

TECHNICAL SPECIFICATION



**Safety of machinery –
Safety-related sensors used for the protection of persons**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 13.110; 21.020

ISBN 978-2-8322-6819-3

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

FOREWORD.....	6
INTRODUCTION.....	8
1 Scope.....	9
2 Normative references	10
3 Terms and definitions	10
3.1 Characteristics and performance criteria	11
3.2 Dependability	12
3.3 Procedures and architectural deliberations	14
3.4 Terms related to system.....	16
3.5 Fusion.....	18
3.6 Safety related information	18
3.7 Test	20
3.8 User groups	22
3.9 Verification and validation	22
4 Lifecycle and interconnection to safety-related electrical control systems (SCS).....	24
4.1 General.....	24
4.2 Hazard and risk analysis	26
4.2.1 General	26
4.2.2 Hazard caused by SRS/SRSS.....	27
4.2.3 Required SRS/SRSS performance class	28
4.3 Correspondence SRS/SRSS performance class.....	28
5 Design and development phase	29
5.1 General.....	29
5.2 SRS/SRSS functions.....	29
5.3 Design analysis.....	30
5.4 Simulation.....	30
5.5 Sensing zone(s).....	31
5.6 Safety related zone	31
5.7 Automation related zone	31
5.8 Detection capability and dependability	31
5.8.1 General	31
5.8.2 Object classes and physical properties	32
5.8.3 Environmental influences.....	33
5.9 User interface	37
5.9.1 General	37
5.9.2 Mounting	37
5.9.3 Safety related information.....	37
6 Integration and installation phase	40
6.1 General.....	40
6.2 Fusion of SRS into an SRSS.....	40
6.2.1 General	40
6.2.2 Limits of use after fusion.....	41
6.2.3 Detection capability after fusion.....	41
6.2.4 Sensing zone(s) after fusion	42
6.2.5 Dependability under environmental condition after fusion	42
6.2.6 Safety related information after fusion	42

6.2.7	SRSS performance class after fusion	43
6.2.8	Response time after fusion	44
6.2.9	Verification and validation after fusion	44
6.3	Calibration at user side	44
6.3.1	General	44
6.3.2	Calibration procedure and equipment	45
6.3.3	Verification and validation of calibration	45
7	Operation, maintenance and modification phases	45
8	Verification and validation	46
8.1	General	46
8.2	Verification of an SRS/SRSS	46
8.3	Validation of an SRS/SRSS	47
8.4	Analysis	48
8.5	Test	49
8.5.1	General	49
8.5.2	Test classification	49
8.5.3	Test method and test setup	50
8.5.4	Test piece	51
8.5.5	Test plan and test results	51
9	Information for use	52
Annex A (informative)	Examination of systematic capabilities	54
Annex B (informative)	User groups	55
B.1	User groups of SRS/SRSS and groups addressed by this document	55
B.2	User groups addressed by fusion	55
Annex C (informative)	Functional decomposition and/or integration	58
Annex D (normative)	Generation and application of simulation models	59
D.1	General	59
D.2	Recommendations for use	59
D.3	Simulation objectives and measures to achieve them	59
D.4	Verification	62
Annex E (informative)	Child properties and behaviour	64
E.1	General	64
E.2	Sizes of parts of body	64
Annex F (informative)	Environmental influences	68
F.1	General	68
F.2	Example 1 for application of environmental influences	68
F.3	Example 2 for application of environmental influences	70
Annex G (informative)	Faults, failures and influences resulting in a loss of SRS/SRSS safety related function	71
G.1	General	71
G.2	Failure to danger	74
G.3	Normal operation	75
G.4	Signal to initiate the fault reaction function and confidence information as part of safety related information	75
Annex H (informative)	Test aspects	77
H.1	General	77
H.2	Mechanical influence test	77
Annex I (informative)	Examples of functions, safety related information and fusion	81

I.1	Example of functions.....	81
I.2	Example of safety related information	82
I.3	Example of fusion	83
	Bibliography.....	87
	Figure 1 – Measurement accuracy and measurement uncertainty	12
	Figure 2 – Example 1 of SRS architecture.....	24
	Figure 3 – Example 2 of SRS architecture.....	25
	Figure 4 –Example of SRSS architecture	25
	Figure 5 – Interconnection of an SRS/SRSS into hazard and risk analysis	27
	Figure 6 – Safety related information of an SRS/SRSS	38
	Figure A.1 – Example for examination of systematic capabilities using safety related sensor standards	54
	Figure C.1 – Interconnection of functions and objects	58
	Figure C.2 – Example of functions performed in an SRSS.....	58
	Figure D.1 – Verification process	62
	Figure E.1 – Body height children	65
	Figure E.2 – Chest depth children	66
	Figure E.3 – Head width children	66
	Figure E.4 – Head length children	67
	Figure G.1 – Combination of faults, failures or errors resulting in additional risk through loss of safety function or bypassing.....	72
	Figure G.2 – Analysis of systematic capabilities during design and development to prevent systematic faults resulting in failure to danger	73
	Figure G.3 – Mode of action for systematic fault resulting in fault reaction function	76
	Figure G.4 – Mode of action for errors resulting in appropriate confidence information.....	76
	Figure I.1 – Example of SRS applied on driveway intersection	81
	Figure I.2 – Example of SRS/SRSS providing decision and confidence information.....	82
	Figure I.3 – Example of SRS/SRSS providing measurement and confidence information.....	83
	Figure I.4 – First example of fusion of 2 SRS into an SRSS with combined sensing zones.....	84
	Figure I.5 – Fusion of SRS safety related information	84
	Figure I.6 – Approach of verification and validation based on SRS Information for use and SRSS Safety Requirement specification	85
	Figure I.7 – Second example of fusion of 2 SRS into an SRSS with combined sensing zones.....	86
	Table 1 – Correspondence between level of safety performance and minimum required SRS/SRSS performance class	29
	Table 2 – Functions of an SRS/SRSS as applicable.....	30
	Table 4 – Limits for failure to danger condition (loss of the detection capability) due to environmental interference for high demand mode	35
	Table 5 – Minimum required coverage probability/decision probability at high demand rate	39
	Table 6 – Maximum applicable SRSS performance class after fusion using two SRS	44

Table 7 – Means to be used for evaluation of verification measures and verification results	47
Table 8 – Overview of information for use to be provided	52
Table B.1 – Roles and task of addressed user groups.....	55
Table B.2 – Addressed user groups for different integration types using sensing unit, SRS/ SRSS as element or SRS as subsystem	56
Table D.1 – Simulation objectives and measures for SRS/SRSS of low complexity	60
Table D.2 – Simulation objectives and measures for SRS/SRSS of high complexity.....	61
Table E.1– Body height children	64
Table E.2 – Chest depth children	65
Table E.3 – Head width children	66
Table E.4 – Head length children	67
Table F.1 – Example 1 of environmental influence and classes according to IEC 60721-3-5	69
Table F.2 – Example 2 of environmental influence and classes according to IEC 60721-3-3	70
Table G.1 – Demand rates used for the calculation of Table G.2 values.....	74
Table G.2 – Limits for failure to danger condition (loss of the detection capability) due to environmental influence for high demand mode	74
Table H.1 – Example of test plan and test result for mechanical influence test.....	78

INTERNATIONAL ELECTROTECHNICAL COMMISSION

SAFETY OF MACHINERY –

Safety-related sensors used for the protection of persons

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

The main task of IEC technical committees is to prepare International Standards. In exceptional circumstances, a technical committee may propose the publication of a Technical Specification when

- the required support cannot be obtained for the publication of an International Standard, despite repeated efforts, or
- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

Technical Specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC TS 62998-1, which is a Technical Specification, has been prepared by IEC technical committee TC 44: Safety of machinery – Electrotechnical aspects.

The text of this Technical Specification is based on the following documents:

Draft TS	Report on voting
44/826/DTS	44/839A/RVDTS

Full information on the voting for the approval of this Technical Specification can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 62998 series, published under the general title *Safety of machinery*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

Safety related sensors are applied to machinery presenting a risk of personal injury. They provide protection by causing the machine to revert to a safe condition before a person can be placed in a hazardous situation.

IEC 61496 (all parts) provides design and performance requirements of electro-sensitive protective equipment (ESPE). It gives a clear but limited guideline for

- specific sensor technologies (like optical sensors) or sensing functions (like capability to detect a specified object);
- typical conditions representing indoor use in industrial environment;
- detection of objects representing parts of body of adults using the properties geometry and reflectivity;
- design, functional requirements and tests in accordance with ESPE specific safety performance classification in types (2,3 and 4).

Autonomous systems like automated guided vehicles (AGV), service robotics or human machine interaction in industries show an increasing demand, for example in

- new sensor technologies (e.g. radar, ultrasonic sensors),
- new kind of sensor functions (e.g. classification of objects, position of an object), and
- combination of different sensor technologies in a sensor system.

Sensor manufacturers or integrators use in such cases generic functional safety standards as guideline for the safety related product design. Generic functional safety standards like IEC 61508 (all parts) or sector specific machinery standards like IEC 62061 or ISO 13849 (all parts) are general and product design can be carried out without inappropriate limitations. Applying these standards would require a dedicated analysis of systematic capabilities of a sensor or sensor system (e.g. dependability of the sensing function under tolerance conditions and environmental influences). There is not enough guidance given in these standards to prevent design failures or insufficient capability to detect the specified object in certain environmental conditions. This can result in an intolerable risk for persons.

This document fills the gap for the examination of systematic capabilities between design specific sensor standards and generic functional safety standards of electrical, electronic or programmable electronic control systems.

NOTE 1 Examples for the examination of systematic capabilities by using different safety related sensor standards are given in Annex A.

This document is addressed to safety related sensor manufacturers and integrators of safety related sensors into a safety related sensor system.

NOTE 2 Examples for addressed user groups are given in Annex B.

SAFETY OF MACHINERY –

Safety-related sensors used for the protection of persons

1 Scope

This Technical Specification gives requirements for the development and integration of safety related sensors (SRS) and safety related sensor systems (SRSS) used for protection of persons with special attention to systematic capabilities.

This generic standard only applies if

- protection of persons is to be performed by using sensors, and
- standards for functional safety of electrical control systems address sensor(s) as subsystem or subsystem element, and
- product specific sensor standards (e.g. IEC 61496 (all parts), IEC 60947-5-2) do not contain all necessary provisions, or product specific sensor standards are not developed.

The approach of examination of systematic capabilities by using different safety related sensor standards is described in Annex A.

The requirements and methods within this document are limited to the purpose of protection of persons

- by detection of potentially hazardous objects,
- by detection of a body, parts of a body and objects associated to parts of a body entering a hazardous area, or
- by classification respective discrimination of these against other objects.

NOTE 1 Application of SRS/SRSS in public can require detecting not only of persons, but also their associated equipment, for example wheelchairs, walking sticks or infusion stands.

Performance classes of sensors and sensor systems are defined in accordance with existing functional safety standards (e.g. IEC 62061, IEC 61508 (all parts), and ISO 13849 (all parts)).

NOTE 2 There will be no definitions of or interconnections to the types as defined in IEC 61496-1 within this document to simplify and prevent misuse. Simplification for end users is achieved by correlation to existing PL, SIL or SIL_{cl}.

Special attention is given to the sensing function and dependability of the detection capability. Environmental influences and tests for indoor and outdoor use are defined which influence the sensing function and dependability of the detection capability.

NOTE 3 Environmental influences, their classification and test procedures are primarily specified in accordance with generic environmental standards. More specific requirements and tests are only described in absence of respective standards.

This document can be relevant to applications other than those for the protection of persons in industries, for example, for the protection of persons in public like agriculture or metro stations.

This document does not consider and address proven in use (e.g. processes or elements) as done in IEC 61508-2.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document 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.

IEC 60068 (all parts), *Environmental testing*

IEC 60204-1, *Safety of machinery – Electrical equipment of machines – Part 1: General requirements*

IEC 60721 (all parts), *Classification of environmental conditions*

IEC 60825-1, *Safety of laser products – Part 1: Equipment classification and requirements*

IEC 61010-1, *Safety requirements for electrical equipment for measurement, control, and laboratory use – Part 1: General requirements*

IEC 61508 (all parts), *Functional safety of electrical/electronic/programmable electronic safety-related systems*

IEC 61496-1:2012, *Safety of machinery – Electro-sensitive protective equipment – Part 1: General requirements and tests*

IEC 62061:2005, *Safety of machinery – Functional safety of safety-related electrical, electronic and programmable electronic control systems*

IEC 62061:2005/AMD1:2012

IEC 62061:2005/AMD2:2015

IEC 62471, *Photobiological safety of lamps and lamp systems*

ISO 7250 (all parts), *Basic human body measurements for technological design*

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

ISO 25119 (all parts), *Tractors and machinery for agriculture and forestry – Safety-related parts of control systems*

ISO 26262 (all parts), *Road vehicles – Functional safety*

CEN/CENELEC Guide 14, *Child safety – Guidance for its inclusion in standards*