International Standard

ISO 19014-1

Second edition
2026-10

Earth-moving machinery — Functional safety —

Part 1: Methodology to determine safety-related parts of the control system and performance requirements

Engins de terrassement — Sécurité fonctionnelle —

Partie 1: Méthodologie pour la détermination des parties du système de commande relatives à la sécurité et les exigences de performance

Reference number
ISO 19014-1:2026(en)

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Published in Switzerland

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Foreword

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

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

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

This document was prepared by Technical Committee ISO/TC 127, *Earth-moving machinery*, Subcommittee SC 2, *Safety, ergonomics and general requirements*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 151, *Construction equipment and building material machines - Safety,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 19014-1:2018), which has been technically revised.

The main changes are as follows:

— clarification of “quality measure” in subclause 6.6;

— revision of wording covering controllability when multiple actions are required to avoid a hazard (subclause 6.5);

— addition of the terms "machine abuse", "idle factor", and "work cycle" in Clause 3;

— revision of the machine control system safety analysis (MCSSA) process;

— addition of requirements covering information for use, in accordance with ISO Guide 78.

A list of all parts in the ISO 19014 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.

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Introduction

This document addresses systems of all energy types used for functional safety in earth-moving machinery.

The structure of safety standards in the field of machinery is as follows.

Type-A standards (basic standards) give basic concepts, principles for design and general aspects that can be applied to machinery.

Type-B standards (generic safety standards) deal with one or more safety aspects, or one or more types of safeguards that can be used across a wide range of machinery.

— Type-B1 standards on particular safety aspects (e.g. safety distances, surface temperature, noise).

— Type-B2 standards on safeguards (e.g. two-hands controls, interlocking devices, pressure sensitive devices, guards).

Type-C standards (machinery safety standards) deal with detailed safety requirements for a particular machine or group of machines.

This document is a type-C standard as stated in ISO 12100:2010.

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

— machine and component manufacturers (small, medium and large enterprises);

— health and safety bodies (regulators, accident prevention organizations, market surveillance etc.).

Others can be affected by the level of machinery safety achieved in accordance with this document:

— machine users and employers (small, medium and large enterprises);

— machine users and 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 in the drafting process of this document.

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

When the requirements of this type-C standard differ from those 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.

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Earth-moving machinery — Functional safety —

Part 1:
Methodology to determine safety-related parts of the control system and performance requirements

1 Scope

This document specifies a methodology for the determination of performance levels required for earth-moving machinery as defined in ISO 6165:2022

NOTE 1 For controls determined to be safety-related, the characteristics for architecture, hardware, software, environmental requirements, and performance are covered by other parts in the ISO 19014 series.

NOTE 2 The ISO 19014 series covers the significant hazards caused by the failure of a safety control system and excludes hazards arising from the equipment itself (for example, electric shock or fire).

To cover all the relevant safety requirements for the products in its scope, this document is used in combination with ISO 19014-2:2026, ISO 19014-3:2026, ISO 19014-4:2026, and ISO 19014-5:2026.

This document does not apply to other controls that are not safety control systems (SCS) and that do not mitigate a hazard or perform a control function, and where the operator would be aware of a failure (e.g. windscreen wipers, head lights, cab light).

NOTE 3 A list of safety control systems is included in Annex B.

NOTE 4 Audible warnings are excluded from the requirements of diagnostic coverage.

This document is not applicable to earth-moving machinery manufactured 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 6165:2022, *Earth-moving machinery — Basic types — Identification and vocabulary*

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

ISO 19014-2:2026, *Earth-moving machinery — Functional safety — Part 2: Design and evaluation of hardware and architecture requirements for safety-related parts of the control system*

ISO 19014-3:2026, *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*

ISO 19014-4:2026, *Earth-moving machinery — Functional safety — Part 4: Design and evaluation of software and data transmission for safety-related parts of the control system*

ISO 19014-5:2026, *Earth-moving machinery — Functional safety — Part 5: Tables of performance levels*

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3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12100:2010 and ISO 6165:2022 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
machine performance level
MPL
discrete level to specify the ability of *safety-related part of control systems* (3.3.2) to perform a safety function under reasonably foreseeable conditions

Note 1 to entry: The term MPL is used to describe the performance level from a safety-related part of a control system. The "M" refers to machine and denotes "earth-moving machinery" covered by this document and is used to differentiate from other functional safety standards (e.g. PL, AgPL, ASIL, etc.).

3.1.1
machine performance level required
MPL_r
discrete level required as determined by the processes specified in this document

3.1.2
machine performance level achieved
MPL_a
discrete level achieved by the *safety control systems* (3.3.1), hardware, architecture and software

Note 1 to entry: The process for the determination of MPL_a is covered in ISO 19014-2:2026 and ISO 19014-4:2026.

3.2
functional safety
part of the overall safety relating to the equipment under control and its control system that depends on the correct functioning of the *safety control system (SCS)* (3.3.1) and other risk reduction measures

[SOURCE: IEC 61508-4:2010, 3.1.12, modified — “EUC” changed to “equipment under control”, “EUC control system” changed to “its control system”, “E/E/PE safety-related systems” changed to “safety control system)”.]

3.3
machine control system
MCS
system which responds to input signals from parts of machine elements, *operator* (3.4.1), external control equipment or any combination of these and generates output signals causing the machine to behave in the intended manner

Note 1 to entry: The machine control system can use any technology or any combination of different technologies (e.g. electrical/electronic, hydraulic, pneumatic and mechanical).

[SOURCE: ISO 13849-1:2023, 3.1.2]

3.3.1
safety control system
SCS
sub-system or system used by an *MCS* (3.3) to achieve *functional safety* (3.2) by affecting machine functionality or mitigation of a hazard

Note 1 to entry: A system which can fail in a way that creates a hazard is considered an SCS.

Note 2 to entry: For example, an SCS for propulsion can include throttle, gear shift, start and stop, etc.

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3.3.2
safety-related part of the control system
SRP/CS
part of a control system that performs a safety function starting from a safety-related input(s) to generating a safety-related output(s)

Note 1 to entry: The safety-related parts of a control system start at the point where the safety-related inputs are initiated (including, for example, the actuating cam and the roller of the position switch) and end at the output of the power control elements (including, for example, the main contacts of a contactor).

Note 2 to entry: If monitoring systems are used for diagnostic coverage, they are also considered as SRP/CS.

Note 3 to entry: SRP/CS is a part or component within the specific MCS.

[SOURCE: ISO 13849-1:2023, 3.1.1, modified — Notes 2 and 3 to entry have been added.]

3.4
person group
groups of people analysed in the *MCSSA* (3.14)

3.4.1
operator
person operating the earth-moving machinery and aware of associated risks or hazards

3.4.2
co-worker
person working in the vicinity of a machine and aware of associated hazards

3.4.3
bystander
person including non-employee, child, or member of the public with little or no awareness of machine hazards and no training

3.4.4
maintainer
person whose function is to perform maintenance tasks on the machine

Note 1 to entry: A maintainer is trained and familiar with the machine.

3.5
controllability
ability to avoid harm to the *person group* (3.4) at risk through the timely reactions of the *operator* (3.4.1), possibly with the support of alternative controls

3.6
exposure
percentage of time a *person group* (3.4) is exposed to the hazard

Note 1 to entry: The exposure is the product of the following dependent probabilities: *application use case* (3.11), *hazard time* (3.12), and *person group exposure* (3.15).

3.7
severity
estimate of the extent of harm to one or more individuals that can occur in a potentially hazardous event

[SOURCE: ISO 26262-1:2018, 3.154]

3.8
operation indicator
means by which the state of the equipment or machinery is represented to an observer

Note 1 to entry: Operation indicator includes a warning indicator and an immediate action warning indicator.

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3.8.1
warning indicator
visual, sensory or audible indications where an action from the *operator* (3.4.1) or *machine control system* (3.3) is required

3.8.2
immediate action warning indicator
warning indicator (3.8.1) requiring immediate action from the *operator* (3.4.1) to mitigate hazard or system failure

3.9
application
different industries where a machine is used in, that can have different hazardous events from one another

Note 1 to entry: Applications can include general construction, road construction, waste management, quarrying, etc.

3.10
use case
intended use of a machine within an *application* (3.9)

Note 1 to entry: For example, a dozer can have dozing, ripping, travel and maintenance use cases within an application.

3.11
application use case
highest percentage of time a machine is anticipated to be used in a *use case* (3.10) within a given *application* (3.9) during the intended use of the life cycle of the machine

Note 1 to entry: Because the application use case represents the highest percentage of time, and not the average, that a machine in the population spends in a use case, the sum of application use cases across an application can be greater than 100 %.

3.12
hazard time
percentage of time within the *work cycle* (3.20) of the *application use case* (3.11) where it is reasonably foreseeable that a hazard can exist if the control system being assessed fails

Note 1 to entry: For example, a dozer pushing material off a high wall is only exposed to the hazard of going over the high wall for the time where the machine is traveling towards the high wall within the stopping distance of the machine.

3.13
hazard zone
any space within and/or around machinery in which a person can be exposed to a hazard from the *SCS* (3.3.1) under analysis

[SOURCE: ISO 12100:2010, 3.11, modified — "from the SCS under analysis" has been added.]

3.14
machine control system safety analysis
MCSSA
risk assessment used to determine the MPL_r (3.1.1) for the *SCS* (3.3.1) on a machine as outlined in this document

3.15
person group exposure
highest percentage of *hazard time* (3.12) that someone from the *person group* (3.4) being assessed is present in the *hazard zone* (3.13)

Note 1 to entry: The analysis is a sum of all the persons exposed from the person group, not a single individual within that group i.e. not a single car driving by, but the flow of traffic.

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3.16
failure type
description of the type of failure that can occur in an *SCS* (3.3.1)

Note 1 to entry: Failure types to consider include failure to apply, failure to release, uncommanded apply, uncommanded release, incorrect apply rate, incorrect release rate or incorrect direction, etc.

3.17
worst credible harm
estimation of *severity* (3.7) of the most severe harm that can realistically occur from a single hazardous event

3.18
machine abuse
activities that are outside the intended use of the machine and are beyond the reasonably foreseeable usage as communicated in the machine operation and service literature

EXAMPLE 1 Standing under a suspended load.

EXAMPLE 2 Using earth-moving machinery as an elevating work platform.

EXAMPLE 3 Intentionally driving machines in a way that would harm oneself or others.

EXAMPLE 4 Performing activities that are illegal.

Note 1 to entry: It is considered "machine abuse" to perform some maintenance tasks with the engine running or systems energized unless otherwise stated in the operator's manual.

3.19
idle factor
percentage adjustment to the *H* variable to account for the amount of time a machine is powered but not actively performing its intended function

Note 1 to entry: Idle factor accounts for maximum or minimum idle time depending on the *failure type* (3.16).

3.20
work cycle
repeated process or task a machine performs within a use case

Note 1 to entry: Work cycles can be broken down into segments and steps.

4 Method to determine machine performance level required (MPL_r) for safety-related part of the control system (SRP/CS)

4.1 General

A machine control system safety analysis (MCSSA) determines the amount of risk reduction of hazards associated with control systems that is required for safety control systems (SCS). This reduction is quantified by the machine performance level (MPL) and the hazards are identified using the risk assessment principles as defined in ISO 12100:2010 or by other means.

NOTE 1 Step 2 as shown in Annex A demonstrates the relationship between ISO 12100:2010 and the ISO 19014 series as a complementary protective measure.

NOTE 2 The ISO 19014 series can also be used to assess the functional safety requirements of other off-road mobile machinery.

Functional safety is achieved by one or more SCS which rely on many technologies (e.g. mechanical, hydraulic, pneumatic, electrical, electronic, programmable electronic).

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