



BSI Standards Publication

Adjustable speed electrical power drive systems

Part 5-3: Safety requirements — Functional, electrical
and environmental requirements for encoders

National foreword

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Safety requirements - Functional, electrical and environmental
requirements for encoders
(IEC 61800-5-3:2021)

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Partie 5-3: Exigences de sécurité - Exigences fonctionnelle,
électrique et environnementale pour codeurs
(IEC 61800-5-3:2021)

Elektrische Leistungsantriebssysteme mit einstellbarer
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Encodern (Gebern) - Funktional, elektrisch und
umwelttechnisch
(IEC 61800-5-3:2021)

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European foreword

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IEC 61508-6:2010	NOTE	Approved as EN 61508-6:2010 (not modified)

Annex ZA (normative)

Normative references to international publications with their corresponding European publications

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.

NOTE 1 Where an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

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<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 60068-2-1	-	Environmental testing - Part 2-1: Tests - Test A: Cold	EN 60068-2-1	-
IEC 60068-2-47	-	Environmental testing - Part 2-47: Test - Mounting of specimens for vibration, impact and similar dynamic tests	EN 60068-2-47	-
IEC 60335-1	-	Household and similar electrical appliances - Safety - Part 1: General requirements	-	-
IEC 60947-5-2	2019	Low-voltage switchgear and controlgear - Part 5-2: Control circuit devices and switching elements - Proximity switches	EN IEC 60947-5-2	2020
-	-		+ A11	2022
IEC 61000-6-7	2014	Electromagnetic compatibility (EMC) - Part 6-7: Generic standards - Immunity requirements for equipment intended to perform functions in a safety-related system (functional safety) in industrial locations	EN 61000-6-7	2015
IEC 61508-2	2010	Functional safety of electrical/electronic/programmable electronic safety-related systems - Part 2: Requirements for electrical/electronic/programmable electronic safety-related systems (see http://www.iec.ch/functionalsafety Functional Safety and IEC 61508)	EN 61508-2	2010
IEC 61800-1	1997	Adjustable speed electrical power drive systems - Part 1: General requirements - Rating specifications for low voltage adjustable speed d.c. power drive systems	EN 61800-1	1998
IEC 61800-5-1	2007	Adjustable speed electrical power drive systems - Part 5-1: Safety requirements - Electrical, thermal and energy	EN 61800-5-1	2007
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IEC 62368-1	2018	Audio/video, information and communication technology equipment - Part 1: Safety requirements	EN IEC 62368-1	2020
ISO 13849-1	2015	Safety of machinery - Safety-related parts of control systems - Part 1: General principles for design	-	-
ISO 13849-2	2012	Safety of machinery - Safety-related parts of control systems - Part 2: Validation	EN ISO 13849-2	2012

INTERNATIONAL STANDARD

NORME INTERNATIONALE



**Adjustable speed electrical power drive systems –
Part 5-3: Safety requirements – Functional, electrical and environmental
requirements for encoders**

**Entraînements électriques de puissance à vitesse variable –
Partie 5-3: Exigences de sécurité – Exigences fonctionnelle, électrique et
environnementale pour codeurs**

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ADJUSTABLE SPEED ELECTRICAL POWER DRIVE SYSTEMS –

**Part 5-3: Safety requirements –
Functional, electrical and environmental requirements for encoders**

FOREWORD

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International Standard IEC 61800-5-3 has been prepared by subcommittee 22G: Adjustable speed electric power drive systems (PDS), of IEC technical committee 22: Power electronic systems and equipment.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
22G/431/FDIS	22G/434/RVD

Full information on the voting for the approval of this International Standard 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.

Terms in *italics* are defined in Clause 3.

A list of all parts in the IEC 61800 series, published under the general title *Adjustable speed electrical power drive systems*, 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.

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INTRODUCTION

As a result of automation, demand for increased production and reduced operator physical effort, control systems of machinery and plant items play an increasing role in the achievement of overall safety. These control systems increasingly employ complex electrical/electronic/programmable electronic devices and systems.

Prominent amongst these devices and systems are *encoder* which are for example applied to measure angle and position of machine parts for use in safety-related applications (*Encoder(SR)*). Based on the *Encoder(SR)*'s output signals, *PDS(SR)* or other *evaluation units* calculate for example speed, acceleration, absolute position, etc., to perform their safety sub-functions SLS, SLA, SLP and others (see IEC 61800-5-2:2016, Clause 4). The *signal processing* necessary to perform some of these *safety sub-functions* may also be included in the *Encoder(SR)*.

Examples of industrial applications are:

- machine tools, robots, production test equipment, test benches;
- papermaking machines, textile production machines, calendars in the rubber industry;
- plastics processing lines, chemicals or metal production lines, rolling-mills;
- cement crushing machines, cement kilns, mixers, centrifuges, extrusion machines;
- drilling machines;
- conveyors, materials handling machines, hoisting equipment (cranes, gantries, etc.);
- pumps, fans, etc.

This document can also be used as a reference for developers using *Encoder(SR)* for other applications, for example in wind power plants.

Users of this document should be aware that some type C standards for machinery currently refer to ISO 13849-1 for safety-related control systems. In this case, *Encoder(SR)* manufacturers may be requested to provide further information (e.g. category and *performance level PL*) to facilitate the integration of an *Encoder(SR)* into the safety-related control systems of such machinery. This has been considered during development of this document and corresponding indications are included where appropriate.

NOTE "Type C standards" are defined in ISO 12100 [1] as machine safety standards dealing with detailed safety requirements for a particular machine or group of machines.

There are many situations where control systems that incorporate *Encoder(SR)* are employed, for example as part of safety measures that have been provided to achieve risk reduction. A typical case is reducing the speed during start-up in order to protect personnel from hazards arising by unexpected fast movements of machine parts. This document gives a methodology to identify the contribution made by an *Encoder(SR)* to identified safety *sub-functions* and to enable the appropriate design of the *Encoder(SR)* and verification that it achieves the required performance.

Measures are given to co-ordinate the safety performance of the *Encoder(SR)* with the intended risk reduction taking into account the probabilities and consequences of its random and systematic *faults*.

ADJUSTABLE SPEED ELECTRICAL POWER DRIVE SYSTEMS –

Part 5-3: Safety requirements – Functional, electrical and environmental requirements for encoders

1 Scope

This part of IEC 61800, which is a product standard, specifies requirements and makes recommendations for the design and development, integration and validation of safety-related *encoder* (*Encoder(SR)*) in terms of their *functional safety* considerations, electrical safety and environmental conditions. It applies to *Encoder(SR)*, being sensors as part of a *PDS(SR)*.

NOTE 1 The term "integration" refers to the *Encoder(SR)* itself, not to its incorporation into the safety-related application.

This document can also be referred to and used for *Encoder(SR)* in any other safety-related application, for example safety-related position monitoring.

NOTE 2 This document specifies only complementary *functional safety*, electrical safety and environmental condition requirements that are not clearly provided by other parts of the IEC 61800 series.

This document is applicable where *functional safety* of an *encoder* is claimed and the *Encoder(SR)* is operating mainly in the high demand or continuous mode.

NOTE 3 While low demand mode operation is possible for an *Encoder(SR)*, this document concentrates on high demand and continuous mode. *Safety sub-functions* implemented for high demand or continuous mode can also be used in low demand mode. Requirements for low demand mode are given in IEC 61508 (all parts) [2]. Some guidance for the estimation of average probability of *dangerous failure* on demand (PFD_{avg}) value is provided in IEC 61800-5-2:2016, Annex F.

The requirements of IEC 61800-5-2:2016 for *PDS(SR)* apply to *Encoder(SR)* as applicable. This document includes additional or different requirements for *Encoder(SR)*. It sets out safety-related considerations of *Encoder(SR)* in terms of the framework of IEC 61508 (all parts), and introduces requirements for *Encoder(SR)* as subsystems of a safety-related system. It is intended to facilitate the realisation of the electrical/electronic/programmable electronic (E/E/PE) and mechanical parts of an *Encoder(SR)* in relation to the safety performance of *safety sub-function(s)* of an *Encoder(SR)*.

Manufacturers and suppliers of *Encoder(SR)* will, by using the normative requirements of this document, indicate to users (system integrator, original equipment manufacturer) the safety performance of the *Encoder(SR)*. This will facilitate the incorporation of *Encoder(SR)* into safety-related control systems using the principles of IEC 61508 (all parts), and possibly its specific sector implementations (for example IEC 61511 (all parts) [3], IEC 61513 [4], IEC 62061 [5] or ISO 13849-1 and ISO 13849-2 (see Clause 2).

By applying the requirements from this document, the corresponding requirements of IEC 61508 (all parts) that are necessary for an *Encoder(SR)* are fulfilled.

This document does not specify requirements for:

- the functional properties of an *Encoder(SR)* without any safety relevance;
- the *hazard* and risk analysis of a particular application;
- the identification of *safety sub-functions* for that application;
- the initial allocation of *SILs* to those *safety sub-functions*;
- the driven equipment except for interface arrangements;

- secondary *hazards* (for example from failure in a production or manufacturing process);
- the *Encoder(SR)* manufacturing process;
- the validity of signals and commands to the *Encoder(SR)*; and
- security aspects (e.g. cyber security or *Encoder(SR)* security of access).

NOTE 4 The *functional safety* requirements of an *Encoder(SR)* are dependent on the application, and can be considered as a part of the overall risk assessment of the installation. Where the supplier of the *Encoder(SR)* is not responsible for the driven equipment, the installation designer is responsible for the risk assessment, and for specifying the functional and safety integrity requirements of the *Encoder(SR)*.

This document applies to *Encoder(SR)* implementing *safety sub-functions* with a *SIL* not greater than *SIL* 3.

This document provides additional information for *Encoder(SR)* claiming conformity with ISO 13849-1:2015.

Figure 1 shows the installation and the functional parts of a *PDS(SR)* including the *Encoder(SR)* (sensor) which is considered in this document.

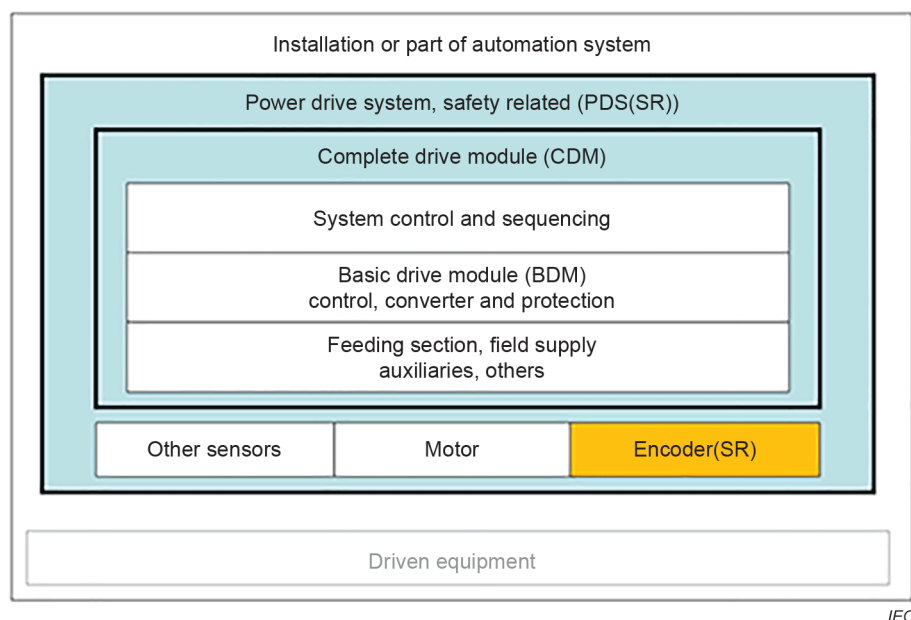


Figure 1 – Context of *Encoder(SR)*

Figure 1 shows a logical representation of a *PDS(SR)* rather than its physical description.

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.

IEC 60068-2-1, *Environmental testing – Part 2-1: Tests – Test A: Cold*

IEC 60068-2-47, *Environmental testing – Part 2-47: Tests – Mounting of specimens for vibration, impact and similar dynamic tests*

IEC 60335-1, *Household and similar electrical appliances – Safety – Part 1: General requirements*

IEC 60947-5-2:2019, *Low-voltage switchgear and controlgear – Part 5-2: Control circuit devices and switching elements – Proximity switches*

IEC 61000-6-7:2014, *Electromagnetic compatibility (EMC) – Part 6-7: Generic standards – Immunity requirements for equipment intended to perform functions in a safety-related system (functional safety) in industrial locations*

IEC 61508-2:2010, *Functional safety of electrical/electronic/programmable electronic safety-related systems – Part 2: Requirements for electrical/electronic/programmable electronic safety-related systems*

IEC 61800-1:1997, *Adjustable speed electrical power drive systems – Part 1: General requirements – Rating specifications for low voltage adjustable speed d.c. power drive systems*

IEC 61800-5-1:2007, *Adjustable speed electrical power drive systems – Part 5-1: Safety requirements – Electrical, thermal and energy*
IEC 61800-5-1:2007/AMD1:2016

IEC 61800-5-2:2016, *Adjustable speed electrical power drive systems – Part 5-2: Safety requirements – Functional*

IEC 62368-1:2018, *Audio/video, information and communication technology equipment – Part 1: Safety requirements*

ISO 13849-1:2015, *Safety of machinery – Safety-related parts of control systems – Part 1: General principles for design*

ISO 13849-2:2012, *Safety of machinery – Safety-related parts of control systems – Part 2: Validation*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

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

Table 1 shows a list of terms and definitions.

Table 1 – List of terms

3.1	<i>encoder</i>	3.19	<i>functional safety</i> <i>FS</i>
3.2	<i>Encoder(SR)</i>	3.20	<i>safety function</i>
3.3	<i>interface unit</i>	3.21	<i>safety sub-function</i>
3.4	<i>evaluation unit</i>	3.22	<i>fault</i>
3.5	<i>PDS(SR)</i>	3.23	<i>dangerous failure</i>
3.6	<i>tolerance range</i>	3.24	<i>hardware fault tolerance</i> <i>HFT</i>
3.7	<i>interpolation</i>	3.25	<i>single-fault tolerance</i>
3.8	<i>solid measure</i>	3.26	<i>safety integrity level</i> <i>SIL</i>
3.9	<i>mechanical fastening</i>	3.27	<i>SIL capability</i>
3.10	<i>mechanical connecting element</i>	3.28	<i>performance level</i> <i>PL</i>
3.11	<i>shaft-rotor coupling</i>	3.29	<i>diagnostic coverage</i> <i>DC</i>
3.12	<i>stator coupling</i>	3.30	<i>safe failure fraction</i> <i>SFF</i>
3.13	<i>bearing blockage</i>	3.31	<i>average frequency of a dangerous failure</i> <i>PFH</i>
3.13.1	<i>spontaneous bearing blockage</i>	3.32	<i>mean time to dangerous failure</i> <i>MTTF_D</i>
3.13.2	<i>gradual bearing blockage</i>	3.33	<i>process safety time</i>
3.14	<i>measurement point for working temperature</i>	3.34	<i>ideal fault detection</i>
3.15	<i>working temperature range</i>	3.35	<i>quantitative FMEDA</i>
3.16	<i>extra low voltage</i> <i>ELV</i>	3.36	<i>qualitative FMEDA</i>
3.17	<i>protective ELV circuit</i> <i>PELV circuit</i>	3.37	<i>signal evaluation</i>
3.18	<i>decisive voltage class</i> <i>DVC</i>	3.38	<i>signal processing</i>

3.1 encoder

electromechanical device that generates an analogue or digital output signal in response to the position of a moveable part

Note 1 to entry: Within this document, the definition of "*encoder*" includes resolvers and all types of motor feedback sensors.

Note 2 to entry: Annex A includes examples of type of *encoder*.

3.2 Encoder(SR)

encoder providing *safety sub-function(s)*

Note 1 to entry: The *safety sub-function(s)* of the *Encoder(SR)* allow(s) execution of safety sub-functions of a *PDS(SR)* or any other safety application.

Note 2 to entry: This definition has been derived from IEC 61800-5-2:2016, 3.16.

3.3 interface unit

separate electronic subassembly of the *Encoder(SR)* for signal conversion

Note 1 to entry: The functionality of the *interface unit* may be integrated in the *Encoder(SR)*.

3.4

evaluation unit

external item of equipment in which the output signal of the *Encoder(SR)* is evaluated

Note 1 to entry: Examples for *evaluation units* are *PDS(SR)*, safety elements for monitoring speed or stoppages.

Note 2 to entry: The *evaluation unit* may also perform diagnostic measures for the *Encoder(SR)*.

3.5

PDS(SR)

adjustable speed electrical power drive system providing safety sub-functions

[SOURCE: IEC 61800-5-2:2016, 3.16]

3.6

tolerance range

span between upper and lower tolerance limit

Note 1 to entry: The *tolerance range* is expressed in measuring units and is applied to *Encoder(SR)* with analogue and digital output signals.

Note 2 to entry: Tolerance range $T(R)$ is usually given in the form $T(R)$: $-X$ to $+Y$, with $T(R) = X + Y$; (e.g. -5 mm to $+5$ mm, 0° to $+10^\circ$, etc.).

Note 3 to entry: The tolerance range should take into account accuracy and resolution.

3.7

interpolation

mathematical method for resolution enhancement

EXAMPLE Forming the arc tangent of the ratio of analogue sine and cosine signal (A/B-signals).

3.8

solid measure

component providing encoded pattern used to determine a mechanical position

EXAMPLE Optical disc, magnetic strip.

Note 1 to entry: Other terms for *solid measure* are scale, disc, ring, strip.

3.9

mechanical fastening

mechanical connection for load transmission between constructional elements or attachment of constructional elements

Note 1 to entry: Load transmission can for example happen

- between stator of the motor and stator of the *Encoder(SR)*,
- between shaft of the motor and shaft of the rotary *Encoder(SR)*,
- between fixed part of the machine and fixed part of the *Encoder(SR)*, or
- between moving part of the machine and moving part of the *Encoder(SR)*.

Note 2 to entry: Load transmission can also happen within the *Encoder(SR)*.

Note 3 to entry: *Mechanical fastenings* are typically realized by bolted joints, fitting keys and key and slot joints.

3.10

mechanical connecting element

rigid or flexible mechanical part used to transmit load between *mechanical fastenings*

Note 1 to entry: *Mechanical connecting elements* are usually designated as couplings.

Note 2 to entry: Couplings may also provide compensation for mechanical tolerances during attachment or operation.

Note 3 to entry: Couplings are usually designated as *shaft-rotor coupling* or as *stator coupling*.

3.11

shaft-rotor coupling

connecting element between the shaft of a rotary *Encoder(SR)* and a driven shaft

Note 1 to entry: The *shaft-rotor coupling* is located between the ends of shafts.

Note 2 to entry: The *shaft-rotor coupling* has the task of compensating for mechanical tolerances during attachment or operation.

Note 3 to entry: The *shaft-rotor coupling* is typically realized as bellow coupling, jaw type coupling, slit type coupling, or lamina type coupling.

3.12

stator coupling

part of a rotary *Encoder(SR)* used to fix the *Encoder(SR)* with regards to a mounting point

Note 1 to entry: The *stator coupling* has the task of compensating for mechanical tolerances during attachment or operation.

Note 2 to entry: The *stator coupling* is fastened to flange or housing.

Note 3 to entry: The *stator coupling* is also known as "torque support".

Note 4 to entry: The *stator coupling* can also be located within the *Encoder(SR)*.

3.13

bearing blockage

situation where the torque necessary for the rotation of the bearing is causing the *Encoder(SR)* to be exposed to forces or torques higher than taken into account during design and development

3.13.1

spontaneous bearing blockage

suddenly occurring *bearing blockage* without any changes to the bearing properties in advance

Note 1 to entry: *Fault* detection prior to the *spontaneous bearing blockage* is not possible.

3.13.2

gradual bearing blockage

slowly occurring *bearing blockage* with preceding change in bearing properties

Note 1 to entry: It might be possible to detect the *fault* in time and set to safe state before the bearing becomes blocked.

Note 2 to entry: A *gradual bearing blockage* can be the result of wear or fatigue.

3.14

measurement point for working temperature

point on the surface of the *Encoder(SR)* for measuring the working temperature

3.15

working temperature range

temperature limits between which the measuring value does not exceed the given fault limits

3.16

extra low voltage

ELV

voltage not exceeding 50 V AC RMS and 120 V DC

Note 1 to entry: RMS ripple voltage of not more than 10 % of the DC component.

[SOURCE: IEC 61800-5-1:2007, 3.9, modified – Note 2 has been deleted.]

3.17

protective ELV circuit

PELV circuit

electrical circuit with the following characteristics:

- the voltage does not continuously exceed *ELV* under single *fault* as well as during normal conditions;
- protective separation from circuits other than *PELV* or *SELV*;
- provisions for earthing of the *PELV circuit*, or its accessible conductive parts, or both

[SOURCE: IEC 61800-5-1:2007, 3.21]

3.18

decisive voltage class

DVC

classification of voltage range used to determine the protective measures against electric shock

Note 1 to entry: According to IEC 61800-5-1:2007, Table 3, the voltage limits of *DVC A* are 25 V AC, 35,4 V AC_{peak} and 60 V DC.

[SOURCE: IEC 61800-5-1:2007, 3.7; modified – Note 1 to entry has been added.]

3.19

functional safety

FS

part of the overall safety relating to the *Encoder(SR)* which depends on the correct functioning of the *safety-related parts of the Encoder(SR)* and on external risk reduction measures

Note 1 to entry: This document only considers those aspects in the definition of *functional safety* that depend on the correct functioning of the *Encoder(SR)*.

[SOURCE: IEC 61800-5-2:2016; 3.11, modified – The abbreviated term "FS" has been added, and the word "*PDS(SR)*" has been replaced with *Encoder(SR)*.]

3.20

safety function

function to be implemented by a safety-related system or other risk reduction measures, that is intended to achieve or maintain a safe state for the equipment or machinery, in respect of a specific hazardous event

[SOURCE: IEC 61800-5-2:2016, 3.22, modified – The words "driven by the *PDS(SR)*" have been deleted.]

3.21

safety sub-function

function(s) with a specified safety performance, to be implemented in whole or in part by an *Encoder(SR)*, which is (are) intended to maintain the safety of the installation or prevent *hazardous* conditions arising at the installation

Note 1 to entry: There are only rare cases where the *safety function* of the complete application is implemented exclusively within the *Encoder(SR)*. In these cases, the *safety function* is still called a *safety sub-function* in this document.

[SOURCE: IEC 61800-5-2:2016, 3.23, modified – The words "*PDS(SR)*" have been replaced by "*Encoder(SR)*". The words "<of a *PDS(SR)*>" and the example in the Note to entry have been deleted.]

3.22**fault**

abnormal condition that may cause a reduction in, or loss of, the capability of a functional unit to perform a required function

[SOURCE: IEC 61508-4:2010, 3.6.1, modified – The note has been deleted.]

3.23**dangerous failure**

failure of a component and/or subsystem and/or system that plays a part in implementing the *safety sub-function* that:

- causes a *safety sub-function* of an *Encoder(SR)* to fail such that the equipment or machinery is put into a hazardous or potentially hazardous state; or
- decreases the probability that the *safety sub-function* operates correctly

[SOURCE: IEC 61800-5-2:2016, 3.5, modified – The word "*PDS(SR)*" has been replaced by "*Encoder(SR)*", and the words "driven by the *PDS(SR)*" have been deleted.]

3.24**hardware fault tolerance****HFT**

ability of an *Encoder(SR)* to continue to perform a required function in the presence of hardware *faults* or errors

Note 1 to entry: According to IEC 61800-5-2:2016, the *HFT* yields requirements for the diagnostic test interval. In addition, the *HFT* in 6.2.3.1 of IEC 61800-5-2:2016 is one of the attributes used for determining an upper limit for the *safety integrity level (SIL)*.

Note 2 to entry: This definition has been derived from IEC 61508-4:2020, 3.6.3.

3.25**single-fault tolerance**

ability of a functional unit to continue to perform a required function in the presence of one *fault* or error

[SOURCE: IEC 61508-4:2010, 3.6.3, modified – The word "single-" has been added in the term, and the words "*faults* or errors" have been replaced with "one *fault* or error".]

3.26**safety integrity level****SIL**

discrete level (one out of a possible three) for specifying the safety integrity requirements of a *safety sub-function* allocated (in whole or in part) to an *Encoder(SR)*

Note 1 to entry: *SIL* 3 has the highest level of safety integrity and *SIL* 1 has the lowest.

Note 2 to entry: *SIL* 4 is not considered in this document as it is not relevant to the risk reduction requirements normally associated with *Encoder(SR)*s. For requirements applicable to *SIL* 4, see IEC 61508.

Note 3 to entry: Several methods of writing are used for *SIL*x. Throughout this document *SIL* x is used.

[SOURCE: IEC 61800-5-2:2016; 3.25, modified – The word "*PDS(SR)*" has been replaced by "*Encoder(SR)*" and Note 4 to entry deleted.]

3.27**SIL capability**

maximum *SIL* that can be claimed to have been achieved by the design of an *Encoder(SR)* in terms of the systematic safety integrity and the architectural constraints on hardware safety integrity

Note 1 to entry: Each of the designated *safety sub-functions* that an *Encoder(SR)* is intended to perform can be associated with a different *SIL capability*.

Note 2 to entry: *SIL capability* includes systematic capability, the fulfilment of the architectural constraints and the hardware failure rate or *PFH* value.

[SOURCE: IEC 61800-5-2:2016, 3.28, modified: – The word "*PDS(SR)*" has been replaced by "*Encoder(SR)*".]

3.28 performance level PL

discrete level used to specify the ability of safety-related parts of control systems to perform a *safety function* under foreseeable conditions

Note 1 to entry: See ISO 13849-1:2015, 4.5.1.

[SOURCE: ISO 13849-1:2015, 3.1.23]

3.29 diagnostic coverage DC

fraction of *dangerous failures* detected by automatic diagnostic tests

Note 1 to entry: This can also be expressed as the ratio of the sum of the detected *dangerous failure* rates λ_{DD} to the sum of the total *dangerous failure* rates λ_D : $DC = \Sigma\lambda_{DD}/\Sigma\lambda_D$.

Note 2 to entry: *Diagnostic coverage* can exist for the whole or parts of a safety-related system. For example, *diagnostic coverage* can exist for sensors and/or logic *subsystems* and/or output *subsystem*.

[SOURCE: IEC 61800-5-2:2016, 3.6, modified – Note 3 to entry has been deleted.]

3.30 safe failure fraction SFF

property of a safety-related component and subsystems that is defined by the ratio of the sum of the average failure rates of safe and dangerous detected failures to the sum of safe and all *dangerous failures*

Note 1 to entry: This ratio is represented by the equation: $SFF = (\Sigma\lambda_S + \Sigma\lambda_{DD})/(\Sigma\lambda_S + \Sigma\lambda_D)$.

Note 2 to entry: See Annex C of IEC 61508-2:2010.

[SOURCE: IEC 61800-5-2:2016, 3.20, modified – Note 3 to entry has been deleted.]

3.31 average frequency of a dangerous failure PFH

average frequency of a *dangerous failure* of an *Encoder(SR)* to perform the specified *safety sub-function* over a given period of time

Note 1 to entry: In IEC 62061, the abbreviation PFH_D is used.

[SOURCE: IEC 61800-5-2:2016, 3.17, modified – The word "*PDS(SR)*" has been replaced by "*Encoder(SR)*" and Note 2 to entry deleted.]

3.32 mean time to dangerous failure MTTF_D

expectation of the mean time to dangerous failure

[SOURCE: ISO 13849-1:2015; 3.1.25]

3.33

process safety time

period of time between a failure of the *Encoder(SR)* that has the potential to cause a hazardous event and the point in time at which action has to be completed to prevent the hazardous event from occurring

[SOURCE: IEC 61508-4:2010, 3.6.20, modified – The wording has been simplified.]

3.34

ideal fault detection

detection of all *dangerous failures* and achievement of a safe state within the *process safety time*

Note 1 to entry: "*Ideal fault detection*" is a method that is applied to impart the property of *single-fault tolerance* to (sub-) systems that have a *HFT* of 0. *Single-fault tolerance* is a necessary condition for categories 3 and 4 according to ISO 13849-1. A detailed description of *ideal fault detection* is included in Annex J.

3.35

quantitative FMEDA

systematic analysis technique to obtain function block failure rates, failure modes and diagnostic capability

Note 1 to entry: The *quantitative FMEDA* (failure modes, effects and diagnostics analysis) provides the input data for quantification (calculation of *PFH*, *SFF*, *MTTF_D* (if conformity with ISO 13849-1:2015 is claimed)). It is carried out separately for each function block and divides the failure rates for all the components contained in the block separately into safe (S), dangerous (D), dangerous detectable (DD) and dangerous undetectable (DU).

3.36

qualitative FMEDA

systematic analysis technique to obtain systematic failures of function blocks

Note 1 to entry: *Qualitative FMEDA* (failure modes, effects and diagnostics analysis) is used for revealing possible systematic effects and scenarios that could impair the performance of the *safety sub-function*. For all components, it verifies that failures with a detrimental effect on the *safety sub-function* are detected and are mastered by the specified diagnostics and that, in the case in question, a certain failure can be justifiably excluded. FMEDA is used particularly for verification of the *single-fault tolerance* of an *Encoder(SR)* (see 8.4).

Note 2 to entry: In connection with static analysis (see Annex L), *qualitative FMEDA* is used for verifying that all potential *fault* scenarios are mastered by the specified diagnostics (see Clause L.7).

3.37

signal evaluation

evaluation of the output signals of the *Encoder(SR)* for the purpose of executing a *safety function*

Note 1 to entry: See also 3.38.

3.38

signal processing

signal evaluation and integrity test of the output signals for the detection of *faults* in the *Encoder(SR)* (diagnostics)

Note 1 to entry: The relationship between *signal processing*, *signal evaluation* and diagnostics is as follows: *signal processing* = *signal evaluation* + diagnostics.

4 Safety sub-functions

4.1 General

Clause 4 describes functions of an *Encoder(SR)* that may be designated as safety-related by the *Encoder(SR)* supplier. The designated *safety sub-functions* in Clause 4 are not considered to form an exhaustive list.

The technical measures required to implement these functions depend on the required *SIL capability* (and *PL capability*, if compliance with ISO 13849-1 is claimed) including the required probability of dangerous hardware failure, as indicated in the *safety requirements specification*. The technical measures are described in Clause 6.

The names of the *safety sub-functions* include the word "safe" to indicate that these functions may be used in a safety-related application on the grounds of a judgement (for example risk analysis) of that specific application, resulting in safety-relevant functions and their integrity to be performed by the *Encoder(SR)*.

The *Encoder(SR)*'s *safety sub-function(s)* may be used for implementation of the safety sub-function(s) of a *PDS(SR)*.

4.2 Safe incremental position (SIP)

This function provides an output signal that is safe in relation to the relative mechanical measurement position.

The relation of the output signal to the relative measurement position shall be within a *tolerance range* that shall be specified and included in the information for use.

4.3 Safe absolute position (SAP)

This function provides an output signal that is safe in relation to the mechanical measurement position.

The relation of the output signal to the measurement position shall be within a *tolerance range* that shall be specified and included in the information for use.

NOTE The reason for splitting the two *safety sub-functions* SIP and SAP is due to the big difference in the way these two different position values are generated and the way they are used.

4.4 Safe speed value (SSV)

This function provides an output signal that is safe in relation to the speed of the moving part.

The relation of the output signal to the speed of the moving part shall be within a *tolerance range* that shall be specified and included in the information for use.

4.5 Safe acceleration value (SAV)

This function provides an output signal that is safe in relation to the acceleration of the moving part.

The relation of the output signal to the acceleration of the moving part shall be within a *tolerance range* that shall be specified and included in the information for use.

4.6 Safety sub-functions for evaluation and signalling

Safety sub-functions providing *signal processing* within the *Encoder(SR)* and respective output signal(s) are possible, for example safely-limited speed SLS (see IEC 61800-5-2:2016, 4.2.4.5). For these *safety sub-functions*, the requirements for design and development, and verification and validation as defined by IEC 61800-5-2 shall apply.

5 Management of functional safety

The requirements of IEC 61800-5-2:2016, Clause 5, shall apply.

6 Requirements for design and development

6.1 General requirements

Table 2 indicates which parts of Clause 6 of IEC 61800-5-2:2016 shall be applied as is and which parts of Clause 6 of IEC 61800-5-2:2016 are modified for *Encoder(SR)*.

Table 3 indicates which parts of IEC 61800-5-1:2007 and IEC 61800-5-1:2007/AMD1:2016 shall be applied as is and which parts of IEC 61800-5-1:2007 and IEC 61800-5-1:2007/AMD1:2016 are modified for *Encoder(SR)*.

Encoder(SR) include diverse technologies and several hardware function blocks, needed to provide the *Encoder(SR)*'s *safety sub-functions*. The realisations of the *Encoder(SR)* are different, but they can always be structured according to the universal architecture described in Annex B. Subclauses 6.5 to 6.8 describe the additional requirements for these hardware function blocks.

**Table 2 – Applicable subclauses of IEC 61800-5-2:2016
for *Encoder(SR)* and respective modifications**

Requirements for <i>PDS(SR)</i> from IEC 61800-5-2:2016		Shall be applied for <i>Encoder(SR)</i> ?	Applicable subclause in this document
6.1	General requirements	No, replaced	6.1 General requirements
6.1.1	Change in operational status	No	
6.1.2	Design standards	No, replaced	6.2 Design standards
6.1.3	Realisation	Yes	
6.1.4	Safety integrity and fault detection	Yes	
6.1.5	Safety and non-safety sub-functions	Yes	
6.1.6	SIL for multiple safety sub-functions within one <i>PDS(SR)</i>	Yes	
6.1.7	Integrated circuits with on-chip redundancy	Yes	
6.1.8	Software requirements	Yes	6.9 Design requirements for software
6.1.9	Design documentation	Yes	
6.2	<i>PDS(SR)</i> design requirements		
6.2.1	Basic and well-tried safety principles	Yes	
6.2.2	Requirements for the estimation of the probability of dangerous random hardware failures per hour (PFH)		
6.2.2.1	General requirements		
6.2.2.1.1	PFH for each safety sub-function	Yes	
6.2.2.1.2	Estimation of PFH	Yes	

Requirements for <i>PDS(SR)</i> from IEC 61800-5-2:2016	Shall be applied for <i>Encoder(SR)</i> ?	Applicable subclause in this document
6.2.2.1.3 Failure rate data	Yes	
6.2.2.1.4 Diagnostic test interval when the hardware fault tolerance is greater than zero	Yes	
6.2.2.1.5 Diagnostic test interval when the hardware fault tolerance is zero	Yes	
6.2.3 Architectural constraints		
6.2.3.1 Limitations of SIL	Yes	
6.2.3.2 Type A and Type B subsystems		
6.2.3.2.1 General	Yes	
6.2.3.2.2 Type A	Yes	
6.2.3.2.3 Type B	Yes	
6.2.3.3 Architectural constraints	Yes	
6.2.4 Estimation of safe failure fraction (SFF)		
6.2.4.1 Methods of analysis	Yes	
6.2.5 Requirements for systematic safety integrity of a <i>PDS(SR)</i> and <i>PDS(SR)</i> subsystems		
6.2.5.1 Requirements for the avoidance of failures		
6.2.5.1.1 General	Yes	
6.2.5.1.2 Choice of design methods	Yes	
6.2.5.1.3 Design measures	Yes	
6.2.5.1.4 Test planning	Yes	
6.2.5.1.5 Design maintenance requirements	Yes	
6.2.5.2 Requirements for the control of systematic faults		
6.2.5.2.1 General	Yes	
6.2.5.2.2 Design features	Yes, with addition	6.6 Design requirements for signal generation
6.2.5.2.3 Testability and maintainability	Yes	
6.2.5.2.4 Human constraints	Yes	
6.2.5.2.5 Protection against unintentional modification	Yes	
6.2.5.2.6 Input acknowledgement and operator mistakes	No	
6.2.5.2.7 <i>PDS(SR)</i> parameterization	Yes, with addition	6.11 Parameterization
6.2.5.2.8 Loss of electrical supply	Yes	
6.2.6 Design requirements for electromagnetic (EM) immunity of a <i>PDS(SR)</i>	Yes	
6.2.7 Design requirements for thermal immunity of a <i>PDS(SR)</i>	No, replaced	6.12 Design requirements for thermal immunity
6.2.8 Design requirements for mechanical immunity of a <i>PDS(SR)</i>	No, replaced	6.13 Design requirements for mechanical immunity
6.3 Behaviour on detection of fault		
6.3.1 Fault detection	Yes, with addition	6.3 Fault detection
6.3.2 Fault tolerance greater than zero	Yes	
6.3.3 Fault tolerance zero	Yes	
6.4 Additional requirements for data communications	Yes	
6.5 <i>PDS(SR)</i> integration and testing requirements		
6.5.1 Hardware integration	Yes	

Requirements for <i>PDS(SR)</i> from IEC 61800-5-2:2016		Shall be applied for <i>Encoder(SR)</i> ?	Applicable subclause in this document
6.5.2	Software integration	Yes	
6.5.3	Modifications during integration	Yes	
6.5.4	Applicable integration tests	Yes	
6.5.5	Test documentation	Yes	

Table 3 – Applicable references of IEC 61800-5-1:2007 and IEC 61800-5-1:2007/AMD1:2016 for *Encoder(SR)* and respective modifications

Requirements for <i>PDS(SR)</i> from IEC 61800-5-1:2016 CSV		Shall be applied for <i>Encoder(SR)</i> ?	Modification for <i>Encoder(SR)</i>
4	Protection against electric shock, thermal, and energy hazards		
4.1	General	Yes	
4.2	Fault conditions	Yes	
4.3	Protection against electric shock		
4.3.1	Decisive voltage classification	Yes	Excluded are <i>Encoder(SR)</i> that are exclusively <ul style="list-style-type: none"> – supplied with voltage source(s) using PELV circuit(s) conforming to DVC A; and – connected to PELV circuits conforming to DVC A.
4.3.2	Protective separation	Yes	Excluded are <i>Encoder(SR)</i> that are exclusively <ul style="list-style-type: none"> – supplied with voltage source(s) using PELV circuit(s) conforming to DVC A; and – connected to PELV circuits conforming to DVC A.
4.3.3	Protection against direct contact	Yes	Excluded are <i>Encoder(SR)</i> that are exclusively <ul style="list-style-type: none"> – supplied with voltage source(s) using PELV circuit(s) conforming to DVC A; and – connected to PELV circuits conforming to DVC A.
4.3.4	Protection in case of direct contact	Yes	Excluded are <i>Encoder(SR)</i> that are exclusively <ul style="list-style-type: none"> – supplied with voltage source(s) using PELV circuit(s) conforming to DVC A; and – connected to PELV circuits conforming to DVC A.
4.3.5	Protection against indirect contact	Yes	Excluded are <i>Encoder(SR)</i> that are exclusively <ul style="list-style-type: none"> – supplied with voltage source(s) using PELV circuit(s) conforming to DVC A; and – connected to PELV circuits conforming to DVC A.

Requirements for <i>PDS(SR)</i> from IEC 61800-5-1:2016 CSV	Shall be applied for <i>Encoder(SR)</i> ?	Modification for <i>Encoder(SR)</i>
4.3.5.1 General	Yes	Excluded are <i>Encoder(SR)</i> that are exclusively <ul style="list-style-type: none"> – supplied with voltage source(s) using PELV circuit(s) conforming to DVC A; and – connected to PELV circuits conforming to DVC A.
4.3.5.2 Insulation between live parts and accessible conductive parts	Yes	Excluded are <i>Encoder(SR)</i> that are exclusively <ul style="list-style-type: none"> – supplied with voltage source(s) using PELV circuit(s) conforming to DVC A; and – connected to PELV circuits conforming to DVC A.
4.3.5.3 Protective bonding circuit	Yes	Excluded are <i>Encoder(SR)</i> that are exclusively <ul style="list-style-type: none"> – supplied with voltage source(s) using PELV circuit(s) conforming to DVC A; and – connected to PELV circuits conforming to DVC A.
4.3.5.4 Protective earthing conductor	Yes	Excluded are <i>Encoder(SR)</i> that are exclusively <ul style="list-style-type: none"> – supplied with voltage source(s) using PELV circuit(s) conforming to DVC A; and – connected to PELV circuits conforming to DVC A.
4.3.5.5 Means of connection for the protective earthing conductor	Yes	Excluded are <i>Encoder(SR)</i> that are exclusively <ul style="list-style-type: none"> – supplied with voltage source(s) using PELV circuit(s) conforming to DVC A; and – connected to PELV circuits conforming to DVC A.
4.3.5.6 Special features in equipment for protective class II	Yes	Excluded are <i>Encoder(SR)</i> that are exclusively <ul style="list-style-type: none"> – supplied with voltage source(s) using PELV circuit(s) conforming to DVC A; and – connected to PELV circuits conforming to DVC A.
4.3.6 Insulation	Yes	See Annex E for an example
4.3.7 Enclosures	Yes	
4.3.8 Wiring and connections	Yes	
4.3.9 Output short-circuit requirements	Yes	
4.3.10 Residual current-operated protective (RCD) or monitoring (RCM) device compatibility	No	
4.3.11 Capacitor discharge	No	
4.3.12 Access conditions for high-voltage PDS	No	
4.4 Protection against thermal hazards	Yes	

Requirements for <i>PDS(SR)</i> from IEC 61800-5-1:2016 CSV		Shall be applied for <i>Encoder(SR)</i> ?	Modification for <i>Encoder(SR)</i>
4.4.1	Minimizing the risk of ignition	Yes	
4.4.2	Insulating materials	Yes	
4.4.3	Flammability of enclosure materials	Yes	
4.4.4	Temperature limits		
4.4.4.1	Internal parts	Yes	
4.4.4.2	External parts of CDM	Yes	
4.4.5	Specific requirements for liquid cooled PDS	No	
4.5	Protection against energy hazards	No	
4.6	Protection against environmental stresses	Yes	

6.2 Design standards

Encoder(SR) shall be designed in accordance with IEC 61800-1, IEC 61800-5-1 and IEC 61800-5-2. This document includes additional requirements specific for *Encoder(SR)* or deviating from the requirements for *PDS(SR)*.

If requirements of this document conflict with the requirements of other applicable standards, the requirements of this document take precedence.

Additionally, the requirements of ISO 13849-1 should be complied with for *Encoder(SR)* dedicated for machinery application.

6.3 Fault detection

The necessary diagnostic measures for *Encoder(SR)* may be split into:

- diagnostic measures performed by the *Encoder(SR)*; and
- diagnostic measures performed in the *evaluation unit*.

If diagnostic measures apply within the *Encoder(SR)*, the detection of a *dangerous fault* shall be indicated to the *evaluation unit*.

If *fault* detection shall be performed in the *evaluation unit*, appropriate requirements and the specification of recommended measures for suitable *fault* detection shall be included in the information for use of the *Encoder(SR)*.

NOTE 1 See Annex I for processing *fault* detection of analogue sine and cosine signals in digital technique.

If the use of position values generated by *interpolation* of the sine and cosine *Encoder(SR)* output signal is not excluded in the instructions for use, appropriate diagnostic measures shall be applied.

EXAMPLE 1 The minimum number of samples per signal period of the *solid measure* is specified.

If *ideal fault detection* is required for the *Encoder(SR)* (see 6.4.1), the diagnostic measures applied for the *Encoder(SR)* shall be suitable for revealing all *faults* that lead to an error in any *safety sub-function* of the *Encoder(SR)* exceeding the *tolerance range* specified in the information for use. The suitability of these measures for *fault* detection shall be proven applying static analysis according to Annex L.

When a *fault* that can lead to loss of the *safety sub-function* is detected, a *fault* reaction function shall be initiated in order to prevent a hazard. Diagnostics and *fault* reaction functions shall be performed within the specified maximum *fault* reaction time.

NOTE 2 The *fault* reaction function of *Encoder(SR)* is usually limited to an indication of a *fault* to the *evaluation unit*.

The fault detection by the *Encoder(SR)* or the evaluation unit shall not be delayed or impeded by functions controlling amplitude and/or phase of analogue signals (see Annex M for examples).

NOTE 3 Analogue signals regarded here can be the output signals of an *Encoder(SR)* with sine and cosine output signals used in signal generation or signal processing of an *Encoder(SR)*.

EXAMPLE 2 Due to a component fault, the sine signal is corrupted, its amplitude is controlled and the phasor length is erroneously maintained within the specified tolerances – even during the passage of each individual period of the solid measure. Fault detection applying phasor length monitoring is impeded.

EXAMPLE 3 Controlling of the amplitudes of sine and cosine signals operates slower than the diagnostic measures apply. A dangerous failure can be detected by phasor length monitoring before the amplitude of sine or cosine signal is processed. A delay of fault detection and an increased fault reaction time is prevented.

6.4 Design requirements for specific types of *Encoder(SR)*

6.4.1 Design requirements for *Encoder(SR)* with sine and cosine output signals

For incremental *Encoder(SR)* that have independent signal generation and *signal processing* for one set of sine and cosine output signals (for example A, /A, B, /B), these signals can be considered redundant for unsigned speed information that will contribute to safety sub-function(s) (for example SLS, SSR, SLA, SS1, SS2 according to IEC 61800-5-2:2016, Clause 4). In this case, the application of *ideal fault detection* is not required and speed can be obtained redundantly by sine and cosine signals if independently evaluated.

NOTE 1 The application of quadrature decoder ICs for evaluation destroys the independency of the sine and cosine signals.

For incremental *Encoder(SR)* that do not have independent signal generation and *signal processing* or where the incremental or absolute position or direction information contributes to safety sub-function(s) (for example SOS, SDI, SCA, SLP, SSR according to IEC 61800-5-2:2016, Clause 4), the set of sine and cosine output signals (e.g. A, /A, B, /B) cannot be considered redundant. These *Encoder(SR)* shall apply *ideal fault detection* (see Annex J for more information) if category 3 or category 4 according to ISO 13849-1:2015 is claimed. If category 4 is claimed for the *Encoder(SR)*, the diagnostic measures applied to achieve *ideal fault detection* shall:

- be redundant; or
- include their own diagnostic measures with a minimum *DC* of 99 %.

Encoder(SR) which apply *ideal fault detection* shall be limited to category 3 when just one integrated circuit without on-chip redundancy according to IEC 61508-2:2010, Annex E, is used for signal generation and/or *signal processing*.

NOTE 2 If on-chip redundancy is fulfilled, the *signal processing* of the sine signal and the cosine signal is considered independent. Since the sine AND the cosine signals are necessary to achieve the safe incremental or absolute position and therefore there is no redundancy of the position information, the *HFT* is still 0.

NOTE 3 The compliance with *ideal fault detection* is necessary to fulfill the requirements for category 3 and category 4 of ISO 13849-1:2015, 6.2.6 and 6.2.7. The definitions of these categories include "...a single fault ... does not lead to the loss of the *safety function*".

NOTE 4 The *hardware fault tolerance (HFT)* is one input parameter necessary for the determination of the *SIL* limit in accordance with the architectural constraints (see H.9.2).

6.4.2 Design requirements for *Encoder(SR)* with incremental and absolute output signals

6.4.2.1 General

Encoder(SR) with incremental and absolute output signals show an architecture with two channels, one providing an incremental signal, the other providing an absolute position information.

6.4.2.2 Generation of the safe absolute position value

In the *evaluation unit*, a redundant absolute position value shall be generated from the incremental output signal of the *Encoder(SR)* and a suitable reference. To produce a safe absolute position value, the absolute position value of the *evaluation unit* and the absolute position value from *Encoder(SR)* shall be compared (cross checked) and shall comply within specified tolerances. See Figure 2 for an example of a hardware architecture.

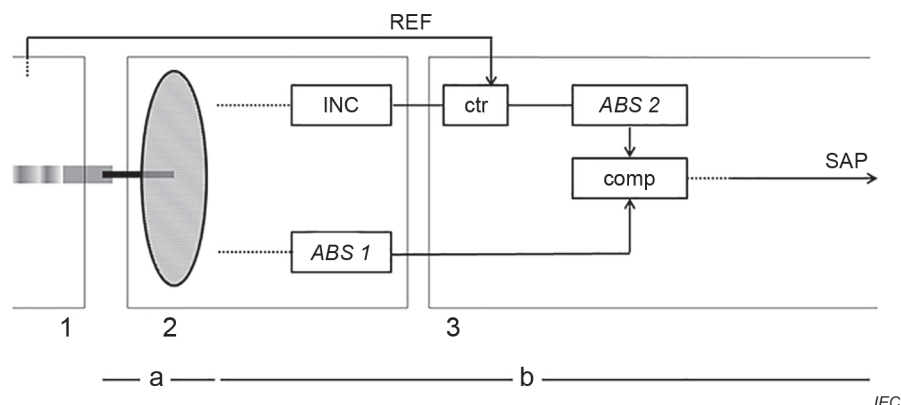
The *Encoder(SR)* shall be designed so that no undetectable dangerous *failure* can occur that causes a simultaneous change in the incremental and absolute position values which results in identical incorrect absolute position values within specified tolerances.

NOTE *Encoder(SR)* with separate, diverse *signal processing* for the incremental and absolute position values usually satisfy this requirement.

The instruction for use of the *Encoder(SR)* shall describe the process in the *evaluation unit* for generating the redundant absolute position value and for detecting *faults* in the absolute position value with the required *DC*.

If the individual channels of the *Encoder(SR)* require dedicated diagnostics performed by the *evaluation unit*, they shall be described in the instructions for use of the *Encoder(SR)*.

The reference of the *evaluation unit* for the second absolute position value shall be independent from the absolute position value of the *Encoder(SR)*.



Key

a	no redundancy, <i>fault</i> exclusion or <i>ideal fault detection</i> applied
b	redundancy, <i>fault</i> detection applied
1	machine
2	<i>Encoder(SR)</i>
3	<i>safe evaluation unit</i>
ABS 1	absolute position value provided by the <i>Encoder(SR)</i>
ABS 2	absolute position value generated by counting the incremental pulses provided by the <i>Encoder(SR)</i>
comp	comparison of ABS 1 with ABS 2
ctr	counter
INC	incremental signal provided by the <i>Encoder(SR)</i>
REF	independent signal from fixed point within the machine to run referencing procedure for ABS 2
SAP	<i>safety sub-function</i> safe absolute position

Figure 2 – Example of hardware architecture of *Encoder(SR)* with incremental and absolute output signal

The application of this type of *Encoder(SR)* provides the *safety sub-function* safe absolute position (SAP).

6.4.3 Design requirements for *Encoder(SR)* with square wave signal interface

Since square wave signal interface do not allow a sufficient diagnosis of the correct functioning of the *Encoder(SR)*, the following requirements shall be fulfilled.

The *Encoder(SR)* with square wave interface shall:

- include all necessary measures to fulfil the requirements of Clause 6 of IEC 61800-5-2:2016;
- provide a safe means to indicate any detected *fault* to the *evaluation unit*.

EXAMPLE Square wave output signals can be of the type HTL, TTL or HC-HTL.

Additionally, the requirements of ISO 13849-1 should be complied with for *Encoder(SR)* dedicated for machinery application.

6.4.4 Design requirements for Resolver

The requirements of this document shall be applied where applicable. In any case, the following requirements shall be applied:

- management of *functional safety* (see Clause 5);
- mechanics (see Clause 6.5);