz. The other functional unit evaluates this signal and detects if the communication is disturbed or alright.

See the corresponding flow chart in [Figure C.14](#).

4.2.3.6 Conformance option: Tool life management

The signals assigned to the conformance option "Tool life management" in [Annex A](#) shall be provided at the interface.

The conformance option "Tool life management" includes signals with the belonging functions which are necessary for the tool life management.

4.2.3.7 Conformance option: Central functions

The signals assigned to the conformance option "Central functions" in [Annex A](#) shall be provided at the interface.

The conformance option "Central functions" includes signals with the belonging functions which are provided by the automated machine tending system for one or more machine(s) and the relevant status information of the machine.

4.2.3.8 Conformance option: Control signals for safety-relevant functions

The signals assigned to the conformance option control signals for safety-relevant functions in [Annex A](#) shall be provided at the interface.

The conformance option control signals for safety-relevant functions includes signals with the belonging functions which are used as a supplement to the safety-relevant interface.

4.2.3.9 Conformance option: With parts data

4.2.3.9.1 General

Signals of the conformance option "With parts data" are divided into:

- signals for controlling data handling;
- preparation data and parts data.

4.2.3.9.2 Signals for controlling data handling

The signals assigned to the conformance option "With parts data" in [Annex A](#) shall be provided at the interface.

See the corresponding flow charts in [Figures C.15](#) to [C.21](#).

NOTE When transferring parts data, the data sovereignty moves from one control to another one together with the part. Ideally, the physical transfer of a part and the data transfer take place at the same time.

4.2.3.9.3 Preparation data and parts data

4.2.3.9.3.1 Signal names and content of preparation data and parts data

This document determines the signal names of the container for the preparation data and parts data. It defines the belonging signals for controlling the container as well. This document does not determine the content of the container for the preparation data and parts data.

The contents of the required preparation data and parts data depends on the specific project. It can be very different and is therefore not standardized within this document.

Examples of information concerning preparation data and parts data:

- part reference number:
 - part type;
 - part family;
- part state;
- part-ID;
- operation index;
- cycle time - target value;
- cycle time - actual value;
- processing progress;
- measurement and correction data;
- clamping process on spindle x;
- production date;
- change positions of the machine;
- washing program number;
- clamping device number, type, and opening width;
- maximum speed of the workpiece spindle.

4.2.3.9.3.2 Use of preparation data and parts data

[Figure 5](#) gives an overview of possibilities for the use of preparation data and parts data and its belonging control signals. The selection of possibilities depends on the specific project.

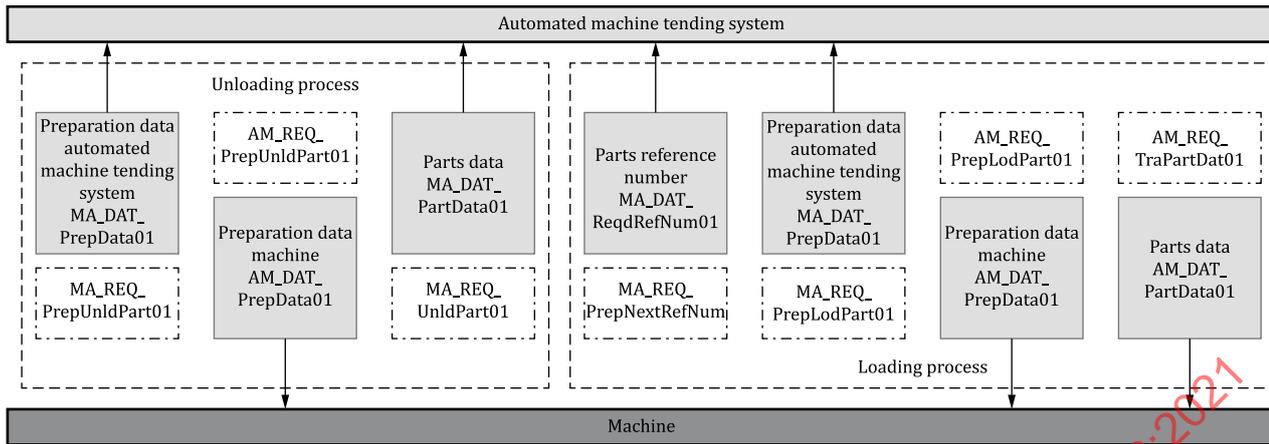


Figure 5 — Overview of possibilities for the use of preparation data and parts data

a) For unloading process

Preparation data are used for controlling the logistic processes for unloading.

They can be provided by the machine to the automated machine tending system or by the automated machine tending system to the machine. Typically, only one direction is used.

Parts data are taken over by the automated machine tending system from the machine during the unloading process.

b) For loading process

Preparation data are used for controlling the logistic processes for loading.

They can be provided by the machine to the automated machine tending system or by the automated machine tending system to the machine. Typically, only one direction is used.

Parts data are information which the automated machine tending system transfers to the machine during the loading.

The parts reference number is transferred from the machine to the automated machine tending system, when the machine takes over the selection of a parts reference number.

4.2.3.10 Conformance option: Setup information

The signals assigned to the conformance option "Setup information" in Annex A shall be provided at the interface.

The conformance option "Setup information" includes signals with the belonging functions which are necessary to report the setup state (setup for the parts family xx or for rework) of a machine to the automated machine tending system.

4.2.3.11 Conformance option: Machine panel

The conformance option "Machine panel" consists of a subset of signals of the basic buttons of a functional unit's panel. The state of these signals is provided at the interface.

The signals assigned to the conformance option "Machine panel" in Annex A shall be provided at the interface.

The conformance option "Machine panel" includes signals with the belonging functions which provide information about using the buttons (hardware or soft key) of a control panel.

4.2.3.12 Conformance option: Part seat control

The signals assigned to the conformance option "Part seat control" in [Annex A](#) shall be provided at the interface.

The conformance option "Part seat control" includes signals with the belonging functions which are necessary for part seat control.

See the corresponding flow chart in [Figure C.22](#).

4.3 Safety interface

4.3.1 General

The safety interface between machine(s) and automated machine tending system determines signals which are necessary for keeping personal safety.

Part of the realization of the safety interface is the definition of a safety matrix to clarify the functional relationships between machine and automated machine tending system depending on the status of main switch, guard(s) and emergency stop.

4.3.2 Principle approach and concept

In principle, an area is considered hazardous concerning functional safety if it can be accessed by humans and hazardous actions (e.g. movement) of a functional unit occurs. Access to an area is possible via a guard and/or a loading access. Hazardous actions depend on the status of main switch and emergency stop of the functional unit.

Mainly, it can be distinguished between loading access open and loading access closed. A machine and automated machine tending system form a common emergency stop area, if the loading access is open or does not exist. If the loading access is closed, each functional unit forms its own emergency stop area. This approach allows maximum flexibility in operating the functional units while being fully compliant with safety requirements.

4.3.3 Matrix for safety-related functional relationships

The matrix in [Figure 6](#) follows the concept in [4.3.2](#) to maximize flexibility in operating the functional units (FU) and should be realized. Then, no further project-specific definitions between the project partners are necessary.

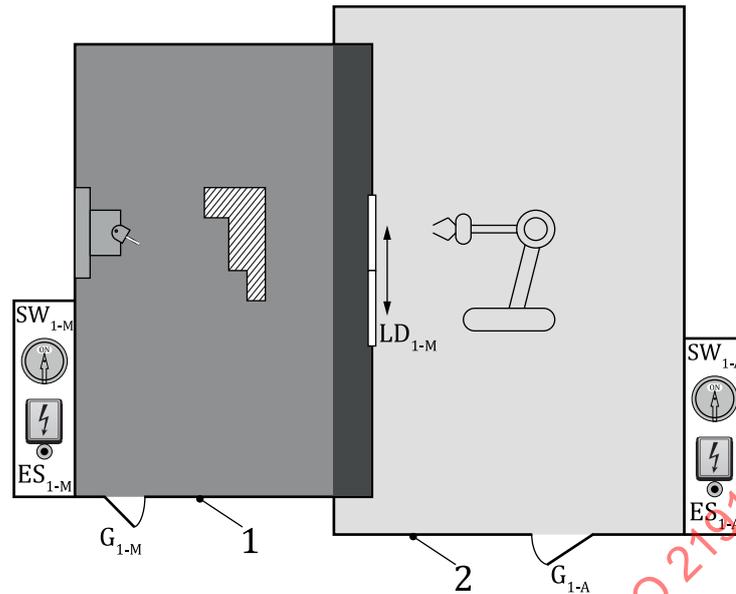
Cause (Action, trigger event):													
FU	Description	Loading access closed						Loading access open					
Automated machine tending system	Emergency stop activated	1						1					
	Guard open		1						1				
	Main switch off ^d			1						1			
Machine	Emergency stop activated				1						1		
	Guard open					1						1	
	Main switch off						1						1
Reaction:													
Description													
Automated machine tending system	STOP	Yes ^a	Yes ^b	Yes ^a	No	No	No	Yes ^a	Yes ^b	Yes ^a	Yes ^b	Yes ^b	Yes ^b
Machine	STOP	No	No	No	Yes ^a	Yes ^b	Yes ^a	Yes ^b	Yes ^{b,c}	Yes ^b	Yes ^a	Yes ^b	Yes ^a

Key

- 1 true
- a Stop-category according to EN 60204-1:2019, 9.2.2.
- b Safety-oriented stop function (PLr = c); unexpected start (PLr = d).
- c If required for safety reasons.
- d Status of main switch is not a dedicated signal at the interface.

Figure 6 — Principle matrix of safety-related functional relationships

Figure 7 illustrates an example system configuration on which the above shown matrix can be applied.

**Key**

- 1 machine
- 2 automated machine tending system
- ES_{1-M} emergency stop button machine
- ES_{1-A} emergency stop button automated machine tending system
- SW_{1-M} main switch machine
- SW_{1-A} main switch automated machine tending system
- G_{1-M} interlocking guard machine
- G_{1-A} interlocking guard automated machine tending system
- LD_{1-M} loading access machine

Figure 7 — Example system configuration

Other matrices for safety-related functional relationships can be realized, e.g. if an activated emergency stop button, shall bring both the automated machine tending system and the machine to STOP. In this case, an individual matrix of safety-related functional relationships shall be defined by the project partners.

Depending on the individual project, definition, implementation and realization of the safety matrix shall be agreed between the project partners in cooperation with the system operator.

[Annex B](#) shows simplified examples for safety matrices for dedicated system configurations.

4.3.4 Distribution of performance levels and PFHD value

In the case of comprehensive safety-related parts of control systems (SRP/CS), distribution of the PFHD value is carried out between the participants at a ratio of 1:2 between access level (signal detection) and exit level (signal evaluation), in order to enable a verification for the functional safety by two individual calculations. Other agreements can be made depending on the specific project.

Calculation of the performance of the control (SRP/CS) shall be carried out in accordance with ISO 13849-1 or IEC 62061.

[Figure 8](#) shows an example on how to distribute PFHD values.

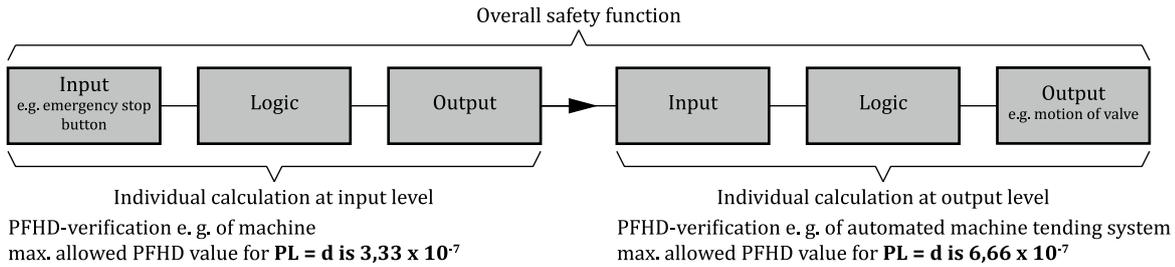


Figure 8 — Example on how to distribute PFHD values

4.4 Control interface

The control-related interface describes signals and data with their functions as well as the belonging flow charts which are transferred for the parts transport between automated machine tending system and machine.

5 Extension of the interfaces

5.1 General

Depending on the complexity of a project on hand, an extension (e.g. of signals) described in this document can become necessary. Therefore, a system-specific extension is allowed.

The principle of a system-specific extension is shown in [Figure 3](#).

The system-specific extension shall be documented.

5.2 Examples of project-specific extensions

5.2.1 General

Project-specific extensions of this document are necessary, for example, if:

- the task can only be fulfilled by additional signals; or
- the machine has more than one interference area.

5.2.2 Additional signals

Additional signals and the belonging functions can be defined for a specific project. The nomenclatures made for this ISO 21919 series shall be taken into account.

5.2.3 More than one interference area

5.2.3.1 Separated safety areas

Signals of the safety interface and control interface shall be completely duplicated.

5.2.3.2 The same safety area

Signals of the control-related interface shall be completely duplicated. There is only one safety-related interface.

Annex A (normative)

List of signals

The spreadsheet listing all signals with its attributes is provided in a machine-readable file at <https://standards.iso.org/iso/21919-2/ed-1/en/>.

Three modes of operation exist.

- Mode of operation 1 (MO 1): an automatic, programmed, sequential operation mode of the machine with the facility for manual or automatic loading/unloading of workpieces and tools, until stopped by program or operator.

It is also referred to as automatic mode. It can include an operational interruption for loading/unloading of workpieces and tools. MO 1 is applicable for machine tending systems and machines.

- Mode of operation 2 (MO 2): an operation mode in which adjustments and preparations for the following machining process are performed by the operator (setter) with the possibility that guards are open and/or protective devices suspended.

It is also referred to as setting mode. Assessments of tool or workpiece position (e.g. by touching the workpiece with a probe or tool in single step mode) are procedures of the setting mode (see ISO 16090-1:2017, 5.2.4.5).

- Mode of operation 3 (MO 3): a limited automatic mode (fixed sequence of separate consecutive steps) started by the operator, which temporarily allows manual control or numerically controlled operation of the machine, with guards opened and/or protective devices suspended. It is also referred to as optional special mode for manual intervention under restricted operating conditions.

Annex B (informative)

Examples for safety matrices

B.1 General

This annex shows examples that illustrate specific configurations of machines and automated machine tending systems together with related safety matrices. Its aim is to support the requirements and recommendations of [4.3](#) and to give guidance on how to setup such a matrix depending on the system configuration.

The first example is a rather simple configuration of one machine that is tended by an automated machine tending system composed of a robot. The setup space of the machine is not separated by a (closable) loading access.

Example 2 in [B.3](#) is similar to Example 1 in [B.2](#). The only difference is that the setup space of the machine is separated by a (closable) loading access.

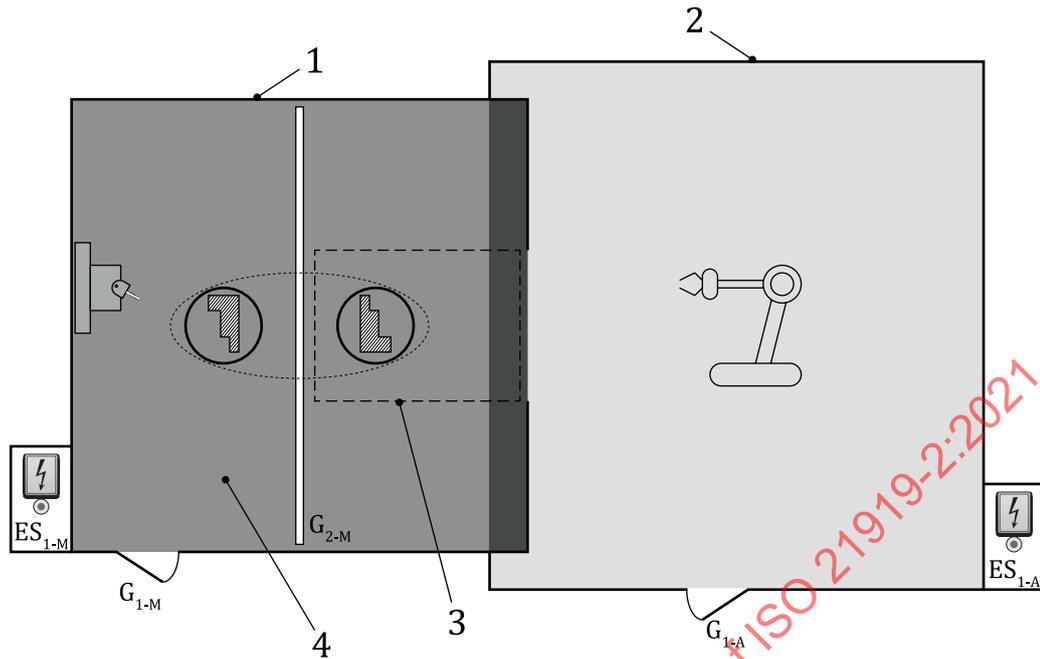
The third example is a rather complex system of several machines that are tended by a gantry from above by a loading access.

The collection of scenarios depicted in these examples are not intended to be exhaustive. For reasons of simplification the inclusion of the main switches is waived.

B.2 Example 1: System configuration with loading setup space without (closable) loading access

B.2.1 Configuration

Specific to the system configuration of this example is that the machine has a loading setup space without a (closable) loading access. The system configuration is shown in the [Figure B.1](#).

**Key**

- 1 machine
- 2 automated machine tending system
- 3 interference area
- 4 machine work space
- ES_{1-M} emergency stop button machine
- ES_{1-A} emergency stop button automated machine tending system
- G_{1-M} interlocking guard machine 1
- G_{2-M} separates work area from automated machine tending system and machine
- G_{1-A} interlocking guard automated machine tending system

Figure B.1 — Loading setup space without (closable) loading access

Concerning functional safety, the following properties are worth mentioning:

- the machine has one guard G_{1-M} that allows access to the working space of the machine;
- the automated machine tending system has one guard G_{1-A} that allows access to the working space of the automated machine tending system;
- the interference area can be accessed from the automated machine tending system at any time as there is no (closable) loading access;
- the interference area can be accessed from the machine working space via guard G_{1-M} and guard G_{2-M} ;
- each functional unit has one emergency stop button.

Concerning interfacing and control, the following properties are worth mentioning:

- in this example the machine places the information of the status of guard G_{1-M} and guard G_{2-M} parallel on the interface as signal MA_SFY_GuardClod; and
- drive elements of the clamping device in the interference area are controlled by the machine.

B.2.2 Safety matrix

Figure B.2 shows the safety matrix of the system configuration shown in Figure B.1.

Safety matrix			Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Cause (Action, trigger event):											
	Signal	Description^a									
Automated machine tending system	ES _{I-A}	Emergency stop okay (not activated) (AM_SFY_NoEStop)	1	0	1	0	1	1	1	1	1
	G _{I-A}	Guard closed (AM_SFY_GuardClod)	1	1	1	1	1	0	1	0	1
Machine	ES _{I-M}	Emergency stop okay (not activated) (MA_SFY_NoEStop)	1	1	0	1	0	1	1	1	1
	G _{I-M}	Guard work space closed	1	1	1	1	1	1	0	1	0
	G _{I-M}	Guard work space/setup space closed	1	1	0	0	0	1	1	0	0
	INFO	(MA_SFY_GuardClod)	1	1	1	1	1	1	1	1	0
Reaction:											
		Description^a									
Automated machine tending system		Automated machine tending system in interference area STOP (independent of the mode of operation (MO))	No	Yes ^b	Yes ^c	Yes ^b	Yes ^c	Yes ^c	No	Yes ^c	Yes ^c
		Automated machine tending system outside interference area STOP (independent of MO)	No	Yes ^b	Yes ^c	Yes ^b	Yes ^c	Yes ^c	No	Yes ^c	Yes ^c
Machine		Machine in interference area STOP (independent of MO)	No	Yes ^c	Yes ^b	Yes ^c	Yes ^b	Yes ^c	No	Yes ^c	Yes ^c
		Machine outside interference area STOP (independent of MO)	No	No	Yes ^b	Yes ^c	Yes ^b	No	Yes ^c	Yes ^c	Yes ^c

- a According to signal state, see ISO 21919-1.
- b Stop category 1 according to EN 60204-1:2019, 9.2.2.
- c Safety-oriented stop function (PLr = c) unexpected start (PLr = d).

Figure B.2 — Safety matrix of a loading setup space without a loading access

B.2.3 Explanation of the scenarios

B.2.3.1 Development of the matrix

The development of the matrix starts with an "everything okay" situation (scenario 0). Scenarios 1 to 4 focus on the emergency stops of the functional units, partly in interaction with guard G_{2-M}.

Scenarios 5 to 8 focus on open guards of the functional units. Emergency stop is assumed as not activated.

B.2.3.2 Scenario 0

In scenario 0, no emergency stop is activated and all guards are closed. Thus, both functional units can operate, i.e. machine and automated machine tending system are ready for production.

B.2.3.3 Scenario 1

In scenario 1 (as distinct from scenario 0), the emergency stop of the automated machine tending system is activated. All guards are closed. As there is no loading access, the automated machine tending system and the interference area form a common emergency stop area. Thus, the automated machine tending system is in STOP, independent of whether it is in or outside of the interference area. As the machine workspace is separated from the interference area by the closed guard G_{2-M} , machine activities outside of the interference area are permitted.

B.2.3.4 Scenario 2

In scenario 2 (as distinct from scenario 0), the emergency stop of the machine is activated. All guards are closed. Thus, the machine is in STOP, independent of whether it is in or outside of the interference area. As there is no loading access, the emergency stop area cannot be limited to the machine. Hence, the automated machine tending system is in STOP as well, independent of whether it is in or outside of the interference area.

B.2.3.5 Scenario 3

In scenario 3 (as in scenario 1), the emergency stop of the automated machine tending system is activated and (as distinct from scenario 1) guard G_{2-M} is open. All other guards are closed. As there is no loading access, the automated machine tending system, the interference area and the machine workspace form a common emergency stop area. Thus, both functional units are in STOP, independent of whether they are in or outside of the interference area.

B.2.3.6 Scenario 4

In scenario 4 (as distinct from scenario 3), the emergency stop of the machine is activated and guard G_{2-M} is open. All other guards are closed. As there is no loading access, the automated machine tending system, the interference area and the machine workspace form a common emergency stop area. Thus, both functional units are in STOP, independent of whether they are in or outside of the interference area.

B.2.3.7 Scenario 5

In scenario 5 (as distinct from scenario 0), guard G_{1-A} is open. No emergency stop is activated. As there is no loading access, the automated machine tending system and the interference area form a common safety area. Thus, the automated machine tending system is in STOP, independent of whether it is in or outside of the interference area. Machine activities outside of the interference area are permitted.

B.2.3.8 Scenario 6

In scenario 6 (as distinct from scenario 0), guard G_{1-M} is open. No emergency stop is activated. G_{2-M} is closed and prevents access from the machine workspace to the interference area and the automated machine tending system. Thus, it is sufficient to have the machine outside interference area in STOP.

B.2.3.9 Scenario 7

In scenario 7 (as distinct from scenario 5), guard G_{1-A} and guard G_{2-M} are open. No emergency stop is activated. As there is no loading access, the automated machine tending system, the interference area

and the machine workspace form a safety area. Thus, both functional units are in STOP, independent of whether they are in or outside of the interference area.

B.2.3.10 Scenario 8

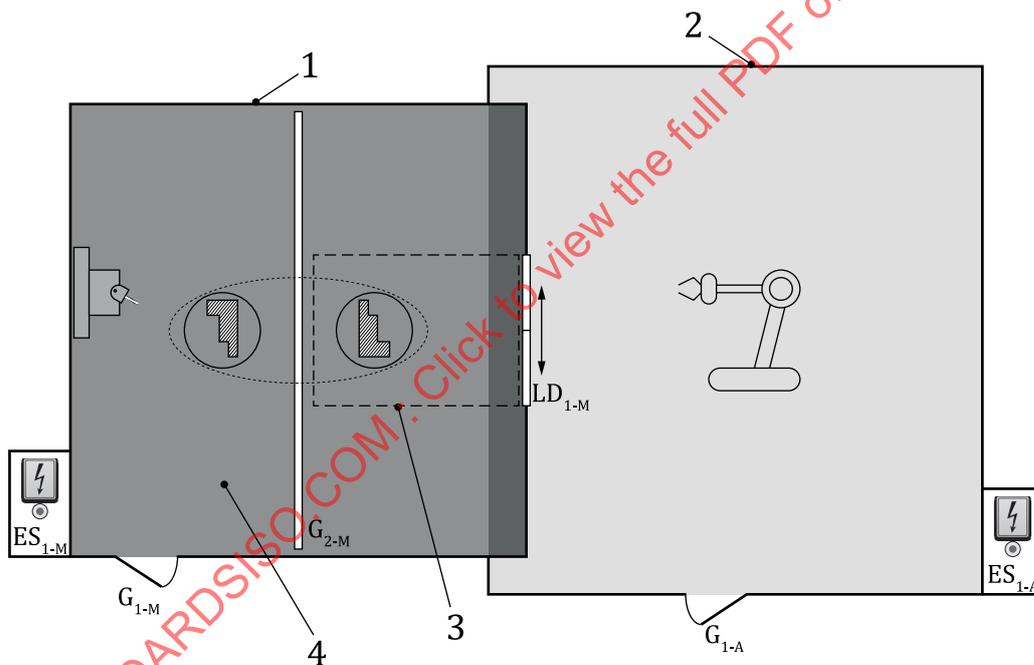
In scenario 8 (as distinct from scenario 6), guard G_{1-M} and guard G_{2-M} are open. No emergency stop is activated. As there is no loading access, the automated machine tending system, the interference area and the machine workspace form a common safety area. Thus, both functional units are in STOP, independent of whether they are in or outside of the interference area.

NOTE Reactions in scenario 7 and 8 are the same. This is obvious as, from the functional safety point of view, it is not relevant if access is possible from the machine (working area) to all other areas or from the automated machine tending area to all other areas.

B.3 Example 2: Loading setup space with loading access

B.3.1 Configuration

Specific to the system configuration of this example is that the machine has a loading setup space with a (closable) loading access. The system configuration is shown in the [Figure B.3](#).



Key

- 1 machine
- 2 automated machine tending system
- 3 interference area
- 4 machine work space
- ES_{1-M} emergency stop button machine
- ES_{1-A} emergency stop button automated machine tending system
- G_{1-M} interlocking guard machine 1
- G_{2-M} separates work area from automated machine tending system and machine
- G_{1-A} interlocking guard automated machine tending system
- LD_{1-M} loading access machine

Figure B.3 — Loading setup space with loading access

Concerning functional safety, the following properties are worth mentioning:

- the machine has one guard G_{1-M} that allows access to the working space of the machine;
- the automated machine tending system has one guard G_{1-A} that allows access to the working space of the automated machine tending system;
- the interference area can be accessed from the automated machine tending system if LD_{1-M} is open;
- the interference area can be accessed from the machine working space via guard G_{1-M} and guard G_{2-M} ;
- each functional unit has one emergency stop button.

Concerning interfacing and control, the following properties are worth mentioning:

- in this example, the machine places the information of the status of guard G_{1-M} and guard G_{2-M} parallel on the interface as signal MA_SFY_GuardClod;
- the loading access is controlled by the machine; and
- drive elements of the clamping device in the interference area are controlled by the machine.

B.3.2 Safety matrix

[Figure B.4](#) shows the safety matrix of the system configuration shown in [Figure B.3](#).

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Safety matrix			Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10
Cause (Action, trigger event):													
	Signal	Description^a											
Automated machine tending system	ES _{1-A}	Emergency stop okay (not activated) (AM_SFY_NoEStop)	1	0	1	0	0	1	1	1	1	1	1
	G _{1-A}	Guard closed (AM_SFY_GuardClod)	1	1	1	1	1	1	0	1	0	1	1
Machine	ES _{1-M}	Emergency stop okay (not activated) (MA_SFY_NoEStop)	1	1	0	1	1	0	1	1	1	1	1
	LD _{1-M}	Loading access machine closed (MA_SFY_LdgDoorClod)	1	1	1	0	0	0	1	1	0	0	0
	G _{1-M}	Guard work space closed	1	1	1	1	1	1	1	0	1	0	0
	G _{2-M}	Guard work space/setup space closed	1	1	1	1	0	1	1	1	1	1	0
	INFO	(MA_SFY_GuardClod)	1	1	1	1	1	1	1	1	1	1	0
Reaction:													
		Description^a											
Automated machine tending system		Automated machine tending system in interference area STOP (independent of MO)	n/a	n/a	n/a	Yes ^b	Yes ^c	Yes ^c	n/a	n/a	Yes ^c	No	Yes ^c
		Automated machine tending system outside interference area STOP (independent of MO)	No	Yes ^b	No	Yes ^b	Yes ^c	Yes ^c	Yes ^c	No	Yes ^c	No	Yes ^c
Machine		Machine in interference area STOP (independent of MO)	No	No	Yes ^b	Yes ^c	Yes ^b	Yes ^b	No	No	Yes ^c	No	Yes ^c
		Machine outside interference area STOP (independent of MO)	No	No	Yes ^b	No	Yes ^b	Yes ^b	No	Yes ^c	No	Yes ^c	Yes ^c

- a According to signal state, see ISO 21919-1.
- b Stop category 1 according to EN 60204-1:2019, 9.2.2.
- c Safety-oriented stop function (PLr = c) unexpected start (PLr = d).

Figure B.4 — Safety matrix of a loading setup space with loading access

B.3.3 Explanation of the scenarios

B.3.3.1 Development of the matrix

The development of the matrix starts with an "everything okay" situation (scenario 0). Scenarios 1 to 5 focus on the emergency stops in interaction with the loading access LD_{1-M}, and partly in interaction with guard G_{2-M}.

Scenarios 6 to 10 focus on open guards of the functional units in interaction with loading access LD_{1-M}. Emergency stop is assumed as not activated.

B.3.3.2 Scenario 0

In scenario 0, no emergency stop is activated, All guards and the loading access are closed. Thus, both functional units can operate, i.e. machine and automated machine tending system are ready for production.

B.3.3.3 Scenario 1

In scenario 1 (as distinct from scenario 0), the emergency stop of the automated machine tending system is activated. All guards and the loading access are closed. Therefore, the emergency stop area of the automated machine tending system does not have to be extended to the interference area, i.e. can be limited to the automated machine tending system. Thus, the automated machine tending system is in STOP, if it is outside of the interference area. The situation where the automated machine tending system is inside of the interference area is not applicable as the loading access is closed. As the machine workspace and the interference area are separated by the loading access, machine activities are permitted, independent of whether it is in or outside of the interference area.

B.3.3.4 Scenario 2

In scenario 2 (as distinct from scenario 0), the emergency stop of the machine is activated. All guards and the loading access are closed. The machine workspace and the interference area form a common emergency stop area. Thus, the machine is in STOP, i.e. no hazardous actions are permitted in or outside of the interference area. As the loading access is closed, the automated machine tending system can operate outside of the interference area. The situation where the automated machine tending system is inside of the interference area is not applicable as the loading access is closed.

B.3.3.5 Scenario 3

In scenario 3 (as in scenario 1), the emergency stop of the automated machine tending system is activated and (as distinct from scenario 1) the loading access LD_{1-M} is open. All other guards are closed. Therefore, the automated machine tending system and the interference area form a common emergency stop area. Thus, the automated machine tending system is in STOP, independent if it is in or outside of the interference area. The machine is in STOP, i.e. no hazardous actions are permitted in the interference area. Machine operation outside of the interference area is not stopped.

B.3.3.6 Scenario 4

In scenario 4 (as in scenario 3) the emergency stop of the automated machine tending system is activated and the loading access LD_{1-M} is open. The guard G_{2-M} is open (as distinct from scenario 3), all other guards are closed. The automated machine tending system, the interference area and the machine workspace form a common emergency stop area. Thus, both functional units are in STOP, independent of whether they are in or outside of the interference area.

B.3.3.7 Scenario 5

In scenario 5 (as in scenario 2), the emergency stop of the machine is activated and all guards are closed. The loading access LD_{1-M} (as distinct from scenario 2) is open. The automated machine tending system, the interference area and the machine workspace form a common emergency stop area. Thus, both functional units are in STOP, independent of whether they are in or outside of the interference area.

B.3.3.8 Scenario 6

In scenario 6 (as in scenario 0), no emergency stop is activated, the loading access and the guards of the machine G_{1-M} and G_{2-M} are closed. The guard G_{1-A} (as distinct from scenario 0) is open. As the loading access is closed, the safety area of the automated machine tending system does not have to be extended to the interference area, i.e. can be limited to the automated machine tending system. The guard G_{1-A} is open. Thus, the automated machine tending system is in STOP if it is outside of the interference area. The situation where the automated machine tending system is inside of the interference area is not

applicable as the loading access is closed. Machine activities are permitted, independent of whether it is in or outside of the interference area.

B.3.3.9 Scenario 7

In scenario 7 (as in scenario 0), no emergency stop is activated. The loading access and the guards G_{1-A} and G_{2-M} are closed. The guard G_{1-M} (as distinct from scenario 0) is open. As the loading access and the guard G_{2-M} are closed, the safety area can be limited to the machine workspace. The guard G_{1-M} is open. Thus, the machine is in STOP, i.e. no hazardous actions are permitted outside of the interference area. Machine activities in the interference area are permitted. As the loading access and guard G_{1-A} are closed, the automated machine tending system can operate if it is outside of the interference area. The situation where the automated machine tending system is inside of the interference area is not applicable as the loading access is closed.

B.3.3.10 Scenario 8

In scenario 8 (as in scenario 6), no emergency stop is activated. The guards of the machine G_{1-M} and G_{2-M} are closed and the guard of the automated machine tending system G_{1-A} is open. The loading access (as distinct from scenario 6) is open. As the loading access is open and the guard G_{2-M} is closed, the automated machine tending system and the interference area form a common safety area. Thus, the automated machine tending system is in STOP, independent of whether it is in or outside of the interference area. The machine is in STOP, i.e. no hazardous actions are permitted in the interference area. Machine operation outside of the interference area is not stopped.

B.3.3.11 Scenario 9

In scenario 9 (as in scenario 0), no emergency stop is activated. The guard of the machine G_{2-M} and of the automated machine tending system G_{1-A} are closed. The loading access and the guard of the machine G_{1-M} (as distinct from scenario 0) are open. As the guard G_{2-M} is closed, the safety area can be limited to the machine workspace. Thus, the machine can operate in the interference area and is in STOP, i.e. no hazardous actions are permitted outside of the interference area. The automated machine tending system can operate, independent of whether it is in or outside of the interference area.

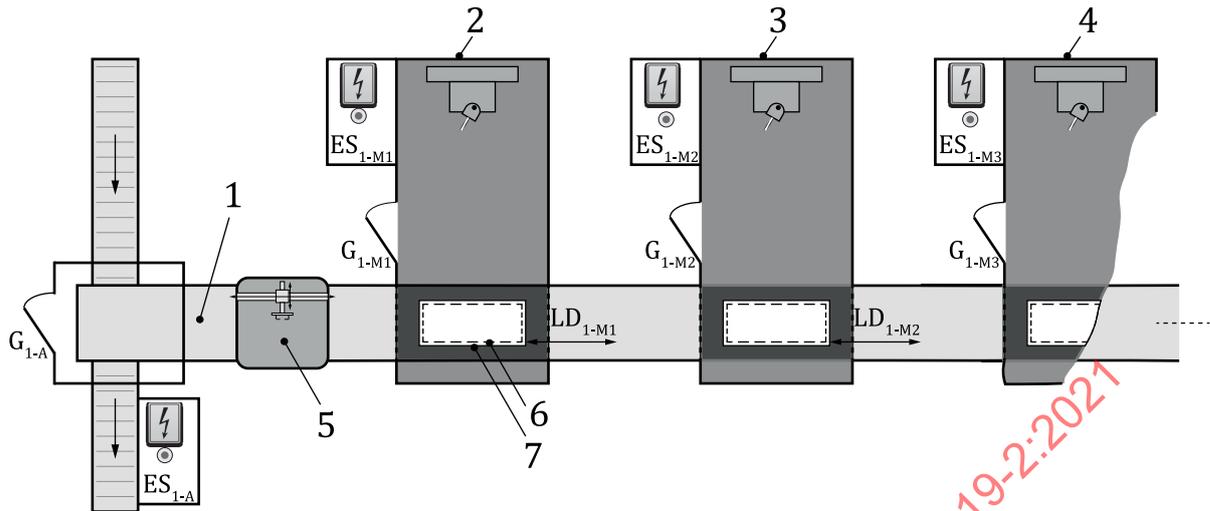
B.3.3.12 Scenario 10

In scenario 10 (as in scenario 9), no emergency stop is activated. The guard of the automated machine tending system G_{1-A} is closed and the loading access and the guard of the machine G_{1-M} are open. The guard of the machine G_{2-M} (as distinct from scenario 9) is open as well. As both guards of the machine and the loading access are open, the machine workspace, the interference area and the automated machine tending system form a common safety area. Thus, both functional units are in STOP, independent of whether they are in or outside of the interference area.

B.4 Example 3: Loading of workspace with loading access from above for several machines

B.4.1 Configuration

Specific to the system configuration of this example is that several machines are tended and have loading access from above. The system configuration is shown in the [Figure B.5](#).

**Key**

- 1 machine tending system
- 2 machine 1
- 3 machine 2
- 4 machine 3
- 5 gantry loader
- 6 interference area
- 7 loading hatch
- ES_{1-M1} emergency stop button machine 1
- ES_{1-M2} emergency stop button machine 2
- ES_{1-M3} emergency stop button machine 3
- ES_{1-A} emergency stop button automated machine tending system
- G_{1-M1} interlocking guard machine 1
- G_{1-M2} interlocking guard machine 2
- G_{1-M3} interlocking guard machine 3
- G_{1-A} interlocking guard automated machine tending system
- LD_{1-M} loading access machine

Figure B.5 — Loading of work space with loading access from above

Concerning functional safety, the following properties are worth mentioning:

- each machine has one guard G_{1-M} that allows access to the working space of the machine;
- the automated machine tending system has one guard G_{1-A} that allows access to the working space of the automated machine tending system;
- the interference area cannot be accessed from the automated machine tending system due to design;
- the interference area can be accessed from the machine working space;
- the access from machine 1 to machine 2 via the loading access is prevented by design;
- each functional unit has one emergency stop button;
- the loading access is controlled by the machine; and
- drive elements of the clamping device in the interference area are controlled by the machine.

B.4.2 Safety matrix

Figure B.6 shows the safety matrix of the system configuration shown in Figure B.5.

Safety matrix			Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Cause (Action, trigger event):							
	Signal	Description^a					
Automated machine tending system	ES _{1-A}	Emergency stop okay (not activated) (AM_SFY_NoEStop)	1	0	0	1	1
	G _{1-A}	Guard closed (AM_SFY_GuardClod)	1	1	1	1	1
Machine 1	ES _{1-M1}	Emergency stop okay (not activated) (MA_SFY_NoEStop)	1	1	1	0	0
	G _{1-M1}	Guard closed (MA_SFY_GuardClod)	1	1	1	1	1
	LD _{1-M1}	Loading access machine closed (MA_SFY_LdgDoorClod)	1	1	0	0	0
Machine 2	ES _{1-M2}	Emergency stop okay (not activated) (MA_SFY_NoEStop)	1	1	1	1	1
	G _{1-M2}	Guard closed (MA_SFY_GuardClod)	1	1	1	1	1
	LD _{1-M2}	Loading access machine closed (MA_SFY_LdgDoorClod)	1	1	1	1	0
Reaction:							
		Description^a					
Automated machine tending system		Automated machine tending system in interference area machine 1 STOP (independent of the mode of operation (MO))	n/a	n/a	Yes ^b	Yes ^c	Yes ^c
		Automated machine tending system in interference area machine 2 STOP (independent of MO)	n/a	n/a	n/a	n/a	Yes ^c
		Automated machine tending system outside interference area machine(s) STOP (independent of MO)	n/a	Yes ^b	Yes ^b	Yes ^c	Yes ^c
Machines		Machine 1 STOP	No	No	Yes ^c	Yes ^b	Yes ^b
		Machine 2 STOP	No	No	No	No	No

Key

- ^a According to signal state, see ISO 21919-1.
- ^b Stop category 1 according to EN 60204-1:2019, 9.2.2.
- ^c Safety-oriented stop function (PLr = c) unexpected start (PLr = d).

Figure B.6 — Safety matrix of work space with loading access from above

B.4.3 Explanation of the scenarios

B.4.3.1 Development of the matrix

The development of the matrix starts with an "everything okay" situation (scenario 0). Scenarios 1 and 2 focus on the emergency stop of the automated machine tending system. Scenarios 3 and 4 focus on the emergency stop of a machine.

For the sake of simplification, guards are not considered in this example. For functional relationships of guards, see [B.2](#) and [B.3](#).

B.4.3.2 Scenario 0

In scenario 0, no emergency stop is activated, and all guards and all loading accesses are closed. Thus, all functional units can operate, i.e. machine and automated machine tending system are ready for production. The situation where the automated machine tending system is inside of the interference area of a machine is not applicable as all loading accesses are closed.

B.4.3.3 Scenario 1

In scenario 1 (as distinct from scenario 0), the emergency stop of the automated machine tending system is activated. All guards and loading accesses are closed. Therefore, the emergency stop area of the automated machine tending system does not have to be extended to an interference area, i.e. can be limited to the automated machine tending system. Thus, the automated machine tending system is in STOP, if it is outside of the interference area. The situation where the automated machine tending system is inside of the interference area is not applicable as all loading accesses are closed. As the machine work spaces and the interference areas are separated from the automated machine tending system by the loading accesses, machine activities are permitted, independent of whether it is in or outside of the interference area.

B.4.3.4 Scenario 2

In scenario 2 (as in scenario 1), the emergency stop of the automated machine tending system is activated. All guards and the loading accesses of machine 2 and machine 3 are closed. The loading access of machine 1 (as distinct from scenario 1) is open. Therefore, the automated machine tending system and machine 1 form a common emergency stop area. Thus, machine 1 is in STOP. The automated machine tending system is in STOP anyway as the emergency stop is activated. For the sake of clarity, it is worth mentioning that the automated machine tending system is inside of the interference area of machine 2 or machine 3 is not applicable as their loading accesses are closed. Machine 2 and machine 3 can operate as they do not have a common emergency stop area with the automated machine tending system.

B.4.3.5 Scenario 3

In scenario 3 (as in scenario 2), all guards and the loading accesses of machine 2 and machine 3 are closed. The loading access of machine 1 is open. The emergency stop of the automated machine tending system is not activated and the emergency stop of machine 1 is activated (as distinct from scenario 2). Therefore, machine 1 and the automated machine tending system form a common emergency stop area. Thus, machine 1 and the automated machine tending system are in STOP. For the sake of clarity, it is worth mentioning that the automated machine tending system is inside of the interference area of machine 2 or machine 3 is not applicable as their loading accesses are closed. Machine 2 and machine 3 can operate as they do not have a common emergency stop area with the automated machine tending system.

B.4.3.6 Scenario 4

In scenario 4 (as in scenario 3), all guards and the loading accesses of machine 3 are closed. The loading access of machine 1 is open. The emergency stop of the automated machine tending system is not

activated and the emergency stop of machine 1 is activated. Loading access of machine 2 (as distinct from scenario 3) is open. Machine 1 and the automated machine tending system form a common emergency stop area. Machine 2 is not part of the common emergency stop area as it is not possible to access machine 2 from machine 1. Thus, machine 1 and the automated machine tending system are in STOP.

For the sake of clarity, it is worth mentioning that the automated machine tending system is inside of the interference area of machine 3 is not applicable as this loading access is closed.

Machine 2 and machine 3 can operate as they do not have a common emergency stop area with the automated machine tending system.

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Annex C (normative)

Flow charts

C.1 Conformance class 1

C.1.1 Simple unloading

Figure C.1 displays the interactions of all relevant signals at the control interface for a simple unloading.

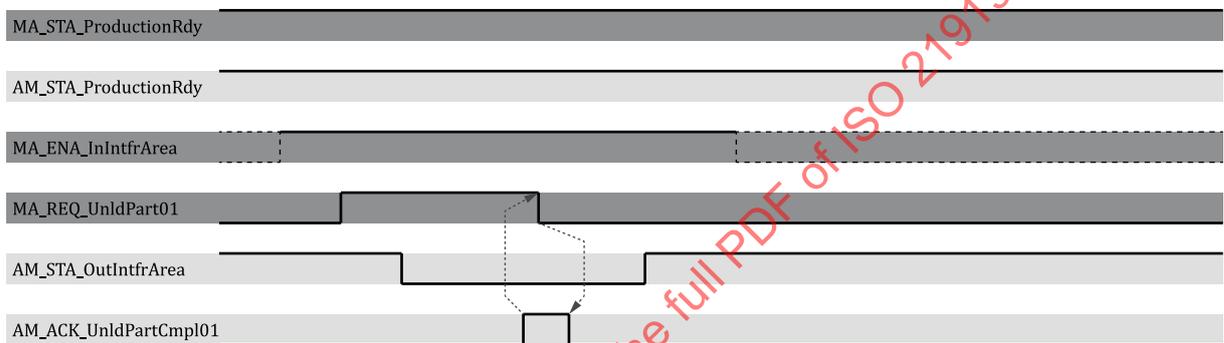


Figure C.1 — Interactions of all relevant signals at the control interface for a simple unloading

C.1.2 Simple loading

Figure C.2 displays the interactions of all relevant signals at the control interface for a simple loading.

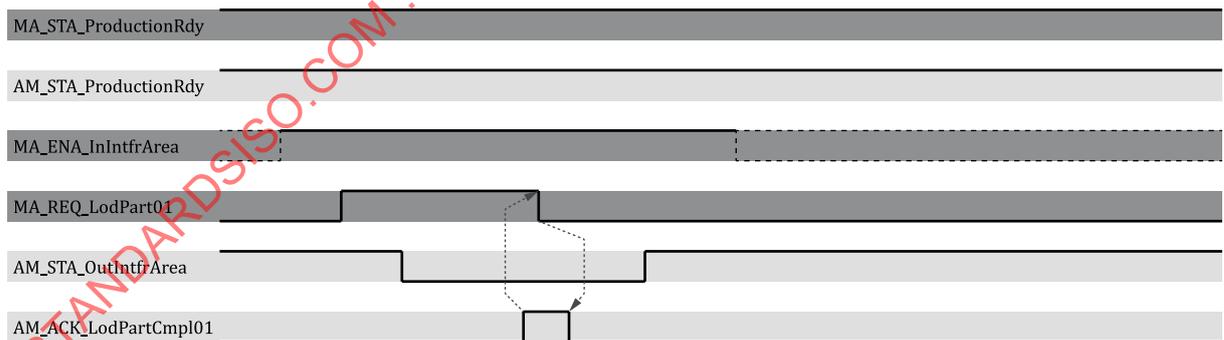


Figure C.2 — Interactions of all relevant signals at the control interface for a simple loading

C.1.3 Simple combined unloading and loading

Figure C.3 displays the interactions of all relevant signals at the control interface for a simple combined unloading and loading.

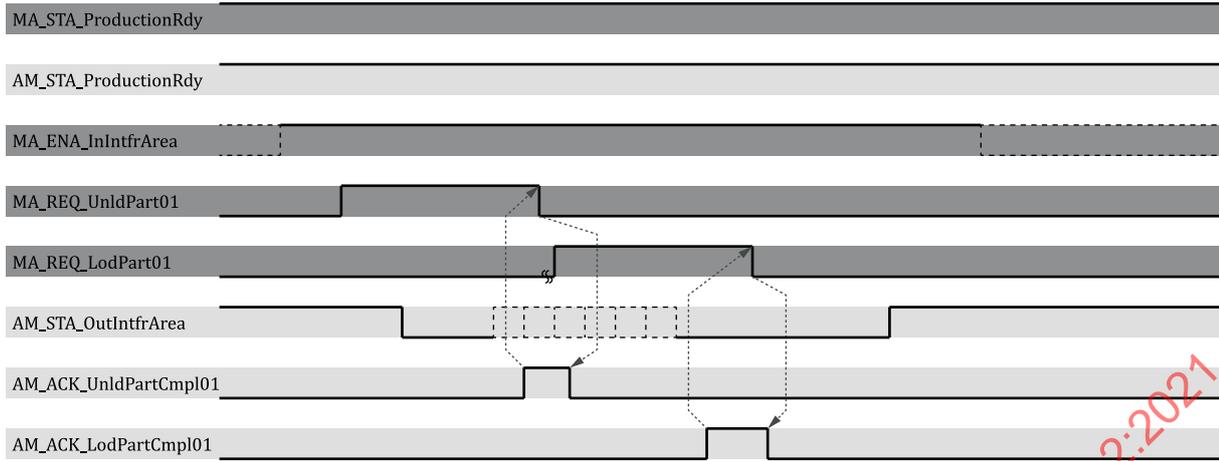
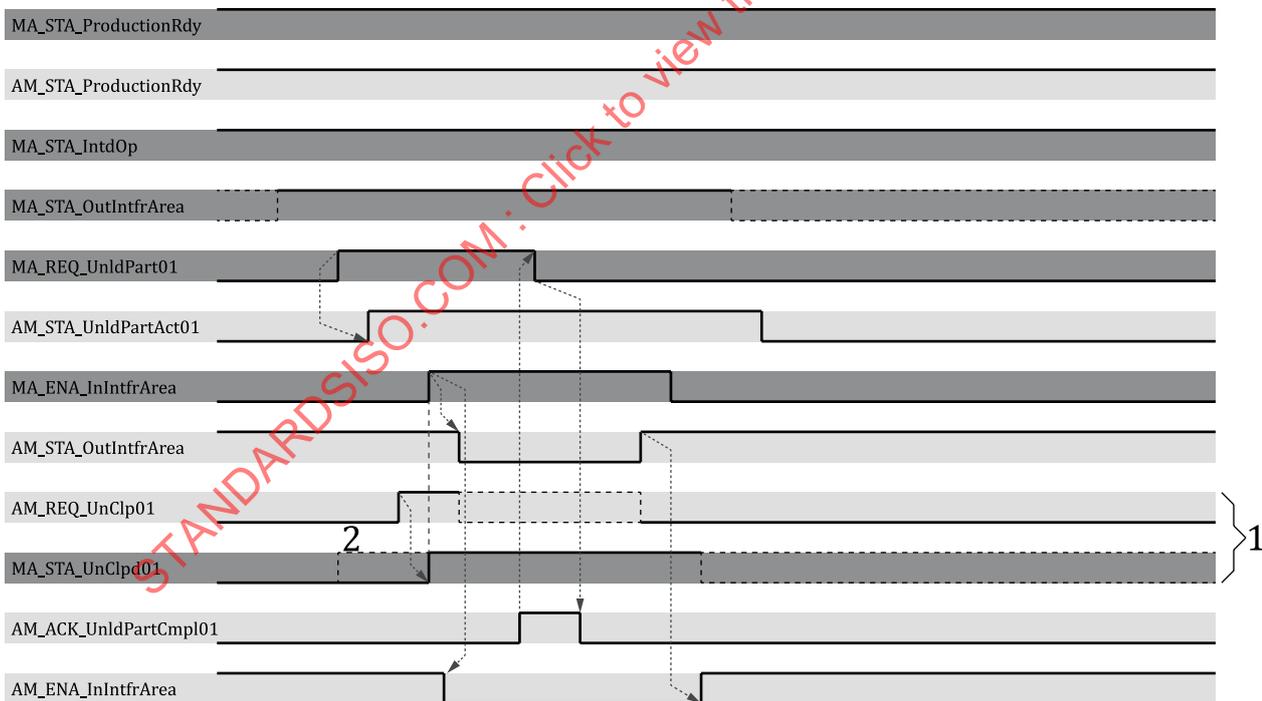


Figure C.3 — Interactions of all relevant signals at the control interface for a simple combined unloading and loading

C.2 Conformance class 2

C.2.1 Unloading with non-coherent transfer, with/without clamping function

Figure C.4 displays the interactions of all relevant signals at the control interface for unloading with non-coherent transfer, with/without clamping function.



Key

- 1 implement signal only, if machine needs the signal clamping function from the automated machine tending system
- 2 depending on the clamping system design

Figure C.4 — Interactions of all relevant signals at the control interface for unloading with non-coherent transfer, with/without clamping function

C.2.2 Unloading with coherent transfer

Figure C.5 displays the interactions of all relevant signals at the control interface for unloading with coherent transfer.

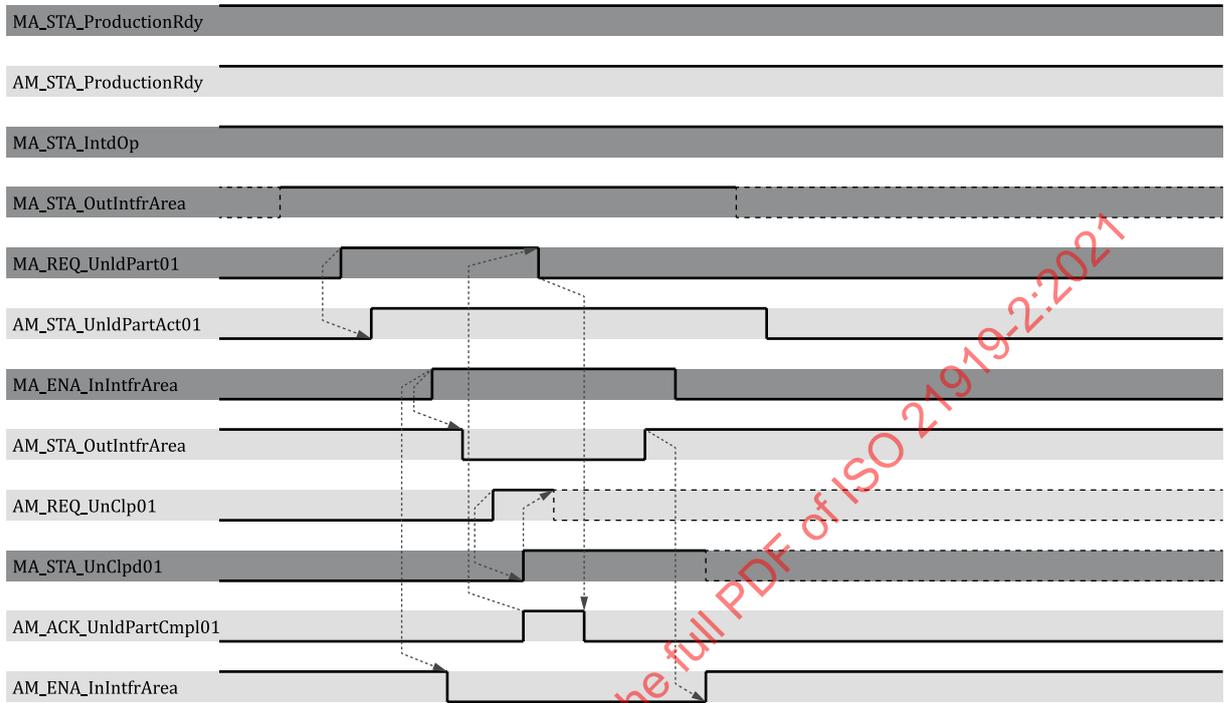
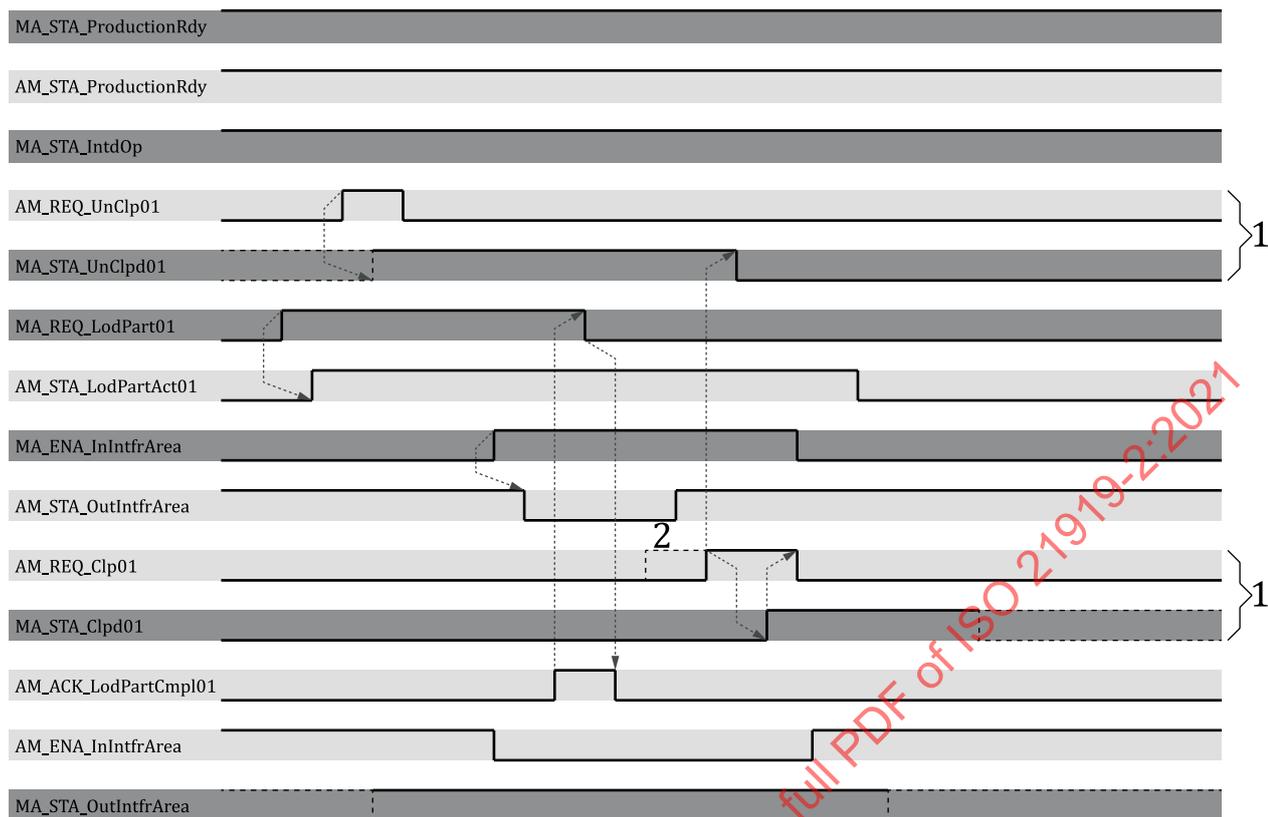


Figure C.5 — Interactions of all relevant signals at the control interface for unloading with coherent transfer

C.2.3 Loading with non-coherent transfer, with/without clamping function

Figure C.6 displays the interactions of all relevant signals at the control interface for loading with non-coherent transfer, with/without clamping function.



Key

- 1 implement signal only, if machine needs the signal clamping function from the automated machine tending system
- 2 depending on the clamping system design

Figure C.6 — Interactions of all relevant signals at the control interface for loading with non-coherent transfer, with/without clamping function

C.2.4 Loading with coherent transfer

Figure C.7 displays the interactions of all relevant signals at the control interface for loading with coherent transfer.

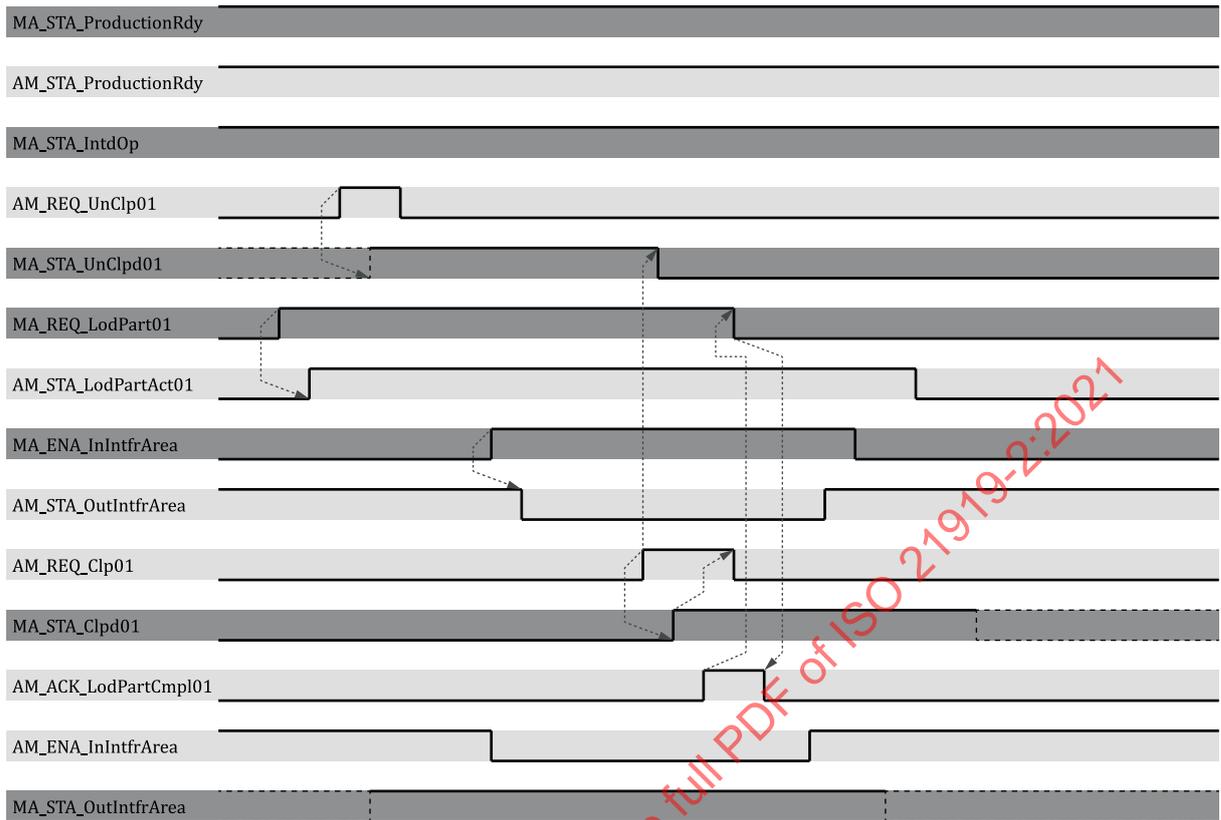


Figure C.7 — Interactions of all relevant signals at the control interface for loading with coherent transfer

C.2.5 Combined unloading and loading with non-coherent transfer, with/without clamping function

[Figure C.8](#) displays the interactions of all relevant signals at the control interface for combined unloading and loading with non-coherent transfer, with/without clamping function.

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