Materials Handling and Intralogistics

VDMA

Design of visible and audible signals of driverless industrial trucks

Contents

Foreword / Legal Note

This guideline has been prepared by

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in cooperation with

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- Berufsgenossenschaft Handel und Waren-logistik (German social accident insurance institution for the trade and logistics industry)

The following document "Design recommenda-tions of visible and audible signals of driverless industrial trucks" is based on the EN ISO 3691-4 and gives a non-binding approach how the requirements of EN ISO 3691-4 may be imple-mented. Whoever uses it must ensure the correct application in the specific case. It is influenced by the state of the art at the time of the respective edition, in particular in the currently published version of EN ISO 3691-4. Ascribing to the sug-gestions described herein does not absolve parties of the responsibility for their own actions. No text in this document claims com-pleteness nor provides exact interpretation of the existing legal provisions and/or safety standards. The contents of this document must not replace the study of the relevant directives, laws, and regulations. Furthermore, the special features of the respective products as well as their different possible applications must be considered.
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Should you encounter any inaccuracies or the possibility of incorrect interpretation in the application of the proposals, please notify VDMA immediately so that any deficiencies can be rectified.

Note
This guideline is a transitional solution and will be withdrawn once a corresponding safety standard is available.

Introduction

The EN ISO 3691-4 defines various cases when a driverless industrial truck shall give an auditory and/or visual signal. It is not specifically regulated how these signals shall be designed.

Standardized communication interfaces can be used to operate mixed fleets of different manufacturers of automated vehicles in a common system. In this case, it is recommended to harmonize the signals of the individual operated vehicles to avoid confusion.

This guide gives recommendations for harmonized signal design, the intention is to integrate these recommendations into EN ISO 3691-4 in due course.

Activities of unification of signals for automatic and autonomous vehicles are ongoing in other industries e.g. automotive and agricultural. These activities were as well considered in this guideline.

This brochure is intended for

- Manufacturers of driverless industrial trucks
- Health and safety authorities
- Market surveillance authorities
- Users of driverless industrial trucks
- System integrators

Normative references

The following documents, in whole or in part, are referenced in this guideline and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies. Besides the referenced standards further documents were considered in the signal design process, they are listed in the bibliography.

EN ISO 3691-4:2023
Industrial trucks – Safety requirements and verification – Part 4: Driverless industrial trucks and their systems

Machinery Directive 2006/42/EC

EN ISO 12100:2010
Safety of machinery –
General principles for design –
Risk assessment and risk reduction

EN 981:2009-01
Safety of machinery - System of auditory and visual danger and information signals

EN ISO 13849-1:2016-06
Safety of machinery – Safety related parts of control systems - Part 1: General principles for design

IEC 60204-1:2016-10
Safety of machinery. Electrical equipment of machines General requirements

SAE J3134:201905
Surface vehicle recommended practice: Automated Driving System (ADS) Marker Lamp

SAE J578_201902
Color specification

ISO/TR 23049:2018-09
Road Vehicles — Ergonomic aspects of external visual communication from automated vehicles to other road users

ISO 5053-1:2020-06
Industrial trucks - Vocabulary

Terms and definitions

For the purposes of this guideline, the terms and definitions given in ISO 5053-1, EN ISO 3691-4, EN 981, EN ISO 12100 as well as the following apply.

Warning field
Area of surveillance currently monitored by the virtual bumper (e.g. safety laser scanner); if an object is detected in this area, so this area is violated, the vehicle starts a controlled deceleration.

Mode
Refers to a general mode the truck is currently in, for example automatic mode or manual mode.

State
Vehicle state encompasses speed, rate of acceleration, deceleration, idle, etc. (ISO/TR 23049)

Perception
Signals that provide information about what the truck perceives of its surroundings, for example an unknown or unexpected object in its path (see ISO/TR 23049).

Intention
The intention refers to a behavior of the truck planned in the near future, for example changing direction from a straight path (see ISO/TR 23049).

Specification of the signals

In this guideline the warning signals will be divided into the following categories described in terms and definitions:

- Mode
- State
- Perception
- Intention

As defined in EN ISO 3691-4 the signals shall be given visually and/or auditory. The recommended main channel shall be visually because of less disturbance and better possibility of assignment to a certain vehicle. In some cases an additional auditory signal is recommended when urgent or important warnings shall be given because auditory signals raise the attention of people and are independent of the gaze direction of intended recipients. Table 1 shows the recommended modality of the signals. If necessary for a truck or application, also only auditive signals might be applied.

In case of redundantly given visual and auditory signals it is recommended to synchronize them temporally.

The signals shall comply with EN ISO 12100 6.4.3.

Optional signals
In addition to the design recommendations for the signals required by EN ISO 3691-4, this guide recommends additional optional signals. If optional signals are used, it is recommended to follow the design rules defined in this guide (see Table 1).

Functional safety of signals
EN ISO 3691-4 define the Performance Level of the safety-related parts of the warning systems. It is recommended to consider the performance level of a multimodal signal to be fulfilled when one of the signals, preferably the visual one, is implemented according to the required performance level. If the risk assessment results in a different conclusion, this should be applied.

Visual signals
It is recommended to utilize separate signaling devices for each of the signal categories to foster fast and intuitive understandability. If this is not feasible, the devices for intention might be the same as for mode.

- **Mode**
  Preferred placement on each corner or on both sides; good visibility from all sides

- **State (including Perception)**
  State and Perception signals are recommended to be displayed using the same devices, preferred placement: in the front and in the back; for omnidirectional vehicles on each side

- **Intention**
  Preferred placement on each corner; on both sides also possible

All recommended specifications regarding the visual signals can be seen in Table 2. Color definitions can be found in SAE J578 and in SAE J3134 for turquoise.

Auditory signals

To be able to display differentiable and meaningful audio signals it is recommended to use a speaker capable of emitting a broadband audio signal.

The maximum sound level of the machine, thus also of the audible signals and generated sound, should not exceed 80 dB(A) according to the Machinery Directive.

In case the vehicles auditory emissions are below the surrounding sound level, an artificially generated sound slightly above surrounding sound level is recommended to be used.

All recommended specifications regarding the visual signals can be seen in Table 4.

Prioritization

In case that two signals shall be displayed at the same time using the same device, the following prioritization order from top to bottom is recommended:

- Emergency stop device activated
- Protective stop active
- Malfunction
- Turning direction / Pivoting direction
- Personal protection means muted
- Operating hazard zone
- Automatic mode

Visibility enhancement and marking of protected zones

Additionally to the above-mentioned safety signals (including blue projected light on the floor in driving direction) projected light can optionally be used to further enhance the visibility of the Truck. This projection can also be used to visualize the size of the safety fields. For these projections the recommended color is red.

Table 1 — List of signals

Information to be signaled	Normative required (EN ISO 3691-4)	Required additionally	Optional	Visual (Visual signals can be omitted if auditory signal is given)	Auditive ● = optional
Vehicle mode					
Battery charging			●	●	
Manual mode (with operator's place)		●		●	
Maintenance mode (without operator's place)		●		●	
Override personal protection means in maintenance mode		●		●	
Automatic mode selected (not yet activated)		●		●	
Automatic mode selected and activated		●		●	
Automatic movement	●			●	●
Automatic movement in operating hazard zone	●			●	●
Automatic movement in restricted zone	●			●	●
Starting automatic movement after standstill of 10s	●			●	●
Reset request			●	●	
Malfunction		●		●	●
Operational stop active	●			●	●
Emergency stop device activated		●		●	●
Personal protection means are muted	●			●	●
Vehicle state					
Driving direction		●		●	
Driving direction – floor projection			●	●	
Braking			●	●	
Vehicle perception					
Protective stop active			●	●	●
Protective stop active – floor projection			●	●	
Warning field violation			●	●	●
Vehicle intention					
Turning left / lane change	●			●	
Turning right / lane change	●			●	
Pivoting left	●			●	
Pivoting right	●			●	

Table 2 — Design recommendations

Information to be signaled	Visual signal	Floor projection	Signal category	Color	Frequency (Hz)	Temporal behavior	Auditory signal	Frequency for repetition of auditory signal (Hz)	comment
Vehicle mode									
Battery charging	●		Mode	white	0,4	fading			
Manual mode (with operator's place)	●		Mode	white		fix			
Maintenance mode (without operator's place)	●		Mode	white		fix			
Override personal protection means in maintenance mode	●		Mode	alternating white/orange	1,6	alternating fast			
Automatic mode selected (not yet activated)	●		Mode	blue-green	0,4	blinking slow			
Automatic mode selected and activated	●		Mode	blue-green		fix			
Automatic movement	●		Mode	blue-green		fix	A1	steady	
Automatic movement in operating hazard zone	●		Mode	alternating orange/blue-green	0,4	alternating slow short gap in between	A3	0,4	
Automatic movement in restricted zone	●		Mode	alternating orange/blue-green	0,4	alternating slow short gap in between	A3	0,4	
Starting automatic movement after standstill of 10s	●		Mode	orange		3 blinks (twice long, once short; 2s in total)	A2	same as light	
Starting automatic movement after standstill of 10s		●	Projection both sides	red		same as LED			
Reset request	●		Mode	blue	0,4	blinking slow			
Malfunction	●		Mode	red		fix	A3	0,4	
Operational stop active	●		Mode	red	1,6	blinking fast as long as vehicle moves. In standstill: fix			
Emergency stop device activated	●		Mode	red		fix			
Personal protection means are muted	●		Mode	alternating orange/blue-green	1,6	alternating fast short gap in between	A4	0,8	1)
Vehicle state									
Driving direction - signals on approaching side	●		State: driving direction	white		fix			
Driving direction - signals on retreating side	●		State: against driving direction	red		fix			
Driving direction - signals on approaching side		●	Projection: driving direction	Blue		fix or running light			2)
Braking	●		State: against driving direction	red, higher intensity than for driving direction		fix, higher intensity			
Vehicle perception									
Protective stop active	●		State: all sides	red	1,6	blinking fast	A5	1,6	3)
Protective stop active		●	Projection on all sides or only on violated side	red	1,6	blinking fast			
Warning field violation	●		State: driving direction	orange	0,4	blinking slow	A3	0,4	4)
Vehicle intention									
Turning left / lane change	●		Intention left or Mode light left	orange	1,6	blinking fast (running light possible)			5)
Turning right / lane change	●		Intention right or Mode light right	orange	1,6	blinking fast (running light possible)			5)
Pivoting left	●		Intention or Mode all sides	orange	1,6	blinking fast or running light			5) 6)
Pivoting right	●		Intention or Mode all sides	orange	1,6	blinking fast or running light			5) 6)

1) for long-term use also 0,4Hz for visual and auditive signal possible (example: automatic assembly trolleys that drive slowly without protective field)
2) Projection of symbols also possible, keep in mind the color of the floor and choose other color in case of problems, avoid red and orange
3) After truck comes to halt: optional continuation of auditory warning, longer pauses or change to A3
4) Auditory signal 4x with the same timing as light, then 30s pause, then repeating
5) Blinking should start in minimum 2s before turning (no Performance-level according to EN ISO 13849-1 required for the early start of blinking)
6) Possibilites: blinking on diagonal corners where vehicle turns to, running light on each corner or running light around the vehicle using all corners

Table 3 — Design recommendations for auditive warnings

Audio signal number		Description	Alternative	urgency	Message category according to EN981	Sound pressure level relative to ambient noise	purpose
A1	Automatic movement	Unobtrusive background sound, Pitch might be raised with increasing vehicle speed. Examples: Sound with slightly modulated spectrum; Electric cars AVAS; Sound of electric forklift truck	Playing music	low	all clear	equal	Pedestrians in the immediate surroundings can notice vehicle coming from behind
A2	Start-up autonomous movement after standstill of 10s	Pattern of three segments with constant pitch and approximately constant volume each. Total length of pattern: 2s. The first two segments are equal in pitch and duration, the third part is slightly shorter and higher in pitch. The pause between the parts is about half as long as the segments. Example: Two segments of 0,5kHz/0,6s; last segment 0,8kHz/0,4s; pauses: 0,2s	Speech output possible in addition to specified sound	medium	caution	15 dB above	Warning people in the direct surroundings
A3	Information: Error / Warning field violation	Sound according to EN 981 from category command. Sound shall not be able to be confused with other sounds from caution or danger category. Example: One segment sound with constant pitch of 1kHz and fading sound pressure level over time. Duration: about 1s	Speech output possible	low / medium	command	slightly above	Raising attention of people around to get them to do something (e.g. clear the way of the vehicle)
A4	Safety canner is muted	Two segments of 0,6s and fading sound pressure level each. Pitch of second segment slightly higher than of the first segment. Short break in between the segments, slightly longer break between repetitions. Example: Two segments 1kHz / 1,1kHz	Speech output possible in addition to specified sound	medium	caution	15 dB above	Warning people in the direct surroundings
A5	Warning: Protective stop active	Two identical segments with upwards sweeping sound. Very short pause between the segments, medium length pause between the patterns. Long pause after two iterations when immediate danger is not present anymore (truck in safe state but warning still active) Example: sweeping sound from 0,9kHz to 1,35kHz Pause durations	Speech output possible in addition to specified sound	high	danger	15 dB above	Urgent warning to people in the surroundings

Bibliography

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Basic and safety principles for man-machine
interface, marking and identification –
Coding principles for indicators and actuators

EN ISO 7731:2008-12
Ergonomics - Danger signals for public and
work areas - Auditory danger signals

VDA 5050 V2.0:2022
Interface for the communication between
automated guided vehicles (AGV) and a
master control

Impressum

DesignStudio

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