INTERNATIONAL STANDARD

ISO 21919-1

First edition
2019-10

Automation systems and integration — Interfaces for automated machine tending —

Part 1: Overview and fundamental principles

Systèmes d'automatisation et integration — Interfaces pour le chargement automatisé des machines —

Partie 1: Aperçu et principes fondamentaux

Reference number
ISO 21919-1:2019(E)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Page

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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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

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

NOTE 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 devices are robots, handling systems, gantries, 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 in themselves, are often provided by different suppliers and they encounter each other for the first time at the production site. 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 have not yet been defined.

The definition of the interfaces is often project-specific from the start or each supplier tries to establish its in-house standards. These procedures cause great efforts, are prone to failure and 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 range from simple parts removal to material flow dedicated complex production lines. The processing technologies of the machines are independent from 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 ISO 21919. Figure 1 shows an example of a simple automated machine tending system, consisting of a machine tool loaded by a conveyor.

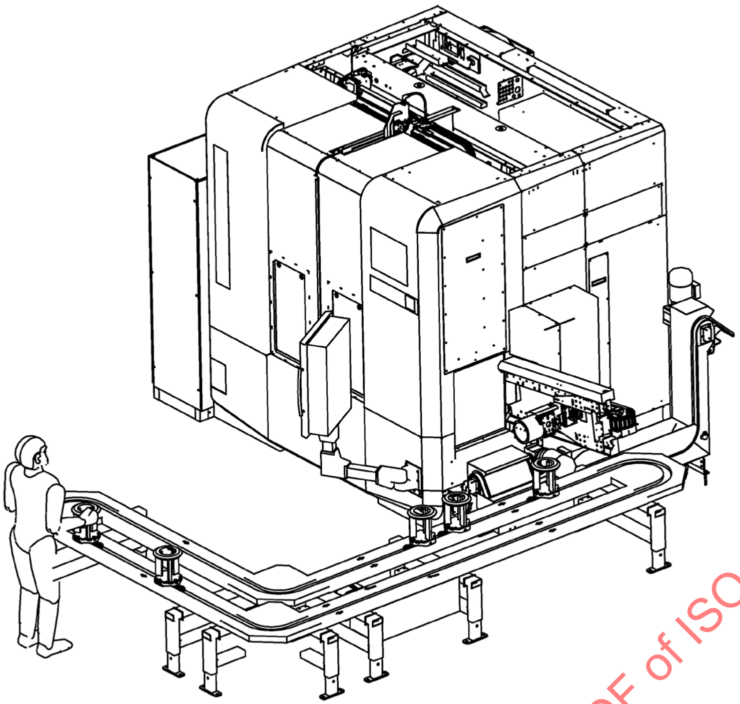

Figure 1 — Example of a simple automated machine tending system

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

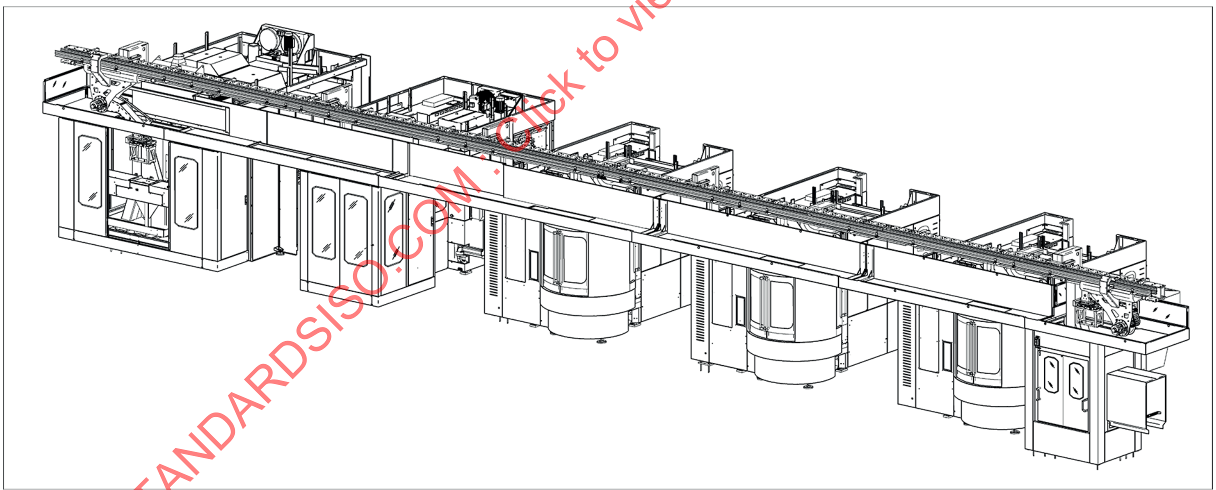

Figure 2 — Example of a complex production line loaded by a gantry

In general, the interfaces for automated machine tending are composed of mechanical, control-related, and safety-related connections.

Automation systems and integration — Interfaces for automated machine tending —

Part 1: Overview and fundamental principles

1 Scope

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

This document 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.

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

— allow a flexible adaptation of the interface(s) to a project-specific scope of functions;

— tie sets of signals tight enough to avoid unnecessary coordination efforts between suppliers of the machine tending devices and machines.

ISO 21919 concentrates on the control-related and safety-related connections. It does not describe the mechanical connections, it does not determine the transfer physics, a pin assignment, the hardware of the interfaces or measure of communication, e.g. protocol, and it is not intended to be used for communication to a MES (Manufacturing Execution System).

NOTE ISO 21919-2 deals with the safety interface and control interface, allocating signals to a conformance class and/or conformance option, describing the detailed functions of each signal, describing and displaying the timing interactions between signals in flow charts and showing examples for safety matrices and safety-related functional relationships.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions 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
part
physical entity with its digital description [*data* (3.19)] that is transported into and out of the *machine* (3.4) by the *machine tending system* (3.3)

EXAMPLE Workpieces, sets of workpieces on workpiece carriers, tools, sets of tools in tool carriers.

3.2
functional unit
device or system which transports, receives or renders *parts* (3.1)

EXAMPLE *Machines* (3.4) and *automated machine tending* (3.5) systems.

3.3
machine tending system
functional unit (3.2) transporting *parts* (3.1) without changing their physical properties

EXAMPLE Robots, conveyors, gantries, bar feed systems, handling systems.

Note 1 to entry: See Figure A.1.

3.4
machine
functional unit (3.2) changing the physical properties of *parts* (3.1)

EXAMPLE Machine tools, measuring machines, washing machines and assembly systems.

Note 1 to entry: See Figure A.1.

3.5
automated machine tending
process of transporting *parts* (3.1) into or out of a *machine* (3.4) by a *machine tending system* (3.3)

Note 1 to entry: See Figure A.1.

3.6
interface
shared boundary between two *functional units* (3.2), defined by various characteristics pertaining to the functions, physical interconnections, *signal* (3.7) exchanges, and other characteristics, as appropriate

[SOURCE: ISO/IEC 2382:2015, 2121308, modified — Notes to entry have been removed.]

3.7
signal
information transferred between *functional units* (3.2) via the *interface* (3.6)

3.8
interference area
shared work area between *functional units* (3.2)

Note 1 to entry: See Figure A.2.

3.9
interference area preposition
interference area (3.8) without the area of the transfer station (device)

Note 1 to entry: See Figure A.2.

3.10
coherent transfer
transfer of *parts* (3.1) where one *functional unit* (3.2) keeps the part form-locked until the other functional unit has it securely clamped

Note 1 to entry: A distinction between coherent and non-coherent transfer can be made for loading and unloading operations.

EXAMPLE When a robot loads a part to a machine tool and keeps its grippers closed until the machine tool has clamped the part. After the machine tool has clamped the part, the robot opens its grippers.

3.11
function mode
status of a *functional unit* (3.2) indicating if *signals* (3.7) are valid/executed

3.12
conformance class
predefined subset of *signals* (3.7) selected to achieve a specified set of functions, for which conformance can be claimed

Note 1 to entry: Predefined sets of functions are conformance class 1 "Minimum set of signals", conformance class 2 "Extended scope" and conformance class 3 "Extended scope with process optimization".

3.13
conformance option
predefined subset of *signals* (3.7) that can be selected to add a set of functions to a *conformance class* (3.12), for which conformance can be claimed

3.14
loading access
interlocking guard which separates the *machine* (3.4) from the *machine tending system* (3.3) for exchanging *parts* (3.1)

EXAMPLE Loading hatches and loading doors.

Note 1 to entry: See Figures A.3 and A.4.

3.15
PFHD value
probability of a dangerours failure per hour

3.16
pulse 1 Hz
signal (3.7) of the format boolean alternating in an interval of 0,5s

3.17
handshake
interaction between *functional units* (3.2) with a request as trigger and an acknowledge or *state* (3.18) *signal* (3.7) as answer

3.18
state
signal (3.7) describing a condition

3.19
data
signal (3.7) containing information relevant to a *part* (3.1)

3.20
interlinked operation
intdOp
function mode (3.11) indicating that a *functional unit* (3.2) participates in the *automated machine tending* (3.5)

3.21
single operation
SOp
function mode (3.11) indicating that a *functional unit* (3.2) is processing/handling a *part* (3.1) but is not in *interlinked operation* (3.20)

3.22
single step
SSp
function mode (3.11) indicating that a *functional unit* (3.2) is traversed in sequential movements where each movement is initiated by an operator

3.23
setup operation
SetOp
function mode (3.11) indicating that an operator can manually execute any movement of a *functional unit* (3.2)

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.

4.2 Structure, range and standards of the interface

4.2.1 General

To transfer the signals, either a hardware interface (parallel wiring) or transmission via a bus system is available.

The function equipotential bonding between the automated machine tending system and the machine shall be implemented. In principle, this is not used as a protective conductor.

For any specific project, it shall be decided whether the power supply (e.g. 0 V and 24 V potential) of the automated machine tending system and/or the machine shall be made available.

NOTE If the power supply is provided by both functional units, safety-relevant devices are supplied even if one functional unit is shut down.

The pin assignment and connector format shall be agreed upon according to the project for the design of the hardware technology as parallel wiring for one or both interfaces.

4.2.2 Characteristics of the interface

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.

Users of this document shall decide one conformance class and can select all desired conformance options and can define a project specific extension, if necessary.

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 signal correlates as shown in the relevant flow charts in ISO 21919-2.

4.2.3 Conformance class

4.2.3.1 Conformance class 1: Minimum set of signals

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.

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

4.2.3.2 Conformance class 2: Extended set of signals

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 the 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.

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

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.

Further details on conformance classes are provided in ISO 21919-2.

4.2.4 Conformance options

The selection of a conformance option allows a set of functions to be added 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.

Further details on conformance options are provided in ISO 21919-2.

Table 1 indicates 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		✓

4.2.5 Extension of the interfaces

4.2.5.1 General

Depending on the complexity of a project at hand, an extension (e.g. of signals) described in this document could 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.

4.2.5.2 Examples of project-specific extensions

Project-specific extensions of this document are necessary, e.g.

— if the task can only be fulfilled by additional signals;

— if the machine has more than one interference area.

4.2.5.2.1 Additional signals

Additional signals and the related functions can be defined for a specific project. The nomenclatures established for ISO 21919 shall be taken into account.

4.2.5.2.2 More than one interference area

4.2.5.2.2.1 Separated safety areas

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

4.2.5.2.2.2 The same safety area

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

Figure 3 shows the principal setup of the interfaces for automated machine tending.

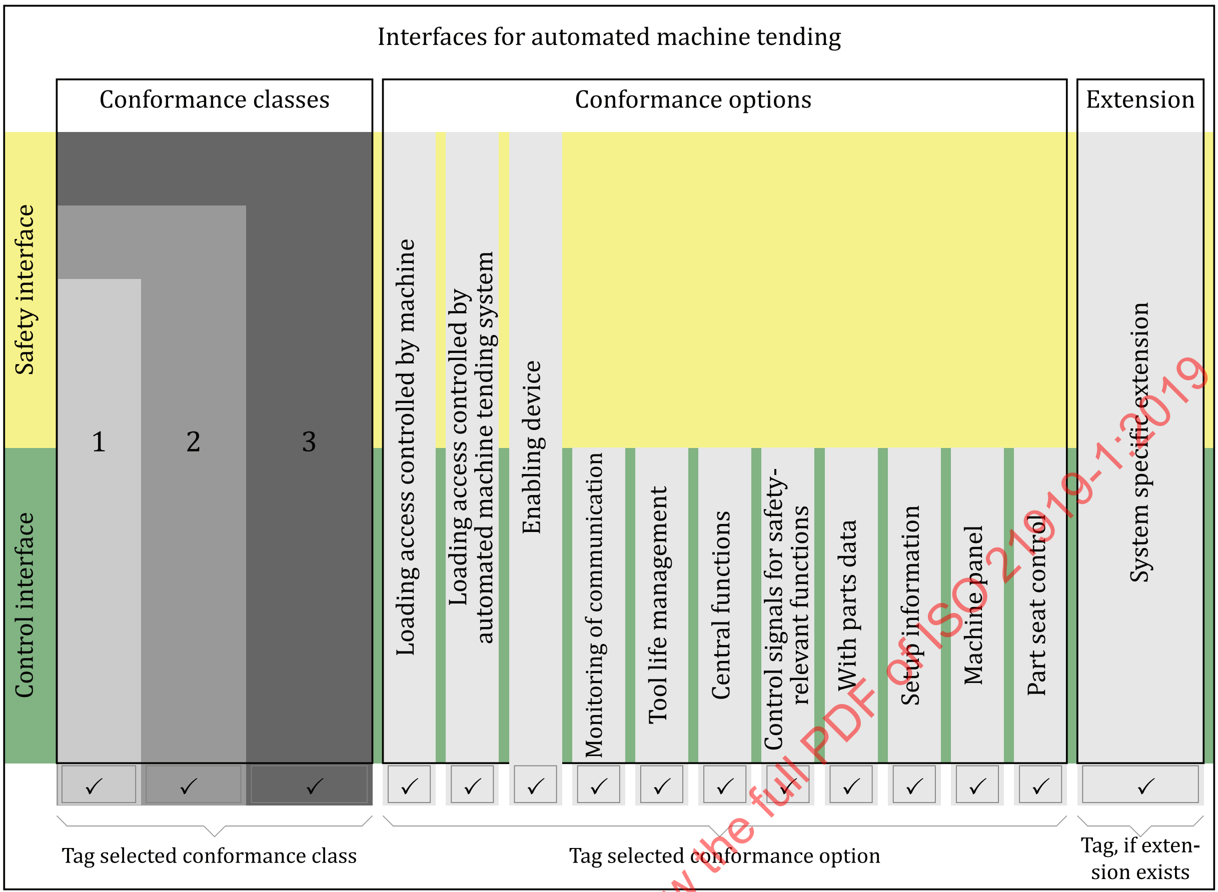

Figure 3 — Principle setup of the interface

4.2.6 Description of the signal structure

4.2.6.1 Range

This subclause specifies the syntax for the definition of signals. The allocation of signals to physical links is not within the scope of this document.

This syntax for defining the standardized set of signals is used, for example, in ISO 21919-2.

4.2.6.2 Attributes

4.2.6.2.1 General

Each signal of the interface shall have the following attributes:

— symbol name;

— comment;

— format;

— signal behaviour;

— function mode automated machine tending system;

— function mode machine;

— PFHD value (only for safety relevant interface);

— description.

Figure 4 shows an example of a signal and its attributes.

AM_SFY_GuardClod		← Symbol name
Comment:	Guard closed	← Comment
Format:	BOOLEAN	← Format
Behaviour of signal:	State	← Signal behaviour
Function mode AM:	IntdOp, SOp, SSp, SetOp	← Function mode automated machine tending system
Function mode MA:	IntdOp, SOp, SSp, SetOp	← Function mode machine
PFHD value ≤:	3,33*10-7 in cat. 3	← PFHD value
Description:	Access to interference area by automated machine tending system (and/or other machines) not possible.	← Description

Figure 4 — Example of a signal and its attributes

All attributes of signals are described in the following subclauses.

4.2.6.2.2 Symbol name

4.2.6.2.2.1 General

The symbol name is composed of three segments, which are separated by an underscore. It has a maximum of 24 characters and describes the signal in the state logic "1".

EXAMPLES "MA_STA_LdgDoorOpnd" on logic "1" → loading access open

"MA_STA_LdgDoorOpnd" on logic "0" → loading access not open

The formats of the three segments of the symbol names are as follows.

4.2.6.2.2.2 First segment

The first segment always consists of two letters written in upper case. It determines the direction of the signal.

AM → signal from "**A**utomated machine tending system" to "**M**achine"

MA → signal from "**Ma**chine" to "**A**utomated machine tending system"

4.2.6.2.2.3 Second segment

The second segment always consists of three letters written in upper case. For safety-relevant signals it is always SFY to have a clear indication, for control-relevant signals it indicates the type of signal.

The following signal types for control-related signals are allowed:

— STA State;

— REQ Request;

— ACK Acknowledge;

— MPA Machine panel;

— ENA Enabled;

— INF Information;

— DAT Data.

Further details are given in 4.2.8.

4.2.6.2.2.4 Third segment

The third segment consists of up to 17 alphanumeric characters. It is made up of 1 or more abbreviated English words or parts of words which are used to explain the meaning of the signal (descriptive name). Words or parts of words start with a capital letter.

A possibly existing consecutive number, e.g. 01 at the end of the third segment indicates that, depending on the machine, there might be further signals with the same symbol name, but with a different consecutive number. This is the case, for example, if a machine can handle several parts.

Figure 5 shows an example for the symbol name of a signal.

EXAMPLE **EnaUnlckGuard** → EnableUnlockGuard (REQUEST Release guard door)

AM_REQ_EnaUnlckGuard

Figure 5 — Example for the symbol name of a signal

4.2.6.2.3 Comment

The comment field is a sort explanation of the signal and its function.

Figure 6 shows an example for a comment to the symbol name of a signal.

Comment:	REQUEST Enable unlock guard

Figure 6 — Example for a comment to the symbol name of a signal

4.2.6.2.4 Format

The format of the signal is defined in the format field.

Examples are:

— Boolean;

— UINT16 (unsigned integer 16);

— UINTX (unsigned integer X; "X" is a power of 2).

Other formats can be defined in specific projects.

Figure 7 shows an example for the format of a signal.

Format:	BOOLEAN

Figure 7 — Example for the format of a signal

4.2.6.2.5 Behaviour of signal

The signal behaviour is defined in this field.

The following signal behaviours are allowed:

— pulse 1 Hz;

— handshake;

— state;

— data.

Figure 8 shows an example for the behaviour of a signal.

Behaviour of signal:	Handshake

Figure 8 — Example for the behaviour of a signal

4.2.6.2.6 Function mode

The function mode of the automated machine tending system and the machine(s) are defined in these fields.

The following function modes are allowed:

— IntdOp Interlinked operation;

— SOp Single operation;

— SSp Single step;

— SetOp Setup operation

Figure 9 shows an example for function modes.

AM_REQ_CleanPartSeat01	
Comment:	REQUEST clean seat Part01
Format:	BOOLEAN
Behaviour of signal:	Handshake
Function mode AM:	IntdOp, SOp, SSp
Function mode MA:	IntdOp
Description:	Clean seat.

Figure 9 — Example for function modes

The automated machine tending system will only send the signal if it is in function mode IntdOp, SOp or SSp, however independent of the function mode of the machine.

It is only if the machine is in function mode IntdOp that it will respond to the signal of the automated machine tending system.

4.2.6.2.7 PFHD value

The value is defined in this field. It is only existent at signals of the safety interface.

Figure 10 shows an example for a PFHD value for a signal of the safety interface.

PFHD value ≤:	3,33*10-7 in cat. 3

Figure 10 — Example for a PFHD value for a signal of the safety interface

4.2.6.2.8 Description

This field is a supplement to the comment field.

Figure 11 shows an example for a description of a signal.

Description:	Automated machine tending system is ready for automatic loading and unloading.

Figure 11 — Example for a description of a signal

4.2.7 Index for parts-related signals

This document describes that one or more parts can be loaded/unloaded, however only in one interference area. Therefore the "parts-related signals" have an index (01, 02, ...).

4.2.8 Standards for signal exchange

4.2.8.1 General

A functional unit shall provide/accept all signals of the selected conformance class and the selected conformance options at the interface.

This document describes which signals are exchanged at the interfaces and the relationship of the signals to each other. It does not describe which functions (links) are stored in a functional unit.

4.2.8.2 Use of the attribute function mode

4.2.8.2.1 Automated machine tending system sends signal to machine

The attribute "Function mode AM" describes in which function modes the machine tending system shall send a valid signal. The attribute "Function mode MA" describes in which function modes the machine shall evaluate the signal.

4.2.8.2.2 Machine sends signal to automated machine tending system

The attribute "Function mode MA" describes in which function modes the machine shall send a valid signal. The attribute "Function mode AM" describes in which function modes the machine tending system shall evaluate the signal.

4.2.8.3 Request

4.2.8.3.1 Principle

A request shall be acknowledged. The signal type on the recipient's side determines if the acknowledgement is carried out as acknowledge or as state.

4.2.8.3.2 Recipient entered a function

4.2.8.3.2.1 Function can be executed

The functional unit recipient acknowledges the incoming request according to the entered function together with the belonging acknowledge or state signal.

Examples are given in ISO 21919-2.

4.2.8.3.2.2 Function cannot be executed

The recipient of the request cannot execute the entered function, therefore the request shall be acknowledged negatively.

4.2.8.3.3 Recipient did not enter a function

4.2.8.3.3.1 General

If the functional unit recipient of a request has not entered a function, it shall acknowledge the incoming request as follows, depending on whether the acknowledgement is defined as acknowledge or state.

EXAMPLE The signalling interface is set up including the conformance option "Central Function". It includes the function WarmUp. The automated machine tending system sends the request AM_REQ_WarmUp. According to the determination mentioned above, the recipient of this request responds with the state "MA_STA_WarmedUp". This also applies if the function WarmUp has not been realized (as in the example machine tool).

4.2.8.3.3.2 Acknowledgement by acknowledge signal

An incoming request signal is bridged to the outgoing acknowledge signal in the functional unit.

Figure 12 shows an example of how to acknowledge a request by an acknowledge signal.

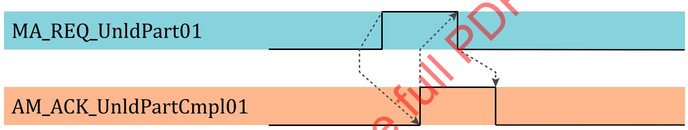

Figure 12 — Example of how to acknowledge a request by an acknowledge signal

4.2.8.3.3.3 Acknowledgement by state signal

The functional unit recipient can send the state signal constantly without changing its value.

Figure 13 shows an example of how to acknowledge a request by a state signal.

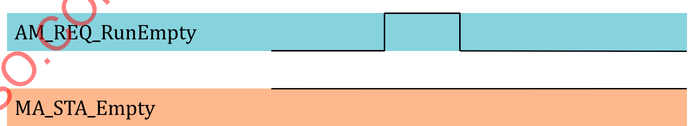

Figure 13 — Example of how to acknowledge a request by a state signal

4.2.8.4 ENA

Signals of the type ENA (Enable) give clearance to the functional unit recipient from the functional unit sender to operate in the relevant area.

4.2.8.5 INF

Opposite to STATE signals INF signals (Information) provide information that is not intended to control a functional unit.

4.2.8.6 MPA

MPA signals (Machine Panel) report a status of the functional unit. This signal type is only applied at the conformance option "Machine Panel".

If no function is entered at the MPA signal, the signal shall be set to a logical "0".

Actions that are carried out by the functional unit receiving a MPA signal are not provided by ISO 21919.

4.2.8.7 DAT

DAT signals (Data) report an information package to the functional unit recipient.

5 Documentation

The following information shall be documented:

— interface characterization on conformance class 1, conformance class 2 or conformance class 3;

— executed conformance options;

— address allocation;

— project-specific extension of signals (if applicable).

