

भू-संचलन मशीनरी — संघात चेतावनी
और परिवर्जन
भाग 1 सामान्य अपेक्षाएँ

Earth-Moving Machinery — Collision
Warning and Avoidance
Part 1 General Requirements


ICS 53.100

© BIS 2024
© ISO 2022



भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS
मानक भवन, 9 बहादुर शाह ज़फर मार्ग, नई दिल्ली - 110002
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI - 110002
www.bis.gov.in www.standardsbis.in


NATIONAL FOREWORD

This Indian Standard (Part 1) which is identical to ISO 21815-1 : 2022 'Earth-moving machinery — Collision warning and avoidance — Part 1: General requirements' issued by the International Organization for Standardization (ISO) was adopted by the Bureau of Indian Standards on recommendation of the Earth **Moving Equipment and Material Handling**  ional Committee and approval of the Mechanical Engineering Division Council.

The text of ISO standard is proposed for publication as an Indian Standard without deviations. Certain terminologies and conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

- a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'; and
- b) Comma (,) has been used as a decimal marker, while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standard, which are to be substituted in their respective place, are listed below along with their degree of equivalence for the editions indicated:

| <i>International Standard</i> | <i>Corresponding Indian Standard</i> | <i>Degree of Equivalence</i> |
|--|--|--|
| ISO 3450 : 2011 Earth-moving machinery — Wheeled or high-speed rubber-tracked machines — Performance requirements and test procedures for brake systems | IS 16479 : 2020 Performance requirements and test procedures of braking systems for wheeled or high-speed rubber tracked earth moving machines and construction equipment vehicles (<i>first revision</i>) |  Identical |
| ISO 12100 : 2010 Safety of machinery — General principles for design — Risk assessment and risk reduction | IS 16819 : 2018/ISO 12100 : 2010 Safety of machinery — General principles for design — Risk assessment and risk reduction | Identical |
| ISO 13766-1 Earth-moving and building construction machinery — Electromagnetic compatibility (EMC) of machines with internal electrical power supply — Part 1: General EMC requirements under typical electromagnetic environmental conditions | IS/ISO 13766-1 : 2018 Earth-moving and building construction machinery — Electromagnetic compatibility (EMC) of machines with internal electrical power supply: Part 1 General EMC requirements under typical electromagnetic environmental conditions | Identical |
| ISO 13766-2 Earth-moving and building construction machinery — Electromagnetic compatibility (EMC) of machines with internal electrical power supply — Part 2: Additional EMC requirements for functional safety | IS/ISO 13766-2 : 2018 Earth-moving and building construction machinery — electromagnetic compatibility (EMC) of machines with internal electrical power supply: Part 2 Additional EMC requirements for functional safety | Identical |
| ISO 13849-1 : 2023 Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design | IS 16810 (Part 1) : 2018/ISO 13849-1 : 2015 Safety of machinery — Safety related parts of control systems: Part 1 General principles for design | Identical |

(Continued on third cover)

Contents

Page

| | |
|---|-----------|
| Introduction | v |
| 1 Scope | 1 |
| 2 Normative references | 1 |
| 3 Terms and definitions | 2 |
| 4 Performance requirements | 4 |
| 4.1 General requirements..... | 4 |
| 4.1.1 General..... | 4 |
| 4.1.2 Electro-magnetic compatibility (EMC)..... | 4 |
| 4.1.3 Environmental condition requirements..... | 4 |
| 4.1.4 Functional safety..... | 4 |
| 4.1.5 Risk assessment..... | 4 |
| 4.1.6 Analysis on machine modification..... | 5 |
| 4.2 Requirements on CxS..... | 5 |
| 4.2.1 General..... | 5 |
| 4.2.2 Detection of intended objects..... | 5 |
| 4.2.3 Collision risk levels and CxS actions..... | 5 |
| 4.2.4 System limitations..... | 5 |
| 4.3 Outline of process flow for CxS..... | 6 |
| 4.4 False CxS actions..... | 6 |
| 4.5 Operating state transition of CxS..... | 6 |
| 4.5.1 General..... | 6 |
| 4.5.2 Switching between normal mode and stand-by mode..... | 6 |
| 4.5.3 Switching between normal mode to override mode..... | 7 |
| 4.5.4 Status information..... | 7 |
| 4.6 Self-checking, status indication and failure warning..... | 7 |
| 4.7 Protection against unauthorized modification of system functions..... | 8 |
| 5 System classification | 8 |
| 5.1 General..... | 8 |
| 5.2 System capability types..... | 8 |
| 5.2.1 Take-off inhibition CxS (TIC)..... | 8 |
| 5.2.2 Swing inhibition CxS (SIC)..... | 8 |
| 5.2.3 Manoeuvring speed CxS (MSC)..... | 8 |
| 5.2.4 Travel speed CxS (TSC)..... | 8 |
| 5.3 System types..... | 9 |
| 5.4 Types of detection..... | 9 |
| 5.5 Description of systems..... | 9 |
| 6 Test procedures | 9 |
| 6.1 General..... | 9 |
| 6.2 Test condition..... | 9 |
| 6.2.1 Test environment condition..... | 9 |
| 6.2.2 Test surface conditions..... | 9 |
| 6.3 Subject machine conditions..... | 10 |
| 6.4 Specification of test objects..... | 10 |
| 6.5 Performance test..... | 10 |
| 6.5.1 General..... | 10 |
| 6.5.2 Test object installation..... | 10 |
| 6.5.3 Subject machine..... | 10 |
| 6.5.4 Test result judgement criteria..... | 10 |
| 6.6 False positive CxS action test..... | 10 |
| 7 CxS information for use | 11 |
| 7.1 Information for the operator..... | 11 |

| | | |
|---------------------|---|-----------|
| 7.2 | Information about residual risks | 11 |
| Annex A | (informative) Machine interaction scenario common examples | 12 |
| Annex B | (informative) Comparison of system functions | 14 |
| Annex C | (informative) Example of operator's manual | 15 |
| Bibliography | | 17 |

Introduction

This document is a type-C standard as stated in ISO 12100.

This document is of relevance, in particular, for the following stakeholder groups representing the market players with regard to machinery safety:

- machine manufacturers (small, medium and large enterprises);
- health and safety bodies (regulators, accident prevention organisations, market surveillance etc.).

Others can be affected by the level of machinery safety achieved with the means of the document by the above-mentioned stakeholder groups:

- machine users/employers (small, medium and large enterprises);
- machine users/employees (e.g. trade unions, organizations for people with special needs);
- service providers, e.g. for maintenance (small, medium and large enterprises);
- consumers (in case of machinery intended for use by consumers).

The above-mentioned stakeholder groups have been given the possibility to participate at the drafting process of this document.

In addition, this document is intended for standardization bodies elaborating type-C standards.

The requirements of this document can be supplemented or modified by a type-C standard.

For machines which are covered by the scope of a type-C standard and which have been designed and built according to the requirements of that standard, the requirements of that type-C standard take precedence.

The machinery concerned and the extent to which hazards, hazardous situations or hazardous events are covered are indicated in the Scope of this document.

When requirements of this type-C standard are different from those which are stated in type-A or type-B standards, the requirements of this type-C standard take precedence over the requirements of the other standards for machines that have been designed and built according to the requirements of this type-C standard.

Increasing use of detection systems and avoidance technology in the area of earth-moving machinery has been supporting operators to safely operate machines in the field of mining and construction. At the same time, there are demands to set standards for machines and systems detecting, alerting and intervening to mitigate collision risk.

There are currently two existing standards in the field: ISO 16001 and ISO 17757. These standards provide guidance for visibility aids and object detection systems and for autonomous and semi-autonomous machines, however, there is currently no standard that describes collision risk awareness, warning signals and collision avoidance actions of the machinery operated by humans when there is a risk of collision.

Collision warning and avoidance systems are developing technologies and algorithms are not yet mature and well understood. This document is intended to foster innovation and accelerate the pace of improvements in new collision warning and avoidance technologies. The performance requirements of this document are technology-neutral and do not specify technologies to make the requirements.

The systems described in this document are intended to assist the operator of the machine. As current technologies are unable to achieve full collision warning/avoidance in every situation, the responsibility for safe operation of the machine remains with the operator of the machine.

This document is a part of the ISO 21815 series relating to: communication interfaces, collision risk areas and collision risk levels, specific requirements for collision warning and collision avoidance systems, and specific use case requirements.

Indian Standard

EARTH-MOVING MACHINERY — COLLISION WARNING AND AVOIDANCE

PART1 GENERAL REQUIREMENTS

1 Scope

This document provides terminology and general guidance on the principles of collision warning and collision avoidance systems for:

- earth moving machinery as defined in ISO 6165,
- mobile underground mining machinery as defined in ISO 19296, and
- road construction machinery as defined in ISO 22242.

This document provides general requirements for detection of objects, warnings to the operator, automatic intervention control to avoid collision, and test procedures. It is intended to be used in conjunction with the other parts of the ISO 21815 series, which provide detailed guidance and requirements for collision warning and collision avoidance systems and determining risk areas and risk levels. The specific requirements and definitions for particular types of machines are defined in the use case parts of the ISO 21815 series.

This document covers collision avoidance by speed reduction or motion inhibit: it does not cover avoidance by automatic manoeuvring (e.g. steering) away from the intended object.

The systems described in this document are only intended to assist the operator of the machine. The responsibility for safe operation of the machine remains with the operator of the machine.

This document is not applicable to collision warning and collision avoidance systems installed to the machine before the date of its publication.

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 3450:2011, *Earth-moving machinery — Wheeled or high-speed rubber-tracked machines — Performance requirements and test procedures for brake systems*

ISO 12100:2010, *Safety of machinery — General principles for design — Risk assessment and risk reduction*

ISO 13766-1, *Earth-moving and building construction machinery — Electromagnetic compatibility (EMC) of machines with internal electrical power supply — Part 1: General EMC requirements under typical electromagnetic environmental conditions*

ISO 13766-2, *Earth-moving and building construction machinery — Electromagnetic compatibility (EMC) of machines with internal electrical power supply — Part 2: Additional EMC requirements for functional safety*

ISO 13849 (all parts), *Safety of machinery — Safety-related parts of control systems*

ISO 19014-1, *Earth-moving machinery — Functional safety — Part 1: Methodology to determine safety-related parts of the control system and performance requirements*

ISO 19014-3, *Earth-moving machinery — Functional safety — Part 3: Environmental performance and test requirements of electronic and electrical components used in safety-related parts of the control system*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12100 and the following apply.

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

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

3.1 interaction

situation where a machine encounters an *intended object* (3.5) when moving or about to move, placing itself or the operator at risk, or exposing the intended objects to risk

3.2 warning

transmission of alert information by visual, audible or other means of signals

Note 1 to entry: Warning is targeted to the operator and also can be for people located in close proximity to the machine in addition to operator.

3.3 evasive action

action initiated by the operator to attempt to prevent or avoid a foreseeable collision

EXAMPLE Braking, steering.

3.4 interventional collision avoidance action

automatic action initiated by a *collision avoidance system (CAS)* (3.9) to attempt to prevent or avoid a foreseeable collision

EXAMPLE Braking, inhibiting motion, slowing down.

3.5 intended object

object, such as a person, machine, vehicle or obstacle, which is intended to be detected by a *collision warning system (CWS)* (3.8) or a *collision avoidance system (CAS)* (3.9) when in the *collision risk area* (3.7)

3.6 collision risk level

value that is assigned each *intended object* (3.5) to determine if a collision is foreseeable

Note 1 to entry: Collision risk levels are described in ISO 21815-3 and a future part of the ISO 21815 series dedicated to risk area and risk level for track movement and swing/rotation.

3.7 collision risk area

space analysed to determine the *collision risk level* (3.6)

3.8 collision warning system CWS

system which detects *intended objects* (3.5) in the *collision risk area* (3.7), determines the *collision risk level* (3.6) and provides a *warning* (3.2) to the operator

3.9
collision avoidance system
CAS

system which detects *intended objects* (3.5) in the *collision risk area* (3.7), determine the *collision risk level* (3.6) and provides *interventional collision avoidance action* (3.4)

3.10
CxS

collision warning system (CWS) (3.8) or *collision avoidance system (CAS)* (3.9) or a system providing both

3.11
detection

acknowledgement of *intended objects* (3.5) by a CxS (3.10)

3.12
CxS action

collision warning system (CWS) (3.8) providing *warning* (3.2) to the operator or *collision avoidance system (CAS)* (3.9) taking *interventional collision avoidance action* (3.4)

3.13
false positive CxS action

unnecessary or inappropriate *CxS action* (3.12)

Note 1 to entry: This can be caused by incorrect determination of the *collision risk level* (3.6).

3.14
false negative CxS action

lack of necessary or appropriate *CxS action* (3.12)

Note 1 to entry: This can be caused by incorrect determination of the *collision risk level* (3.6).

3.15
CxS device

CxD

device with sensors providing CxS (3.10) functions to detect *intended objects* (3.5) in the proximity of the machine, determine the *collision risk level* (3.6), warn the operator of the presence of the intended object for a *collision warning system (CWS)* (3.8), and/or provide signals to the machine control system via a communication interface to initiate the appropriate *interventional collision avoidance action* (3.4) on the machine for a *collision avoidance system (CAS)* (3.9)

Note 1 to entry: CxS device is described as CxD in other parts of the ISO 21815 series.

Note 2 to entry: Proximity detection system (PDS) is a colloquial industry term for a physical device providing CWS or CAS functionality.

3.16
normal mode

operational mode whereby a CxS (3.10) is active and ready to provide all functions of the CxS, including *warning* (3.2) information and *interventional collision avoidance action* (3.4)

3.17
stand-by mode

operational mode selected by an authorized person, whereby a CxS (3.10) can be active, but *warning* (3.2) information or *interventional collision avoidance action* (3.4) or both are not provided by the system, and returns to *normal mode* (3.16) by an authorized person

3.18
override mode

operational mode selected by the operator, whereby a CxS (3.10) can be active, but *warning* (3.2) information or *interventional collision avoidance action* (3.4) or both are suspended temporarily and return automatically to *normal mode* (3.16) after a certain condition

3.19 system integrator

entity, providing a whole system by integrating the machine, the interface and the CxS (3.10) devices

4 Performance requirements

4.1 General requirements

4.1.1 General

Machinery and systems shall comply with the safety requirements and/or protective/risk reduction measures of this document. In addition, the machine and systems shall be designed according to the principles of ISO 12100:2010 for relevant but not significant hazards which are not dealt with by this document.

This document specifies the principles of operation, basic functionality, system requirements and general test requirements for collision warning and collision avoidance systems. The ISO 21815 series intends to support the operator to safely operate the machine.

The ISO 21815 series is not intended to require plug-and-play capability between CxS devices and machines. Technical details not described in this document should be agreed upon between the CxS device manufacturer, the machine manufacturer and system integrator, as applicable.

4.1.2 Electro-magnetic compatibility (EMC)

A CxS device providing CWS capability shall be in conformance with ISO 13766-1. A CxS device that provides CAS capability shall be in conformance with both ISO 13766-1 and ISO 13766-2. The EMC testing of the CxS device may be performed treating the CxS device as an electronic sub-assembly or with the CxS device incorporated into the machine.

NOTE The addition of a CxS device could negatively impact conformance of the machine to ISO 13766-1 or ISO 13766-2 and can require a combined re-evaluation of the CxS-equipped machine.

4.1.3 Environmental condition requirements

Safety-related parts (SRP) of a CxS device providing CAS capability identified according to the definition in ISO 19014-1 or the ISO 13849 series shall meet the requirements of ISO 19014-3.

4.1.4 Functional safety

The consequence of adding CxS device shall be analysed using a risk assessment.

The addition of a CxS device with CWS or CAS capability shall not negatively impact the performance level achieved (e.g. the ISO 19014 series, ISO 15998, the ISO 13849 series) of the safety control system of the original machine.

NOTE The addition of CxS device could require a combined re-evaluation of the CxS device-equipped machine.

4.1.5 Risk assessment

A risk assessment for a CxS device-equipped machine shall be completed according to the principles of ISO 12100 by the system integrator. All identified risks shall be mitigated to acceptable risk levels as part of the risk assessment process. The results of the risk assessment shall be formally documented.

4.1.6 Analysis on machine modification

The addition of CxS device shall require an analysis to be completed as it could negatively impact the original machine's safety and performance characteristics (guidance can be found in standards, e.g. the ISO 20474 series, ISO 19296).

4.2 Requirements on CxS

4.2.1 General

The CxS shall detect intended objects (e.g. people, other machines, vehicles, and obstacles) within the collision risk area and provide CxS action as defined below:

- CWS shall provide a warning to instruct the operator to maintain the machine in a stationary state if an intended object is present or to immediately apply evasive action.
- CAS shall provide interventional collision avoidance action without requiring an operator action.

NOTE 1 The collision risk areas can be in front, beside or behind machines along the travel path of the machine. For excavators and other machines where all or part of the machine can rotate, the risk area also includes the area where the machine can rotate. A detailed guideline of a collision risk area and for the collision risk level assessment are described in the other parts of the ISO 21815 series.

NOTE 2 The CxS does not necessarily cover all area that the machine can move.

NOTE 3 CAS can also provide warning to operator.

4.2.2 Detection of intended objects

Appropriate detection technology differs depending on the machine type and the object type intended to be detected. ISO 16001:2017, Annex A summarises existing an object detection system (ODS). The technologies should be selected, and combined as appropriate, according to the CxS design concept, with consideration to the advantages and disadvantages of differing types. Comparison of system functions is described in [Annex B](#).

4.2.3 Collision risk levels and CxS actions

The system shall, based on the detection information of intended objects and machine operating conditions, determine the collision risk level and provide at least one of the CxS actions, as appropriate, as shown below:

- warning signal to the operator (CWS);
- interventional collision avoidance action (CAS).

Interventional collision avoidance actions provided by the system depend on what functions are installed in the system. Collision risk level judgement criteria and interventional collision avoidance actions depend on the machine type (such as dumper, dozer, hydraulic excavators and others).

4.2.4 System limitations

Collision warning and avoidance systems that have limited capabilities (e.g. limited speed and distance) could have different limits of use based on the use cases that are defined in the other parts of the ISO 21815 series. The limitations for each use case shall be defined in the operator's manual.

See [7.1](#) for the requirements on the limitations for each use case in the operator's manual.

4.3 Outline of process flow for CxS

The CWS searches for intended objects in the collision risk area and confirms the existence of intended object. When an intended object is detected, the CWS will provide a warning to the operator as determined by the collision risk level.

The CAS searches for intended objects in the collision risk area and confirms the existence of intended objects. When an intended object is detected, the CAS will provide an interventional collision avoidance action as determined by the collision risk level.

The CxS process flow outline in [Figure 1](#) uses braking as an example of the CxS action.

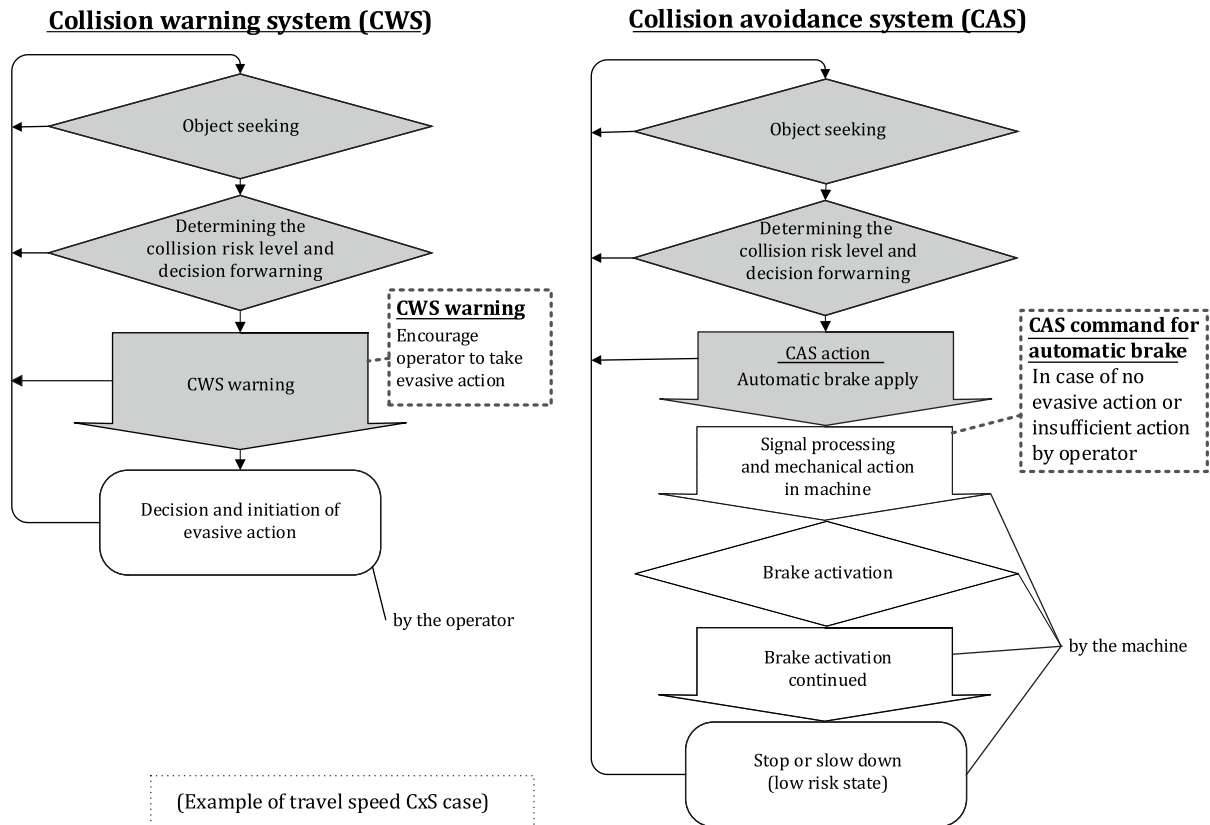


Figure 1 — Example of a high-level process flow diagram for CWS and CAS

4.4 False CxS actions

Both false positive and false negative CxS actions shall be minimized.

4.5 Operating state transition of CxS

4.5.1 General

A CxS may have different operational modes: normal mode, stand-by mode, and override mode. [Figure 2](#) describes an example of the operating state transition of a CxS.

4.5.2 Switching between normal mode and stand-by mode

When a CxS is equipped with a stand-by mode (CxS disengage), it shall be a deliberate action by an authorized person. The CxS shall require authentication means, (e.g. password, key) to enable the stand-by mode.

A CxS shall not be able to automatically switch to the stand-by mode.

By default, a CxS should start in normal mode upon machine start up.

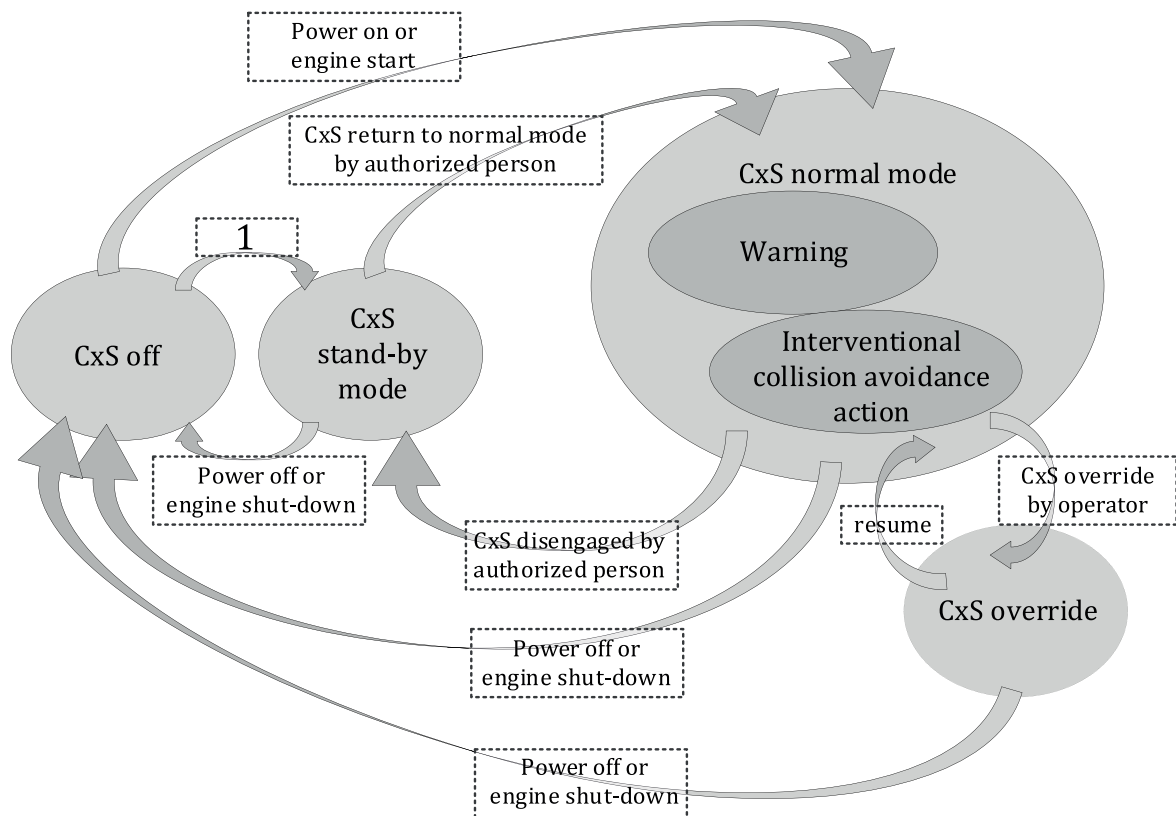
4.5.3 Switching between normal mode to override mode

When a machine is equipped with a means to shift a CxS to an override mode, it shall require a deliberate action by the operator to engage the override mode:

- a CxS shall not be able to automatically switch to the override mode,
- by default, a CxS should start in normal mode upon machine start-up.
- staying in an override mode unintentionally shall not be possible.

4.5.4 Status information

Continuous status indication of operational mode of the CxS shall be provided to the operator. The method of the indication should be according to the principles of ISO 6011.



Key

- 1 power on or engine start, during stand-by mode selected by an authorized person

Figure 2 — Example of CxS transition diagram

4.6 Self-checking, status indication and failure warning

Upon power on, a CxS shall perform an initial system check. While the initial system check is being carried out, the system shall provide an indication showing the status. After completion of the initial system check, the system shall give an appropriate system function indication. Throughout operation, the system shall perform self-diagnosis at a frequency as determined by the manufacturer's risk assessment. When a CxS detects a loss of its function, the system shall inform the operator. When CxS

capability is detected as not available because it is outside of its specified limits of use (e.g. speed), the operator shall be informed. The method to indicate the operating status should be according to the principles of ISO 6011.

4.7 Protection against unauthorized modification of system functions

A CxS shall be designed to prevent unauthorized modification of the CxS internal parameters or software.

EXAMPLE Protections against unauthorized modification such as passwords, key locks.

5 System classification

5.1 General

The CxS can provide either CWS or CAS or both. Systems can be built to provide multiple different capabilities. Additional capabilities that are not listed are possible. [Annex A](#) describes common examples of machine interaction scenario.

5.2 System capability types

There are four types of system capabilities: take-off inhibition CxS (TIC), swing inhibition CxS (SIC), manoeuvring speed CxS (MSC), and travel speed CxS (TSC).

5.2.1 Take-off inhibition CxS (TIC)

A TIC is a CxS that determines that the collision risk level before movement (e.g. forward, reverse) is initiated followed by providing CxS action. A CAS system inhibits machine movement.

NOTE 1 Typical machines are dumper, grader, wheel loader, dozer excavator.

NOTE 2 Motion inhibition prevents a machine from moving while stationary.

5.2.2 Swing inhibition CxS (SIC)

A SIC is a CxS that determines that the collision risk level before swing movement (e.g. rotation) is initiated followed by providing CxS action. A CAS system inhibits machine movement.

NOTE 1 Typical machines are excavators and backhoe loaders.

NOTE 2 Motion inhibition prevents a machine from moving while stationary.

5.2.3 Manoeuvring speed CxS (MSC)

An MSC is a CxS that determines the collision risk level at low manoeuvring speeds (e.g. below 10 km/h) and provides CxS action. An MSC needs to work in all possible directions of travel (e.g. forward, reverse). The system may be designed only to work below the manoeuvring speed.

NOTE Typical machines are dumpers, graders, wheel loaders, dozers, excavators.

5.2.4 Travel speed CxS (TSC)

A TSC is a CxS that determines the collision risk level at high travel speed and provides CxS action. The system may be designed to operate at speeds only above the manoeuvring speed (e.g. above 10 km/h) and only in the forward direction.

NOTE Typical machines are dumpers, graders, wheel loaders.

5.3 System types

There are two system types of CxS: CWS and CAS.

NOTE A CxS can provide both warning and avoidance CxS actions.

5.4 Types of detection

A CxS can passively detect (e.g. camera, radar) intended objects that are not instrumented or a CxS can require the intended object to be instrumented (e.g. RFID).

5.5 Description of systems

CxS can be described by combining multiple classifications.

EXAMPLE 1 Provides warning and avoidance for take-off for intended objects of large machines, small vehicles, and human using a passive system.

EXAMPLE 2 Provides avoidance when manoeuvring when the intended object is instrumented.

6 Test procedures

6.1 General

The system integrator shall conduct testing based on technical information provided by the machine manufacturer and the CxS device manufacturer. The test procedures described here provides minimum requirements of a CxS for typical operational situations, and do not represent all situations in all conditions.

The test procedures prescribe test conditions to assure that the process can be repeated and produce stable results. Detection technology, the type of earthmoving machinery with the system, and the shape of the test object define the test methods. Detailed test procedures are described in other parts of the ISO 21815 series.

The test condition shall be recorded.

6.2 Test condition

6.2.1 Test environment condition

There shall be no precipitation that affects the testing.

EXAMPLE Rain, snow, sleet, hail.

There shall be no wind strong enough to affect the testing.

Ambient temperature during test shall be within the operating range of the tested machine and CxS devices.

The system integrator can design the test based on the information about the environment condition provided by the CxS device manufacturer and the machine manufacturer.

6.2.2 Test surface conditions

The test surface shall consist of a hard, dry surface with a well-composed base, and the ground moisture may be present to the extent that it does not adversely affect the test. The test surface shall not have a slope of more than 3 % at right-angles to the direction of travel.

The slope in the direction of travel shall be no greater than 1 %, or as specified for the test being carried out.

6.3 Subject machine conditions

The test configuration of the subject machine that is within the scope of ISO 3450:2011 shall be according to ISO 3450:2011, 5.4.

The test configuration of the applicable braking or safety standards (e.g. ISO 18758-2, ISO 19296, ISO 10265) should be used for subject machines outside the scope of ISO 3450:2011.

6.4 Specification of test objects

The test object may be an actual intended object or a substitute test object giving equivalent detection results as the actual intended object. When a collision risk is foreseen in the test procedure, the test object may be replaced by the substitute test object. Even when same substitute test object is selected, results could vary depending on the detection system used. Therefore, an appropriate method should be selected to reproduce the characteristics of the test object.

Record the details of the test object.

6.5 Performance test

6.5.1 General

Testing shall be carried out under the conditions determined in [6.5](#). The results shall be recorded for evaluation. The test shall be performed three times with each test condition, as defined in [6.3](#) and [6.4](#).

6.5.2 Test object installation

The test object installation method, orientation and movement shall be defined in detail.

6.5.3 Subject machine

The operating conditions for the subject machine based on the limitations of the CxS shall be defined. The operating test condition of subject machine should simulate real operating condition as closely as possible within safe limits. When the subject machine is tested for traveling condition, the travel position which is defined by the machine's manufacturer shall be used.

6.5.4 Test result judgement criteria

Determine if the set judgement criteria have been achieved. The judgement criteria could be set by the system integrator under the given machine condition based on information provided by the machine and/or the CxS devices' manufacturer. Judgement criteria should be able to ensure that the CxS warns the operator as intended, initiates interventional collision avoidance action, and/or stops the machine before colliding with the test object or inhibits machine motion, at the standard test condition described in [Clause 6](#).

Detailed requirements will be described in other parts of the ISO 21815 series.

6.6 False positive CxS action test

The test shall verify that the system does not provide unnecessary warnings under the test conditions based on the defined system limitation and specifications, nor give false warning and false interventional collision avoidance action when the risk of collision is not foreseen. The test shall be performed to set simulated situations where the system could mistakenly judge the risk of collision when there is no risk.

7 CxS information for use

7.1 Information for the operator

CxS-equipped machines shall be accompanied with an operator's manual, provided by the system integrator. The system integrator shall compile the operator's manual based on the technical information provided by the machine's manufacturer and the CxS device's manufacturers. The operator's manual shall contain technical and safety instructions and limits of use, aiming to explain the intended use of the system (see ISO 12100:2010, 6.4.5). [Annex C](#) shows examples of information.

7.2 Information about residual risks

A risk assessment of integrating the CxS devices into the machine shall be conducted according to the principles of ISO 12100. Information regarding residual risks shall be communicated through the information for use documentation.

Annex A (informative)

Machine interaction scenario common examples

A.1 General

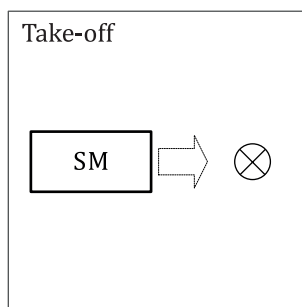
This annex shows examples of machine interactions occurring during machine operation, with descriptions of possible scenarios of interaction, in three categories.

Manufacturers may refer to this to categorize collision cases or to define intended objects and machine performance while a CxS is developed. The scenarios are not limited to the categories listed below.

A.2 Machine interaction scenario definitions

A.2.1 Take-off

The intended object is in the collision risk area around the subject machine. The subject machine is stationary and intending to move ([Figure A.1](#)).



Key

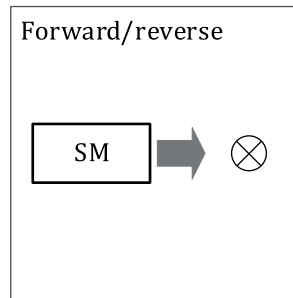
SM subject machine

⊗ intended object

Figure A.1 — Machine interaction scenario example - Take-off

A.2.2 Forward/reverse

Subject machine is moving forward or in reverse and interacts with an intended object in the collision risk area ([Figure A.2](#))



Key

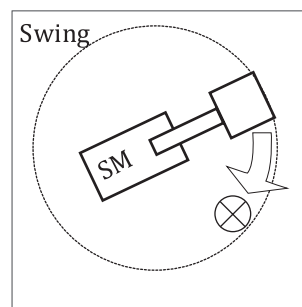
SM subject machine

⊗ intended object

Figure A.2 — Machine interaction scenario example - Forward/reverse

A.2.3 Swing

The subject machine with rotating structure is operating near an intended object. The subject machine is stationary and intending to rotate ([Figure A.3](#)), e.g. excavator, backhoe loader.



Key

SM subject machine

⊗ intended object

Figure A.3 — Machine interaction scenario example - Swing

Annex B (informative)

Comparison of system functions

This annex describes the difference between CxS and other systems defined in ISO 16001.

- Visibility aid (VA) according to ISO 16001 only provides visual information and no warning signal.
- Object detection system (ODS) according to ISO 16001 has no intelligence for determining collision risk level, but only provides warning signals with the condition that intended objects are in the detection zone.

CxS has an appropriate level of intelligence for determining collision risk levels with the existence of intended objects. Appropriate CxS actions are defined on each collision risk level, including warnings and interventional collision avoidance action. [Table B.1](#) shows the comparison of system functions.

Table B.1 — Comparison of VA, ODS, CWS, CAS

| | Visibility aid (VA) | Object detection system (ODS) | Collision warning system (CWS) | Collision avoidance system (CAS) |
|------------------------------------|---|--|---|---|
| Standard | ISO 16001 | ISO 16001 | ISO 21815 | ISO 21815 |
| Description | Provides indirect visibility (visual information) without warning | <ul style="list-style-type: none"> — Detects intended objects — Provides warnings (not defined when/what/how to provide for warning) | <ul style="list-style-type: none"> — Detect intended objects — Determines collision risk levels — Provides appropriate warnings according to the collision risk levels | <ul style="list-style-type: none"> — Detect intended objects — Determines collision risk levels — Provides appropriate interventional collision avoidance actions according to the collision risk levels |
| Object detection by | Operator (by using VA as required) | Operator (with reference of ODS) | Operator and CWS | Operator and CAS |
| Collision risk level determined by | Operator | Operator | Operator and CWS | Operator and CAS |
| Evasive/interventional action by | Operator | Operator | Operator | Operator and CAS |
| Sensors | None | Sensors for detecting intended objects | <ul style="list-style-type: none"> — Sensors for detecting intended objects — Sensors for machine status (e.g. machine speed) | <ul style="list-style-type: none"> — Sensors for detecting intended objects — Sensors for machine status (e.g. machine speed) |
| Intelligence | None | None (No ability to decide when/what/how to provide for warnings. It means no intelligence.) | Intelligence for collision risk level determination | Intelligence for collision risk level determination and for intervention collision avoidance action |

Annex C (informative)

Example of operator's manual

[Table C.1](#) shows examples of an operator's manual containing technical and safety instructions, aiming to explain the intention of use of the system.

Table C.1 — Example of contents in operator's manual

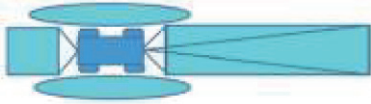
| Item | Contents |
|--|---|
| Description of system performance | To assist the operator of the machine by warning of a foreseeable collision and to give interventional collision avoidance action below 10 km/h, within system limitations |
| Classification | <p>The classes listed below are examples of the intended objects to be detected by CWS and CAS:</p> <ul style="list-style-type: none"> — large machines, — small vehicles, — humans. <p style="text-align: center;">NOTE Intended objects of CxS depend on the application and the machine type, and additional intended object classes that are not listed will be described on other parts of the ISO 21815 series.</p> <p>EXAMPLE 1 Provides take-off inhibition collision warning and avoidance for intended objects of large machines, small vehicles, and human using a passive system.</p> <p>EXAMPLE 2 Provides manoeuvring speed collision avoidance system using an instrumented system.</p> <p>Size and shape of an intended object (e.g. similar size machine and small vehicle) shall be defined and described by the CxS devices manufacturer.</p> |
| Detection range (travelling or standing) | <p>Shape of detection area and size for each capabilities (functions) should be described, as shown in Figure C.1.</p> <div style="text-align: center;">  <p>Figure C.1 — Detection area and size</p> </div> |
| Speed range covered by the system (with stationary intended object) | <p>TSC: forward only (no load) >10 km/h and <X km/h (rated load) >10 km/h and <Y km/h</p> <p>MSC (rated load): forward <10 km/h backward <10 km/h</p> |

Table C.1 (continued)

| Item | Contents |
|---|--|
| External factors affecting system performance and system limitation | EXAMPLE fog, dust; light, sunshine; darkness; obstacles of visibility; terrain condition; payload. |
| Operating instructions | Operating instructions of the system Safe operation instructions Handling instructions Operating instruction at failure |
| Maintenance | Instructions for performance verification Routine for regular performance checks of the system Countermeasures for external conditions which could influence detection performance of the system |
| Instruction of system equipments | Instruction for installation and setting up (including location) Power supply requirements Influence of installation (location, height, angle, etc.) Information to connect with other equipment (if necessary) Proof of regulatory compliance Countries with type approval certificate |
| Jobsite organization | Instruction for jobsite organization for use (including job site preparation) |

Bibliography

- [1] ISO 6011, *Earth-moving machinery — Visual display of machine operation*
- [2] ISO 6165, *Earth-moving machinery — Basic types — Identification and terms and definitions*
- [3] ISO 10265, *Earth-moving machinery — Crawler machines — Performance requirements and test procedures for braking systems*
- [4] ISO 15998, *Earth-moving machinery — Machine-control systems (MCS) using electronic components — Performance criteria and tests for functional safety*
- [5] ISO 16001:2017, *Earth-moving machinery — Object detection systems and visibility aids — Performance requirements and tests*
- [6] ISO 18758-2, *Mining and earth-moving machinery — Rock drill rigs and rock reinforcement rigs — Part 2: Safety requirements*
- [7] ISO 19296, *Mining — Mobile machines working underground — Machine safety*
- [8] ISO 20474 (series), *Earth-moving machinery — Safety*
- [9] ISO/TS 21815-2, *Earth-moving machinery — Collision warning and avoidance — Part 2: On-board J1939 communication interface*
- [10] ISO 21815-3¹⁾, *Earth-moving machinery — Collision warning and avoidance — Part 3: General risk area and risk level*
- [11] ISO 22242, *Road construction and road maintenance machinery and equipment — Basic types — Identification and description*
- [12] IEC 61000 (series), *Electromagnetic compatibility (EMC)*
- [13] IEC 61508 (series), *Functional safety of electrical/electronic/programmable electronic safety-related systems*
- [14] IEC 62061, *Safety of machinery: Functional safety of electrical, electronic and programmable electronic control systems*
- [15] MDG 2007, *Guideline for the selection and implementation of collision management systems for mining*

1) Under preparation. Stage at the time of publication: ISO/CD 21815-3:2022.

(Continued from second cover)

| <i>International Standard</i> | <i>Corresponding Indian Standard</i> | <i>Degree of Equivalence</i> |
|---|---|------------------------------|
| ISO 13849-2 : 2012 Safety of machinery — Safety-related parts of control systems — Part 2: Validation | IS 16810 (Part 2) : 2018/ ISO 13849-2 : 2012 Safety of machinery — Safety related parts of control systems: Part 2 Validation | Identical |
| ISO 19014-1 Earth-moving machinery — Functional safety — Part 1: Methodology to determine safety-related parts of the control system and performance requirements | IS/ISO 19014-1 : 2018 Earth- moving machinery — Functional safety: Part 1 Methodology to determine safety-related parts of the control system and performance requirements | Identical |
| ISO 19014-3 Earth-moving machinery — Functional safety — Part 3: Environmental performance and test requirements of electronic and electrical components used in safety-related parts of the control system | IS/ISO 19014-3 : 2018 Earth-moving machinery — Functional safety: Part 3 Environmental performance and test requirements of electronic and electrical components used in safety-related parts of the control system | Identical |

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 'Rules for rounding off numerical values (*second revision*)'. The number of significant places retained in the rounded-off value should be the same as that of the specified value in this standard.

Bureau of Indian Standards

BIS is a statutory institution established under the *Bureau of Indian Standards Act, 2016* to promote harmonious development of the activities of standardization, marking and quality certification of goods and attending to connected matters in the country.

Copyright

BIS has the copyright of all its publications. No part of these publications may be reproduced in any form without the prior permission in writing of BIS. This does not preclude the free use, in the course of implementing the standard, of necessary details, such as symbols and sizes, type or grade designations. Enquiries relating to copyright be addressed to the Head (Publication & Sales), BIS.

Review of Indian Standards

Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard along with amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the website-www.bis.gov.in or www.standardsbis.in.

This Indian Standard has been developed from Doc No.: MED 07 (23268).

Amendments Issued Since Publication

| Amend No. | Date of Issue | Text Affected |
|-----------|---------------|---------------|
| | | |
| | | |
| | | |
| | | |

BUREAU OF INDIAN STANDARDS

Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110002

Telephones: 2323 0131, 2323 3375, 2323 9402

Website: www.bis.gov.in

Regional Offices:

Central : 601/A, Konnectus Tower -1, 6th Floor,
DMRC Building, Bhavbhuti Marg, New
Delhi 110002

Telephones

{ 2323 7617

Eastern : 8th Floor, Plot No 7/7 & 7/8, CP Block, Sector V,
Salt Lake, Kolkata, West Bengal 700091

{ 2367 0012
{ 2320 9474

Northern : Plot No. 4-A, Sector 27-B, Madhya Marg,
Chandigarh 160019

{ 265 9930

Southern : C.I.T. Campus, IV Cross Road, Taramani, Chennai 600113

{ 2254 1442
{ 2254 1216

Western : 5th Floor/MTNL CETTM Technology Street, Hiranandani Gardens, Powai,
Mumbai - 400076

{ 25700030
{ 25702715

Branches : AHMEDABAD, BENGALURU, BHOPAL, BHUBANESHWAR, CHANDIGARH, CHENNAI, COIMBATORE, DEHRADUN, DELHI, FARIDABAD, GHAZIABAD, GUWAHATI, HARYANA (CHANDIGARH), HUBLI, HYDERABAD, JAIPUR, JAMMU, JAMSHEDPUR, KOCHI, KOLKATA, LUCKNOW, MADURAI, MUMBAI, NAGPUR, NOIDA, PARWANOO, PATNA, PUNE, RAIPUR, RAJKOT, SURAT, VIJAYAWADA.