

INTERNATIONAL STANDARD

NORME INTERNATIONALE



BASIC SAFETY PUBLICATION

PUBLICATION FONDAMENTALE DE SÉCURITÉ

**Electromagnetic compatibility (EMC) –
Part 1-2: General – Methodology for the achievement of functional safety of
electrical and electronic systems including equipment with regard to
electromagnetic phenomena**

**Compatibilité électromagnétique (CEM) –
Partie 1-2: Généralités – Méthodologie pour la réalisation de la sécurité
fonctionnelle des systèmes électriques et électroniques, y compris les
équipements, du point de vue des phénomènes électromagnétiques**



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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 33.100.99

ISBN 978-2-8322-3304-7

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTROMAGNETIC COMPATIBILITY (EMC) –**Part 1-2: General – Methodology for the achievement of functional safety of electrical and electronic systems including equipment with regard to electromagnetic phenomena**

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International Standard IEC 61000-1-2 has been prepared by technical committee 77: Electromagnetic compatibility.

It has the status of a basic safety publication in accordance with IEC Guide 104.

This first edition cancels and replaces the second edition of IEC TS 61000-1-2 published in 2008. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- Alignment with the changes done in the latest edition of the functional safety standard IEC 61508.

- Complete review with regard to transforming this document into an International Standard (instead of the previous edition as Technical Specification).
- New structure of Annex B.

The text of this standard is based on the following documents:

FDIS	Report on voting
77/513/FDIS	77/519/RVD

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

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

A list of all parts in the IEC 61000 series, published under the general title *Electromagnetic compatibility (EMC)*, can be found on the IEC website.

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

- reconfirmed,
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- amended.

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INTRODUCTION

IEC 61000 is published in separate parts according to the following structure:

Part 1: General

General considerations (introduction, fundamental principles)

Definitions, terminology

Part 2: Environment

Description of the environment

Classification of the environment

Compatibility levels

Part 3: Limits

Emission limits

Immunity limits (insofar as they do not fall under the responsibility of the product committees)

Part 4: Testing and measurement techniques

Measurement techniques

Testing techniques

Part 5: Installation and mitigation guidelines

Installation guidelines

Mitigation methods and devices

Part 6: Generic standards

Part 9: Miscellaneous

Each part is further subdivided into several parts, published either as international standards, technical specifications or technical reports, some of which have already been published as sections. Others will be published with the part number followed by a dash and completed by a second number identifying the subdivision (example: IEC 61000-3-11).

Particular considerations for IEC 61000-1-2

The aim of this international standard with regard to EMC and functional safety is to address the possible effects of electromagnetic disturbances on safety-related systems and to specify requirements for the relevant phases of the lifecycle of a safety-related system. The objective is to achieve the systematic capability as specified in the electrical/electronic/programmable electronic system safety requirements specification with regard to electromagnetic aspects.

This document makes use of existing relevant basic IEC standards, as far as appropriate. It considers the work of SC 65A relating to functional safety concepts of the IEC 61508 series and of TC 77 and its subcommittees relating to the electromagnetic environments. More details can be found in the publications of these committees.

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 1-2: General – Methodology for the achievement of functional safety of electrical and electronic systems including equipment with regard to electromagnetic phenomena

1 Scope

This part of IEC 61000 establishes a methodology for the achievement of functional safety only with regard to electromagnetic phenomena. This methodology includes the implication it has on equipment used in such systems and installations.

This standard:

- a) applies to safety-related systems and installations incorporating electrical/electronic/programmable electronic equipment as installed and used under operational conditions;
- b) considers the influence of the electromagnetic environment on safety-related systems;
- c) is not concerned with direct hazards from electromagnetic fields on living beings nor is it concerned with safety related to breakdown of insulation or other mechanisms by which persons can be exposed to electrical hazards.

It mainly covers EMC related aspects of the design and application specific phases of safety-related systems and equipment used therein, and deals in particular with

- some basic concepts in the area of functional safety,
- the various EMC specific steps for the achievement and management of functional safety,
- the description and assessment of the electromagnetic environment,
- the EMC aspects of the design and integration process, taking into account the process of EMC safety planning on system as well as on equipment level,
- the validation and verification processes regarding the immunity against electromagnetic disturbances,
- the performance criterion and some test philosophy considerations for safety-related systems and the equipment used therein,
- aspects related to testing of the immunity of safety-related systems and equipment used therein against electromagnetic disturbances.

This International Standard is applicable to electrical/electronic/programmable electronic (E/E/PE) safety-related systems intended to comply with the requirements of IEC 61508 and/or associated sector-specific functional safety standards. It is intended for designers, manufacturers, installers and users of safety-related systems and can be used as a guide by IEC committees.

For safety-related systems covered by other functional safety standards, the requirements of this standard should be considered in order to identify the appropriate measures that should be taken with relation to EMC and functional safety.

NOTE This standard can also be used as a guide for considering EMC requirements for other systems having a direct contribution to safety.

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 60050-161, *International Electrotechnical Vocabulary (IEV) – Part 161: Electromagnetic compatibility*

IEC TR 61000-1-6, *Electromagnetic compatibility (EMC) – Part 1-6: General – Guide to the assessment of measurement uncertainty*

IEC TR 61000-2-5, *Electromagnetic compatibility (EMC) – Part 2-5: Environment – Description and classification of electromagnetic environments*

IEC 61000-4-X (all parts), *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques*

IEC 61000-4-1, *Electromagnetic compatibility (EMC) – Part 4-1: Testing and measurement techniques – Overview of IEC 61000-4 series*

IEC 61000-6-7, *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 (all parts), *Functional safety of electrical/electronic/programmable electronic safety-related systems*

3 Terms, definitions and abbreviations

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-161 as well as the following apply.

3.1.1

degradation (of performance)

undesired departure in the operational performance of any device, equipment or system from its intended performance

Note 1 to entry: The term "degradation" can apply to temporary or permanent failure.

[SOURCE: IEC 60050-161:1990, 161-01-19]

3.1.2

electrical/electronic/programmable electronic E/E/PE

based on electrical and/or electronic and/or programmable electronic technology

Note 1 to entry: The term is intended to cover any and all devices or systems operating on electrical principles.

EXAMPLE Electrical/electronic/programmable electronic devices include

- electro-mechanical devices (electrical);
- solid-state non-programmable electronic devices (electronic);
- electronic devices based on computer technology (programmable electronic).

[SOURCE: IEC 61508-4:2010, 3.2.13]

3.1.3

electromagnetic compatibility

EMC

ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment

[SOURCE: IEC 60050-161:1990, 161-01-07]

3.1.4

EMC planning

engineering method by which EMC aspects of a project are systematically considered and investigated in order to achieve EMC

Note 1 to entry: All activities connected to EMC planning are described in an EMC plan.

3.1.5

E/E/PE system

system for control, protection or monitoring based on one or more electrical/electronic programmable electronic (E/E/PE) devices, including all elements of the system such as power supplies, sensors and other input devices, data highways and other communications paths, and actuators and other output devices

[SOURCE: IEC 61508-4:2010, 3.3.2]

3.1.6

E/E/PE system safety integrity requirements specification

specification containing the safety integrity requirements of the safety functions that have to be performed by the safety-related systems

Note 1 to entry: This specification is one part (the safety integrity part) of the E/E/PE system safety requirements specification (see 7.10 and 7.10.2.7 of IEC 61508-1:2010).

3.1.7

E/E/PE system safety requirements specification

SSRS

specification containing, for each safety function, the safety function requirements (what the function does), and the safety integrity requirements (the likelihood of the safety function being performed satisfactorily) that have to be performed/met by the safety-related systems

Note 1 to entry: This note applies to the French language only.

3.1.8

(electromagnetic) compatibility level

specified electromagnetic disturbance level used as a reference level for co-ordination in the setting of emission and immunity limits

Note 1 to entry: By convention, the compatibility level is chosen so that there is only a small probability that it will be exceeded by the actual disturbance level. However, electromagnetic compatibility is achieved only if the emission and immunity levels are controlled such that, at each location, the disturbance level resulting from the cumulative emissions is lower than the immunity level for each device, equipment and system situated at the same location.

Note 2 to entry: The compatibility level may be phenomenon, time or location dependent.

[SOURCE: IEC 60050-161:1990, 161-03-10]

3.1.9**electromagnetic disturbance**

any electromagnetic phenomenon which may degrade the performance of a device, equipment or system

Note 1 to entry: An electromagnetic disturbance may be an electromagnetic noise, an unwanted signal or a change in the propagation medium itself.

[SOURCE: IEC 60050-161:1990, 161-01-05, modified – the words " or adversely affect living or inert matter" have been deleted]

3.1.10**electromagnetic environment**

totality of electromagnetic phenomena existing at a given location

[SOURCE: IEC 60050-161:1990, 161-01-01]

3.1.11**electromagnetic interference****EMI**

degradation of the performance of an equipment, transmission channel or system caused by an electromagnetic disturbance

Note 1 to entry: Disturbance and interference are respectively cause and effect.

Note 2 to entry: This note applies to the French language only.

[SOURCE: IEC 60050-161:1990, 161-01-06]

3.1.12**element**

part of a system comprising a single component or any group of components that performs one or more element safety functions.

Note 1 to entry: An element may comprise hardware and/or software.

Note 2 to entry: A typical element is a sensor, programmable controller or final element

[SOURCE: IEC 61508-4:2010, 3.4.5, modified – the word "subsystem" has been replaced by "system"]

3.1.13**element safety function**

that part of a safety function which is implemented by an element

[SOURCE: IEC 61508-4:2010, 3.5.3]

3.1.14**equipment**

general term that refers to a wide variety of possible elements, modules, devices and assemblies of products

3.1.15**equipment under control****EUC**

equipment, machinery, apparatus or plant used for manufacturing, process, transportation, medical or other activities

Note 1 to entry: The EUC control system is separate and distinct from the EUC.

Note 2 to entry: This note applies to the French language only.

[SOURCE: IEC 61508-4:2010, 3.2.1]

3.1.16 equipment requirements specification ERS

equipment specification covering safety-related requirements only with regard to electromagnetic phenomena

Note 1 to entry: An equipment requirements specification (ERS) is created for each item of equipment within the safety-related system. Included in each equipment requirements specification is an electromagnetic characteristics specification based upon the maximum electromagnetic environment expected over the lifetime for that particular item of equipment.

Note 2 to entry: This note applies to the French language only.

3.1.17 failure

termination of the ability of a functional unit to provide a required function or operation of a functional unit in any way other than as required

Note 1 to entry: This is based on IEC 60050-191:1990, 191-04-01, with changes to include systematic failures due to, for example, deficiencies in specification or software.

Note 2 to entry: See IEC61508-4 for the relationship between faults and failures, both in the IEC 61508 series and IEC 60050-191.

Note 3 to entry: Performance of required functions necessarily excludes certain behaviour, and some functions may be specified in terms of behaviour to be avoided. The occurrence of such behaviour is a failure.

Note 4 to entry: Failures are either random (in hardware) or systematic (in hardware or software), see IEC 61508-4.

[SOURCE: IEC 61508-4:2010, 3.6.4, modified – in Notes 2 and 4 to entry, the figure and subclause numbers have been replaced by IEC 61508-4.]

3.1.18 fault

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

Note 1 to entry: IEC 60050:1990, 191-05-01, defines “fault” as a state characterised by the inability to perform a required function, excluding the inability during preventative maintenance or other planned actions, or due to lack of external resources.

[SOURCE: ISO/IEC 2382-14:1997, 14.01.10]

3.1.19 functional safety

part of the overall safety relating to the EUC and the EUC control system that depends on the correct functioning of the E/E/PE safety-related systems and other risk reduction measures

Note 1 to entry: In the context of this EMC document, functional safety is that part of the overall safety relating to the electromagnetic environment in which the safety-related system exists.

[SOURCE: IEC 61508-4:2010, 3.1.12, modified – a note has been added.]

3.1.20 installation

combination of equipment, components and systems assembled and/or erected (individually) in a given area

3.1.21**safety function**

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

EXAMPLE Examples of safety functions include:

- functions that are required to be carried out as positive actions to avoid hazardous situations (for example switching off a motor); and
- functions that prevent actions being taken (for example preventing a motor starting).

[SOURCE: IEC 61508-4:2010, 3.5.1]

3.1.22**safety integrity level****SIL**

discrete level (one out of a possible four), corresponding to a range of safety integrity values, where safety integrity level 4 has the highest level of safety integrity and safety integrity level 1 has the lowest

Note 1 to entry: The target failure measures for the four safety integrity levels are specified in Tables 2 and 3 of IEC 61508-1:2010.

Note 2 to entry: Safety integrity levels are used for specifying the safety integrity requirements of the safety functions to be allocated to the E/E/PE safety-related systems.

Note 3 to entry: A safety integrity level (SIL) is not a property of a system, element or component. The correct interpretation of the phrase “SIL n safety-related system” (where n is 1, 2, 3 or 4) is that the system is potentially capable of supporting safety functions with a safety integrity level up to n .

Note 4 to entry: This note applies to the French language only.

[SOURCE: IEC 61508-4:2010, 3.5.8]

3.1.23**safety manual for compliant items**

document that provides all the information relating to the functional safety of an element, in respect of specified element safety functions, that is required to ensure that the system meets the requirements of IEC 61508 series

3.1.24**safety-related system**

designated system that both

- implements the required safety functions necessary to achieve or maintain a safe state for the EUC; and
- is intended to achieve, on its own or with other E/E/PE safety-related systems and other risk reduction measures, the necessary safety integrity for the required safety functions

Note 1 to entry: A safety-related system includes all the hardware, software and supporting services (for example, power supplies) necessary to carry out the specified safety function (sensors, other input devices, final elements (actuators) and other output devices are therefore included in the safety-related system).

Note 2 to entry: For further information, see IEC 61508-4.

[SOURCE: IEC 61508-4:2010, 3.4.1, modified – the original note 2 has been modified.]

3.1.25**systematic capability**

measure (expressed on a scale of SC 1 to SC 4) of the confidence that the systematic safety integrity of an element meets the requirements of the specified SIL, in respect of the specified element safety function, when the element is applied in accordance with the instructions specified in the compliant item safety manual for the element

Note 1 to entry: Systematic capability is determined with reference to the requirements for the avoidance and control of systematic faults (see IEC 61508-2 and IEC 61508-3).

Note 2 to entry: What is a relevant systematic failure mechanism will depend on the nature of the element. For example, for an element comprising solely software, only software failure mechanisms will need to be considered. For an element comprising hardware and software, it will be necessary to consider both systematic hardware and software failure mechanisms.

Note 3 to entry: A systematic capability of SC N for an element, in respect of the specified element safety function, means that the systematic safety integrity of SIL N has been met when the element is applied in accordance with the instructions specified in the compliant item safety manual for the element.

Note 4 to entry: This document only specifies what needs to be done to claim a level of systematic capability for an item of E/E/PE equipment, in so far as electromagnetic disturbances are concerned.

3.1.26

testing

demonstration by empirical means that an implemented solution conforms to its specification

3.1.27

validation

confirmation by examination and provision of objective evidence that the particular requirements for a specific intended use are fulfilled

Note 1 to entry: Validation is the activity of demonstrating that the safety-related system under consideration, before or after installation, meets in all respects the SSRS for that safety-related system. Therefore, for example, EMC validation means confirming by examination and provision of objective evidence that the performance relating to electromagnetic phenomena meets the E/E/PE system safety integrity requirements specification.

[SOURCE: IEC 61508-4:2010, 3.8.2, modified – note 1 from the original definition has been deleted.]

3.1.28

verification

confirmation by examination and provision of objective evidence that the requirements have been fulfilled

Note 1 to entry: In the context of this standard, verification is the activity of demonstrating for each phase of the relevant lifecycle, that, by analysis and/or tests, for the specific inputs, the deliverables meet in all respects the objectives and requirements set for this phase.

Note 2 to entry: Example: verification activities include:

- reviews on outputs (documents from all phases of the safety lifecycle) to ensure compliance with the objectives and requirements of the phase taking into account the specific inputs to that phase;
- design reviews;
- tests performed on the designed products to ensure that they perform according to their specification;
- integration tests performed where different parts of a system are put together in a step-by-step manner and by the performance of immunity tests against electromagnetic disturbances to ensure that all parts work together in the specified manner.

[SOURCE: IEC 61508-4:2010, 3.8.1, modified – a note 1 has been added and the example from the original definition has been made into Note 3.]

3.2 Abbreviations

AM	Amplitude modulation
CRC	Cyclic redundant check
CW	Continuous wave
DS	(performance criterion) “defined state”, see 8.4.2
ECC	Error correction codes
EDC	Error detection codes
EM	Electromagnetic

EMI	Electromagnetic interference
ERS	Equipment requirement specification
ESD	Electrostatic discharge
ETA	Event tree analysis
EUC	Equipment under control
EUT	Equipment under test
FMEA	Failure modes and effect analysis
FMECA	Failure modes effects and criticality analysis
FTA	Fault tree analysis
HEMP	High altitude electromagnetic pulse
HF	High frequency
HPEM	High power electromagnetics
HR	Highly recommended
ISM	Industrial, scientific and medical
LF	Low frequency
M	Mandatory
PLC	Power line communications
PLT	Power line telecommunications
PM	Pulse modulation
R	Recommended
RAM	Random access memory
RF	Radio frequency
ROM	Read only memory
SC	Systematic capability
SIL	Safety integrity level
SSRS	System safety requirement specification
UPS	Uninterruptable power system

4 General considerations

4.1 General

The function of electrical or electronic safety-related systems shall not be affected by external influences in a way that could lead to an unacceptable risk of harm to persons and/or environment. Acceptable performance with respect to electromagnetic disturbances is therefore necessary. A comprehensive safety analysis shall include the effects of electromagnetic disturbances.

IEC 61508 has the status of a basic safety publication according to IEC Guide 104 and deals with the topic of functional safety of electric/electronic/programmable electronic (E/E/PE) safety-related systems. It sets the overall requirements to achieve functional safety. However, it does not give detailed requirements relating to effects of electromagnetic disturbances. This part of IEC 61000 gives guidance to deal with the effects of electromagnetic disturbances on safety-related systems, and on equipment intended to be used in safety-related systems.

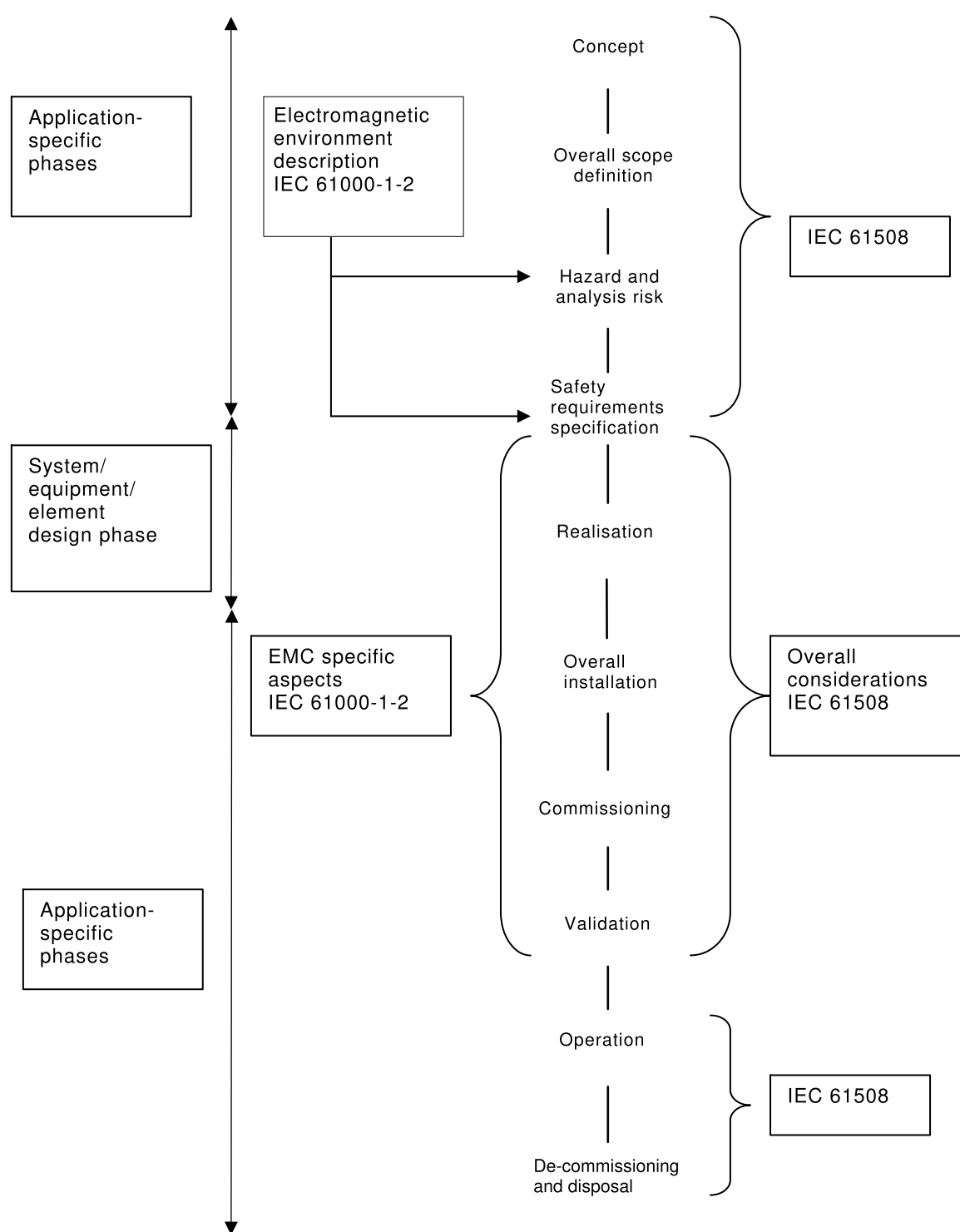
The concept of IEC 61508 is based on a safety lifecycle model (see Figure 1). The concept comprises activities during application-specific phases and activities relating to the concept, design, implementation, operation, maintenance and decommissioning of the safety-related system. The interface between the earlier application-specific phases and the design phases is

the E/E/PE system safety requirements specification (SSRS). This SSRS shall specify all relevant requirements of the intended application(s), in order to achieve the required functional safety.

The safety-related system intended to implement the specified safety function(s) shall comply with the requirements of the SSRS. Equipment (or elements, see 3.1.12) intended for use in that system shall fulfil the relevant requirements derived from the SSRS and given in the ERS (see Table 1).

Table 1 – E/E/PE system safety requirements specification, interfaces and responsibilities according to IEC 61508

Interface	Responsibilities
Application (system level)	E/E/PE system safety requirements specification a) Definition of safety-related function, based on a risk assessment of the intended application (IEC 61508) (which function may cause a dangerous failure) b) Selection of appropriate SIL (required) based on a risk assessment of the intended application (IEC 61508) c) Definition of the environment in which the system is intended to work (IEC 61508, IEC 61000-2-5)
E/E/PE equipment intended for use in a safety-related system	The equipment manufacturer shall fulfil the relevant requirements of the ERS. This includes: ensuring that there is adequate confidence that electromagnetic disturbances will not result in dangerous systematic failures (systematic capability with respect to electromagnetic disturbances); and producing evidence that appropriate methods and techniques have been employed.



IEC

NOTE 1 The diagram shows a simplified overview of the relationship between IEC 61508 and IEC 61000-1-2. Issues of electromagnetic disturbances may need careful consideration during safety lifecycle stages other than covered by IEC 61000-1-2, for example maintenance activities for electromagnetic characteristics may be required during the “use-of-equipment” phase to ensure continued safety-related system performance.

NOTE 2 Verification and management of functional safety are not shown in the diagram but it is relevant to all lifecycle phases.

**Figure 1 – Relationship between IEC 61000-1-2
and the simplified safety lifecycle as per IEC 61508**

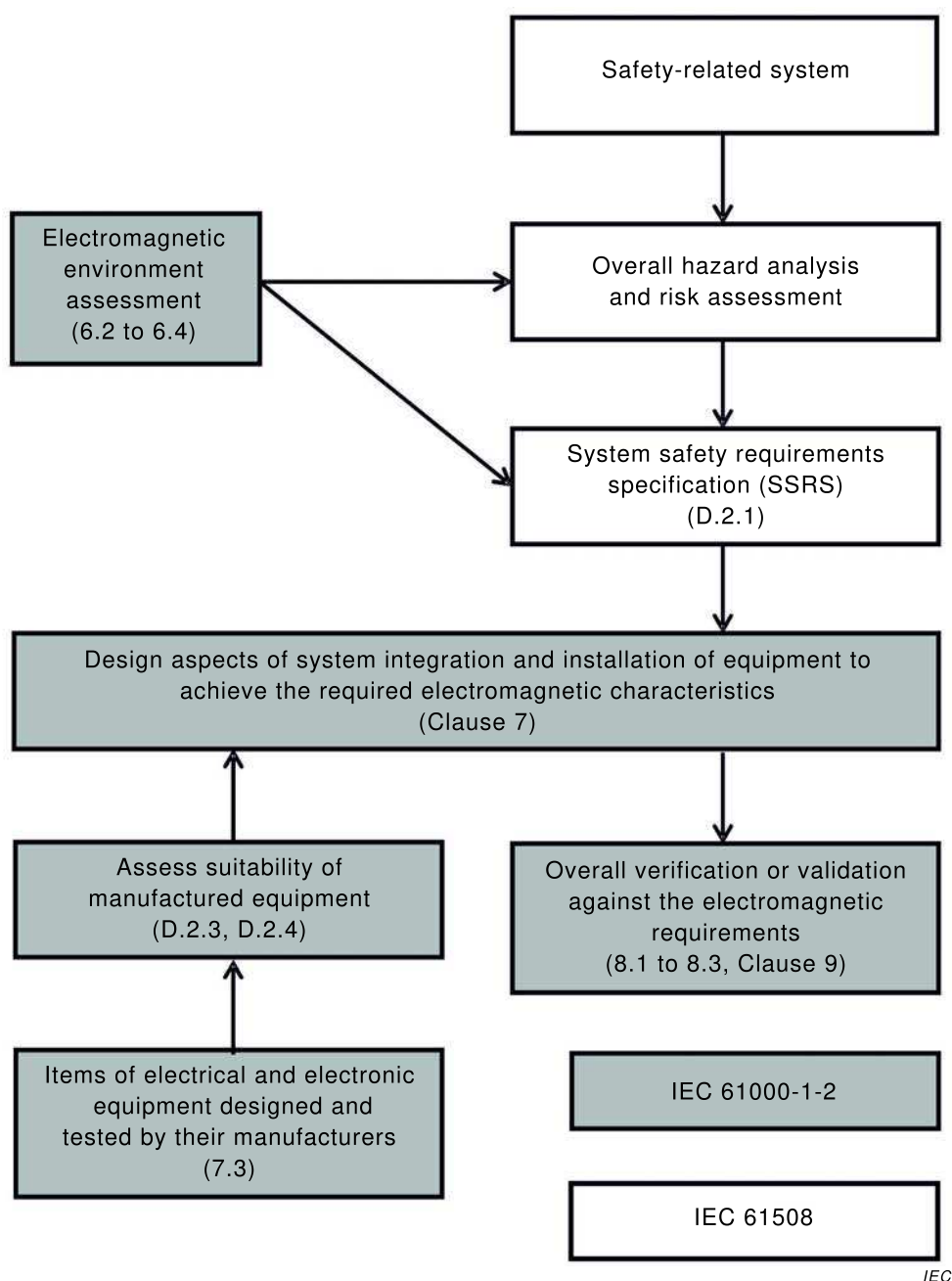
4.2 Considerations with regard to electromagnetic phenomena

The correct operation of a safety-related system depends on several factors. IEC 61508 contains the overall consideration for safety-related systems. The specific aspects related to electromagnetic disturbances are considered in this standard.

These aspects comprise:

- the electromagnetic environment (see Clause 6)
 - assessing environment information,
 - deriving test levels and methods,
 - considerations on electromagnetic phenomena and safety integrity levels (SILs);
- the electromagnetic aspects of the design and integration processes (see Clause 7)
 - system level,
 - equipment level;
- verification/validation for functional safety with respect to electromagnetic phenomena (see Clause 8)
 - verification and validation processes,
 - performance criteria and test philosophy;
- immunity testing with regard to functional safety (see Clause 9)
 - considerations on test methods and levels,
 - considerations on immunity testing with regard to systematic capability.

Figure 2 shows the mutual relationship between these aspects as well as those treated within IEC 61508. Though the E/E/PE system safety requirements specification is primarily an aspect of IEC 61508 it shall consider the outcome of an assessment of the electromagnetic environment in which the safety-related system is intended to be operated.



IEC

NOTE (Reference no.) refers to related clauses/subclauses in this document.

Figure 2 – Basic approach to achieve functional safety only with regard to electromagnetic phenomena

5 Achievement of functional safety

5.1 General

The achievement of functional safety requires an understanding of some basic terms and concepts within the area of functional safety, these being:

- safety lifecycle: necessary activities involved in the implementation of safety-related systems, occurring during a period of time that starts at the concept phase and finishes when the safety-related system is no longer available for use (see 5.2);

- safety integrity: it is the probability of a safety-related system to satisfactorily perform the required safety functions under all stated conditions within a stated period of time (see 5.3).

NOTE IEC 61000-1-2 does not deal with all phases of the whole lifecycle (see also Figure 1).

5.2 Safety lifecycle

The overall lifecycle relevant for the functional safety of safety-related E/E/PE systems is defined in IEC 61508, and Figure 1 shows a simplified version.

For safety-related E/E/PE systems, the E/E/PE system safety requirements specification is within the scope of IEC 61508. It is also partly within the scope of IEC 61000-1-2 for the specification of the electromagnetic environmental conditions.

The overall design process and the necessary design features to achieve functional safety of safety-related E/E/PE systems are defined in IEC 61508. This includes requirements for design features that make the safety-related system tolerant against electromagnetic disturbances.

The phases of design, implementation, validation, commissioning and modification of safety-related E/E/PE systems are covered by the scopes of both IEC 61508 and IEC 61000-1-2. IEC 61508 comprises all aspects relevant for functional safety and IEC 61000-1-2 deals with the aspects related to electromagnetic phenomena.

Operation, maintenance and decommissioning of safety-related E/E/PE systems are within the scope of the IEC 61508 series.

For E/E/PE equipment (or elements) used in safety-related systems within the scope of IEC 61508, the approach to deal with aspects related to electromagnetic phenomena is different from that used for safety-related systems.

The intended state/condition that equipment goes to and/or maintains upon the occurrence of a fault shall be specified. For example, this specification could be simply a statement that the equipment will provide a specified output signal upon detection of an equipment fault.

This specified behaviour of equipment shall be considered during several of the lifecycle phases of the equipment. These include the concept, overall planning, design and development, integration, operation and maintenance, validation, and modification phases. The hazard and risk analysis, overall safety requirements, and safety requirements allocation phases do not apply at the equipment level.

5.3 Safety integrity

The failure or malfunction of a safety-related system due to an electromagnetic disturbance with a given strength is systematic. Measures taken to control EMC-related dangerous failures of systems shall be regarded as part of the systematic capability of the system in question, and need to be integrated into the IEC 61508 lifecycle as necessary.

Any element that has been demonstrated to meet the requirements of the IEC 61508 series concerning systematic safety integrity with respect to a particular element safety function is said to have a corresponding systematic capability (SC). This only applies when the element is used in accordance with the instructions in its safety manual for compliant items.

The EMC information necessary to integrate elements into the intended application shall be included in their safety manuals for compliant items.

5.4 Specific steps for the achievement of functional safety with regard to electromagnetic disturbances

To achieve functional safety, the following actions with regard to electromagnetic influences shall be undertaken:

- a) determine the structure, design and intended functions of the planned or existing safety-related system;
- b) describe the relevant electromagnetic environment in which the safety-related system is intended to be used over its lifecycle (see 6.1);
- c) determine the physical and climatic environments and the degradation due to normal use and foreseeable misuse with respect to electromagnetic aspects in which the safety-related system is intended to be used over its lifecycle;
- d) implement EMC aspects in the design process (see Clause 7) of safety-related systems (see 7.3);
- e) perform verification/validation with respect to electromagnetic disturbances for functional safety (see Clause 8);
- f) modify the design or installation measures, if necessary;
- g) produce EMC specific operation and maintenance instructions to ensure the specified functional safety over time (these instructions would be added to the safety manual for compliant items).

5.5 Management of EMC for functional safety

5.5.1 General

The requirements of 5.5 indicate activities that are necessary for the management of functional safety performance of safety-related systems with respect to electromagnetic phenomena. These management activities for safety-related systems are described at the system level, however activities at the element level are described where necessary.

5.5.2 Management of functional safety performance with respect to electromagnetic phenomena at system level

An organisation with responsibility for demonstrating the EMC of a safety-related system or equipment, or for any of the activities within the scope of this document, shall appoint one or more persons to take overall responsibility for

- the system or element, or for all relevant activities;
- coordinating activities for performance with respect to electromagnetic disturbances;
- the interfaces between those activities and other activities carried out by other organizations;
- carrying out all the requirements of 5.5; and
- ensuring that EMC is sufficient and demonstrated in accordance with the objectives and requirements of this document.

The responsibility for coordination, and for overall EMC for functional safety, shall be identified and reside in one or a small number of persons with sufficient management authority. However the responsibility for sub-aspects may be delegated to others, particularly to those with relevant expertise on that special aspect.

For those activities for which the organisation is responsible, the policy and strategy for achieving functional safety with respect to electromagnetic phenomena shall be duly specified in a comprehensive plan, together with the means for evaluating their achievement, and the means by which they are communicated within the organization.

All persons, departments and sub-contractors responsible for carrying out safety-related activities for performance with respect to electromagnetic phenomena should be identified. Their responsibilities shall be fully and clearly communicated to them. Where appropriate other persons, departments and organizations, which could influence the safety-related performance achieved by the system, shall be made aware of these responsibilities.

The individuals who have responsibility for one or more of the activities within the scope of this document, shall, in respect of those activities for which they have responsibility, specify all management and technical activities that are necessary to ensure the achievement and demonstration of functional safety performance with respect to electromagnetic phenomena of the safety-related systems. This includes the selected measures, techniques and tests used to meet the requirements of this document.

As part of the functional safety management activities, procedures shall be specified for ensuring that all persons involved in any activity within the scope of this document have the appropriate training, technical knowledge, experience and qualifications, accredited as necessary, relevant to the specific duties that they have to perform. These procedures shall define what information is to be communicated between interfaces, and what form the communication shall take. In addition, the procedures shall document how cases of reported electromagnetic disturbances on the safety-related system are analysed for their relevance to the systems or activities for which the organisation is responsible, and that recommendations are made to minimise the probability of a recurrence. Procedures shall be specified for ensuring prompt follow-up and satisfactory resolution of relevant recommendations relating to safety-related systems, including those arising from verification, validation and incident reporting and analysis.

Organizations shall maintain a system to initiate changes as a result of defects relevant to electromagnetic phenomena being detected in safety-related systems or equipment for which they are responsible and, if they are unable to make the changes themselves, to inform users of the need for modification in the event of the defect affecting safety.

NOTE More information on management of functional safety is given in IEC 61508-1.

5.5.3 Management of functional safety performance with respect to electromagnetic phenomena at element supplier level

In general, a safety-related system is a combination of a number of elements integrated together to provide one or more safety functions, and possibly additional non-safety-related functions. The functional and performance requirements of individual elements may be specified and designed as a bespoke product or procured as a commercial off the shelf product. Suppliers providing products or services to an organization having overall responsibility for one or more activities within the scope of this document shall deliver products or services as specified by that organization.

Where the element is bespoke, the overall responsibility for management of performance with respect to electromagnetic phenomena of the element safety function is that defined in 5.5.2.

For non-bespoken elements, the supplier is responsible for assessing and detailing the performance of the product in accordance with the requirements specified in this standard. The organisation shall implement procedures for ensuring that the performance of the element, obtained through the validation process, is suitably documented in a safety manual and that this information is made available to all potential users of the product.

6 Electromagnetic environment

6.1 General

The electromagnetic environment is defined as the totality of electromagnetic phenomena existing at a particular location. These phenomena can vary over time. Information on the electromagnetic environment shall be available in the E/E/PE system safety requirements specification (see Figure 2). The electromagnetic environment is influenced by, for example:

- fixed and moving sources of electromagnetic energy,
- low, medium and high voltage equipment,
- control, signalling, communication and power systems,
- intentional radiators,
- physical processes (e.g. atmospheric discharges, switching actions),
- random or infrequent transients,

which all can produce disturbances that adversely impact the safety-related system or element under consideration.

Table 2 gives an overview of the principal electromagnetic phenomena which shall be considered for the achievement of functional safety for safety-related systems. This list is not necessarily complete, but it shall be used to begin the consideration of electromagnetic environments that can impact functional safety.

The occurrence of several electromagnetic phenomena at the same time, for example harmonics and unidirectional transients, or radiated fields and ESD, should be taken into account. This does not necessarily mean that simultaneous testing is required; other techniques and measures may be preferable (see Annex B).

Table 2 – Overview of electromagnetic phenomena

Electromagnetic phenomena	Sources and characteristics
Harmonics	
Voltage amplitude variations	
Voltage dips	
Voltage interruptions	
Voltage unbalance	
Voltage frequency variations	
Common mode voltages	
Signalling voltage 0,1 kHz to 3 kHz	
Induced LF	
DC in AC networks	
LF magnetic field	
LF electric field	
Direct-conducted	
HF-conducted induced CW	
Signalling voltage	
Unidirectional transients	
HF-conducted oscillatory transients	
Radiated CW (AM and PM)	
Conducted and radiated HPEM ^a	

Electromagnetic phenomena	Sources and characteristics
High altitude electromagnetic pulse (HEMP) ^b	
Intentional EMI ^c	
^a To be considered in case of special conditions (see IEC 61000-2-13). ^b To be considered in case of special conditions (see IEC 61000-2-9). ^c To be considered in case of special conditions.	

6.2 Electromagnetic environment information

Many publications include basic descriptions of electromagnetic environments considering the electromagnetic phenomena and disturbance levels typically expected in such environments. General information about the description and the levels of electromagnetic disturbances in various locations can be found in the standards or technical reports of the IEC 61000-2 series. Examples of descriptions of various environments are given in IEC 61000-2-5. These descriptions, however, are given in terms of compatibility levels.

IEC 61000-4-1 gives applicability assistance and provides general recommendations concerning the choice of relevant tests described in the IEC 61000-4 series. It is noted that standards designed for the achievement of EMC, which are based primarily on technical/economic factors, may not adequately describe the electromagnetic environment for the achievement of functional safety for safety-related systems.

Table A.1 provides an example for the selection of electromagnetic phenomena to be considered when specifying requirements. Since the electromagnetic environment does not vary with respect to the SIL of systems placed in an installation, most severe electromagnetic environments shall be considered for all electromagnetic functional safety situations.

The most severe electromagnetic environment in which the safety-related system is to be installed shall be determined (e.g. by means of measurements, assessments, etc.) by either designers, manufacturers, installers or users of the safety-related system. All types of the electromagnetic phenomena (see Table 2) shall be considered. The information from IEC 61000-2-5 summarized in Table A.1 is presented as a guide but does not cover the higher disturbance levels that can occur at some locations. Once the most severe electromagnetic environment is known, the safety-related system designer shall choose only equipment specified by the equipment manufacturer for use in an electromagnetic environment equal to or more severe than the maximum environment. Equipment manufacturers typically specify that their equipment has been tested to applicable EMC standards and comply with them at specified levels. If the known application environment exceeds the equipment specifications, appropriate means shall be applied to ensure adequate performance. Such means could include shielding enclosures or other techniques as detailed in Annex B.

The levels of electromagnetic disturbances indicated in various EMC standards, reports or technical specifications shall be considered very cautiously with regard to their application for functional safety. In particular, consideration shall be given to the following:

- The electromagnetic disturbance levels vary according to a statistical distribution (see Figure E.1), and the levels shown as examples in Table A.1 can be exceeded in some particular circumstances. However, such circumstances may only exist infrequently or at particular sites. It is important to establish the levels of these disturbances for functional safety purposes.
- The standardised immunity test methods, test levels and performance criteria found in the immunity test standards are related to operational requirements and not to functional safety. If tests based on these test methods are being performed, safety-related test levels and performance criteria are to be defined for each of the electromagnetic phenomena (for example in IEC 61000-6-7).

- c) The electromagnetic characteristics of elements and systems can degrade with age, for example through physical degradation of protection measures. This lifecycle aspect of electromagnetic influences is to be considered.

6.3 Methodology to assess the electromagnetic environment

Relevant and significant information exists within the EMC body of publications regarding the electromagnetic environment where most electrical or electronic equipment operates.

In cases where insufficient information exists within such EMC publications, alternative activities shall be undertaken in order to obtain appropriate knowledge about the electromagnetic environment at locations of interest. Such activities may include:

- undertake literature review of other EMC resources to ascertain the electromagnetic characteristics of similar locations of interest,
- undertake an electromagnetic survey at a representative or at the said location of interest; such a survey may consist of both a measurement campaign to determine the characteristics of the electromagnetic phenomena present and an electromagnetic analysis to assess the data and the characteristics of electromagnetic phenomena produced by known emitters.

The information obtained about the electromagnetic environment shall be assessed such that data can be derived regarding

- the electromagnetic phenomena that could possibly occur at the locations of interest,
- the characteristics of those electromagnetic phenomena, for example their levels, frequency, modulation, rise time, etc.

NOTE 1 For automotive and aerospace applications, there are groups working within the ISO that have produced relevant information regarding EMC of those applications. This information can be used as a starting point to describe a set of electromagnetic environments appropriate for functional safety aspects.

NOTE 2 With respect to surveys it is recognized that any survey is limited in time and locations. Long term monitoring and data logging can be used to improve the confidence in the assessment of the most severe electromagnetic environment.

6.4 Deriving test levels and methods

After the electromagnetic characteristics have been established for a particular environment, these shall be used to design the safety-related systems. While good design is a critical part of the overall process, it is well established that realistic tests are required to ensure that the safety-related systems achieve their SSRS. The IEC EMC community has developed a significant number of immunity tests for equipment and systems; these shall be considered as a starting point for testing of electromagnetic characteristics for functional safety.

For each electromagnetic phenomenon established for a particular environment, the safety-related system specifier shall include the phenomenon in the E/E/PE system safety requirements specification and examine the existing IEC immunity test method (using IEC 61000-4-1 as an initial guide) to determine whether the test method is appropriate. The system specifier shall also check to see if the parameters required to test to the electromagnetic characteristics of the environment are within their suggested ranges for the basic immunity test standards (refer to the IEC 61000-4 series of standards).

NOTE Immunity requirements, as defined for example in the generic standard IEC 61000-6-2, aim at supporting and achieving sufficient operation under normal conditions. Corresponding immunity test levels are derived for the most frequent electromagnetic phenomena and on a technical/economic approach taking into account issues of availability of the equipment or system under consideration. Consequently, it can be expected and it is accepted by all parties involved that the equipment or system may be disturbed in a few cases. This approach can be accepted for normal functions of an equipment or system, but it is inadequate for safety-related functions. Hence aspects of functional safety cannot be considered to be covered by the usual immunity requirements, as for example defined in IEC 61000-6-2, without a particular consideration of the electromagnetic environment in which the equipment or system is intended to be used.

In order to be able to justify the test method and test parameters, the safety-related system designer shall be aware that immunity testing has uncertainty associated with it (see, for example, IEC 61000-1-6). The uncertainty due to the test equipment can be calculated using test equipment data. In addition it shall be necessary to evaluate the environmental conditions, which are not defined by the standards. After the complete evaluation of uncertainty, one or more of the following approaches may be used to compensate for this testing uncertainty depending on the factors of uncertainty.

- a) If the available immunity test equipment is suitable, and if testing to levels above the electromagnetic disturbance level is used, then the SSRS (or ERS) shall determine the margin to failure and the description of how the safety-related system (or equipment) reacts to an electromagnetic induced failure.
- b) If the available immunity test equipment is not suitable due to the unavailability of the required test parameters (for example amplitude, frequency, modulation, repetition rate, etc.) then
 - 1) the safety-related system designer shall request the appropriate test equipment be obtained and used;and/or
 - 2) the safety-related system designer shall specify that electromagnetic mitigation methods be applied at the system level so the safety-related equipment may be assigned a reduced electromagnetic specification to parameters that can be tested by the available test equipment (for example through the use of shielded racks, surge protection devices for wire and cable entries, fibre optic data lines, power line isolation techniques, etc.). IEC 61000-5-6 provides examples of these types of mitigation methods. The applied mitigation methods (shields, surge protection devices, isolation methods, etc.) shall become a permanent part of the system design, and they shall be separately tested to ensure that they reduce the external electromagnetic environments to the specified test levels.

7 EMC aspects of the design and integration process

7.1 General

EMC safety planning shall be performed taking into account functional safety considerations. It is a strategy to ensure EMC of a safety-related system with respect to other systems in the vicinity and with respect to the environment of the outside world (see Annex F). The aim of EMC safety planning is to provide EMC at acceptable cost by meeting target requirements during all development stages of project implementation. This means considering, investigating and assessing all the EMC issues which might arise during the project schedule. All these activities and steps shall be described in an EMC safety plan. The depth and extent of the EMC safety planning depends on the complexity of the system and the SIL required in the E/E/PE system safety requirements specification.

NOTE In many instances, EMC planning is performed due to requirements other than safety. In this case it can be extended in order to include aspects of functional safety. Further information about the process of EMC safety planning is given in Annex F.

During electromagnetic design management, one or more identified persons shall be responsible for the creation and execution of the EMC safety plan. The EMC safety plan shall, as part of its coverage, include considerations for maintaining the electromagnetic characteristics of the equipment and/or system throughout its lifetime right up to de-commissioning. The evidence demonstrating compliance to the EMC requirements of the SSRS shall be documented in the safety manual or similar. The safety manual shall detail information necessary to enable the user to maintain, repair and refurbish (where such is not undertaken by the manufacturer) the element and/or system. The safety manual shall also contain relevant information on any restrictions concerning future changes to the electromagnetic environment.

7.2 EMC aspects on system level

The functional safety of a safety-related system shall not be unacceptably impacted by its electromagnetic environment. This requires that the performance of the safety-related system is sufficient for the intended safety integrity and electromagnetic environment, over its lifetime. The system design shall document the expected lifetime and anticipated environment of the system.

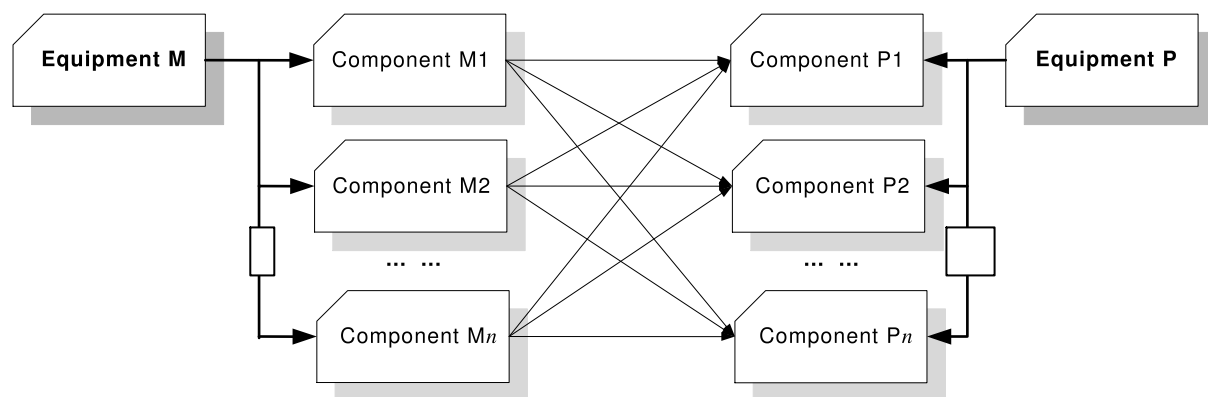
All electromagnetic disturbances generated within the safety-related system shall not unacceptably impact the functional safety of the other parts of the safety-related system.

Electromagnetic disturbances may cause systematic or “common cause” faults. This ability of an electromagnetic disturbance to affect multiple items of equipment of a safety-related system is due to the system design and therefore shall be addressed by the measures and techniques presented below and in Annex B.

All EMC measures shall be designed and implemented in such a way that they are effective over the lifetime of the system when taking into account the physical environment (which includes mechanical, climatic, chemical, biological and other stresses and strains). This is because exposure to its physical environment over its lifetime can alter the electromagnetic emissions of a safety-related system, and also alter the way it responds to electromagnetic disturbances. The design of the safety-related system shall be such that it maintains its required electromagnetic characteristics over its lifetime.

The electromagnetic characteristics of a safety-related system depend, but are not necessarily reliant, upon the electromagnetic characteristics of each individual item of equipment. For this purpose, the following procedure shall be used:

- The entire system is formally divided into items of equipment.
- All the items of equipment of the system are to be described in terms of their EMC characteristics. An item of equipment might contain several components (for example power supply, printed circuit board, display) as well as a cabling scheme.
- The interaction between each combination of items of equipment shall be analysed and assessed in terms of the influence of both the external and internal electromagnetic environments. This might result in an analysis and assessment of the electromagnetic characteristics of all the combinations of components of both items of equipment, as shown schematically for example in Figure 3.
- The functional performance criteria of the various components when they are interfered with shall be analysed in terms of their overall impact on the particular design of the safety-related system concerned. Some degradations of performance that are acceptable for a component when it is tested stand-alone, or in a different system, may not be acceptable if they occur in a particular safety-related system.



IEC

Figure 3 – EMC between equipment M and equipment P

Further guidance on design, design management techniques and other measures is given in Table 3. These techniques are graded in terms of SIL according to best expert judgement. Table 3 also refers to technical design measures that are given in Annex B.

Table 3 – Design, design management techniques and other measures

No.	Design, design management technique or other measures	SIL 1	SIL 2	SIL 3	SIL 4
1	EMC safety planning	R	HR	M	M
2	Provide the end user with information on restrictions on the application of the system or equipment including those relating to the electromagnetic environment	R	HR	M	M
3	Consider lifecycle and technical design measures (see for example Annex B)	R	HR	HR	HR
4	Consider the EMC requirements stated in the product safety manual for all purchased products and equipment	M	M	M	M
5	Procedures for maintaining lifetime electromagnetic characteristics in operation, maintenance, repair and refurbishment, modifications and upgrades	HR	HR	M	M
6	Consider the effects of reasonably foreseeable faults and misuse on the electromagnetic characteristics and mitigation measures	M	M	M	M
M	The technique or measure is a mandatory requirement and shall be carried out for this safety integrity level (or systematic capability).				
HR	The technique or measure is highly recommended for this safety integrity level (or ‘systematic capability’) and shall be carried out unless there is a technical justification for not doing it. If this technique or measure is not used then the rationale behind not using it shall be fully detailed during the safety planning and agreed upon with the assessor.				
R	The technique or measure is recommended for this safety integrity level (or systematic capability) and should be carried out as a lower recommendation to a HR recommendation.				
When a technique or measure is recommended it is considered to be more likely to achieve the desired result than alternative techniques or measures. If it is not mandatory or highly recommended, an alternate technique or measure may be justified.					

7.3 EMC aspects on equipment level

The electromagnetic performance of a safety-related system depends to some degree upon the electromagnetic characteristics of its equipment, the electromagnetic environment and mitigation measures employed. Performance shall be sufficient to meet the E/E/PE system safety requirements specification over the anticipated lifetime of the system. Any electromagnetic disturbances generated by equipment inside of a safety-related system shall not unduly affect the other items of equipment of the safety-related system.

All EMC measures shall be designed and implemented in such a way that they are effective over the lifetime of the equipment when taking into account the physical environment (which includes mechanical, climatic, chemical, biological and other stresses and strains). This is because emissions and immunity can be altered over the lifetime of the equipment by exposure to its physical environment. The design of the equipment shall be such that it maintains its required electromagnetic characteristics throughout its lifetime.

Hence immunity against electromagnetic disturbances shall be considered at the equipment level. Equipment immunity requirements shall be derived by taking into account

- the external electromagnetic environment the equipment is specified for;
- the local electromagnetic environment the equipment may be exposed to due to other equipment in close proximity;
- requirements derived from system/equipment aspects taking into account any system mitigation measures and;
- any requirements as identified during the process of EMC safety planning.

This results in an ERS, which shall include:

- the electromagnetic disturbances which the equipment design may have to withstand, whilst maintaining its desired electromagnetic characteristics;
- the immunity requirements (see IEC 61000-6-7 for examples);
- any particular test parameter requirements (according to the intended use in the system or in the systems) and;
- any performance criteria specifying a defined behaviour of the equipment under test (for example using a particular performance criterion taking into account aspects of functional safety of the overall system) (see 8.4.1 and 8.4.2).

NOTE 1 The ERS considers the situation at a particular installation. It is not necessarily identical to the product specification that a manufacturer fulfils for the products it offers on the market and to which it has to prove evidence by application of appropriate methods (e.g. in a safety manual for compliant items). In some cases both the specifications may be identical, but in other cases additional measures might have to be applied to the product in order to be compliant with the ERS). See Annex D and especially Figure D.2 for a description of this process.

The ERS can be fulfilled by using appropriate design management techniques such as determining electromagnetic susceptibilities, designing electromagnetic characteristics to cope with foreseeable faults and misuse, using more than one layer of protection, avoiding components with non-acceptable electromagnetic characteristics and verifying electromagnetic design aspects individually. Annex B provides a list of some possible measures and techniques.

NOTE 2 The effects of electromagnetic disturbances and the physical environment on items of equipment of the same design are usually common-cause or systematic (see Clause 5) – they have the same effect on all the items at the same time.

8 Verification and validation of functional safety performance in respect of electromagnetic disturbances

8.1 Verification and validation processes

In most cases there is no simple or practicable way to check and to verify by means of testing or measuring that the specified electromagnetic characteristics are achieved for the safety-related system in its entirety with respect to other systems, equipment or the external electromagnetic environment for all operating conditions and operating modes. This is due to the fact that not every combination of operating conditions, of operating modes and of electromagnetic phenomena acting on the system can be achieved in a reasonable way and in a reasonable time. Hence it is recommended that well-defined processes be applied at the system level (or equipment level) in order to demonstrate that the specified electromagnetic characteristics have been achieved in accordance with the E/E/PE system safety requirements specification (or ERS).

In order to demonstrate that a safety-related system complies with the E/E/PE system safety requirements specification, verification and validation activities shall be carried out. Appropriate planning of these activities is required. EMC aspects of verification and validation activities can be included in the EMC-planning and/or separately in system validation and verification planning, as appropriate.

The relationship between the processes of verification and validation, as well as their relation to the safety lifecycle, can be demonstrated by the diagram shown in Figure 4. For clarity the diagram considers those parts of the lifecycle only which are related to EMC specific aspects. The diagram shows these parts in a more detailed structure using a V representation of the lifecycle (instead of the purely sequential representation given in Figure 1).

A V representation reflects the lifecycle in combination with an approach going from the system level via the equipment level to the level of the components of which the system is composed.

NOTE 1 Depending on the complexity of the system, more or fewer levels can be employed.

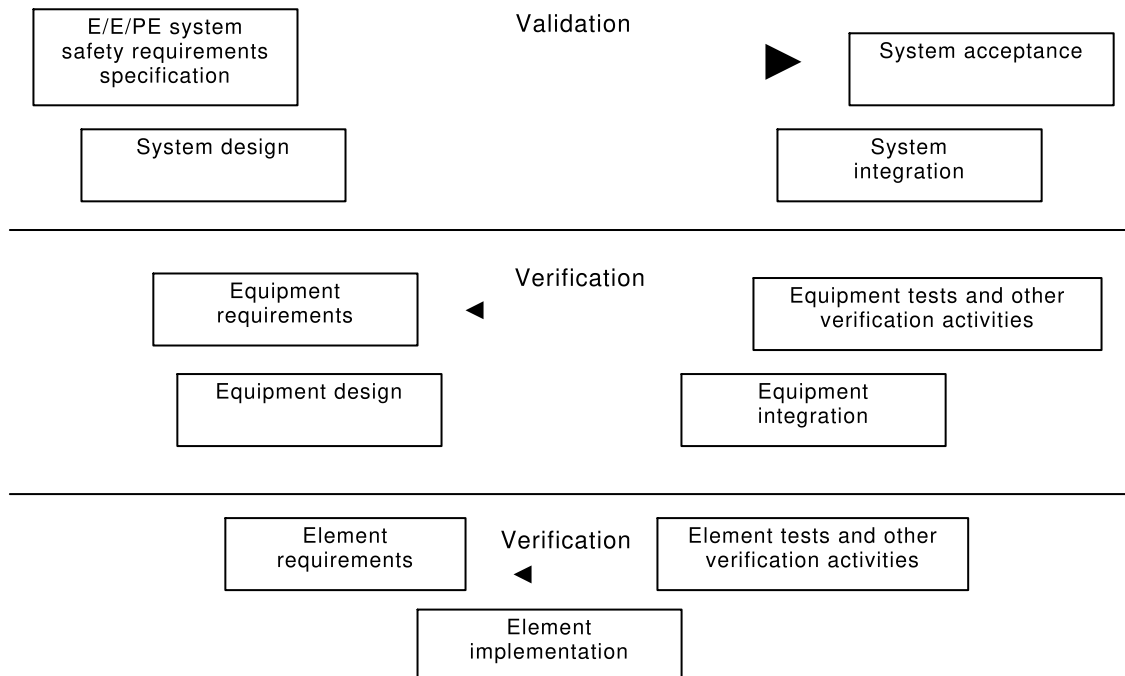
The top-down branch (left side) can generally be assigned to the design and development, and is a refining process beginning with the entire safety-related system and ending with the system's components. The bottom-up branch (right side) is related to assembly, manufacturing, and installation of the whole system.

The V representation indicates that the activities of acceptance are intrinsically linked to the design and development activities insofar as what is actually designed has to be finally checked in regard to the requirements. The representation is effective in showing verification and validation tasks within the lifecycle. It further indicates the level these tasks are assigned to.

EXAMPLE The electromagnetic characteristics required for an entire safety-related system can partly be traced back to the electromagnetic characteristics of the elements making up the entire system. So, during a verification process, the electromagnetic characteristics of the individual elements can be checked to confirm that they support the achievement of the required electromagnetic characteristics for the system.

NOTE 2 An entire safety-related system is normally a singular, application-specific installation. Therefore concrete EMC requirements for a system cannot be defined in a standard as they have to take into account the individual installation specific electromagnetic environment. The other extreme is the element level, where in most cases series products are used. These elements cannot be tested to each and every individual requirement.

On the element level tests may be performed according to international safety related standards like IEC 61326-3-1, IEC 61000-6-7, etc. Gaps between the system level requirement and the element test requirements may be closed by additional measures like additional filtering, installation in shielded racks, use of shielded cables, etc. If elements or safety-related systems rely on mitigation measures, then user instructions, maintenance instructions and other documentation shall indicate that a safety hazard exists if the particular mitigation measure is not correctly installed, operated and/or maintained.



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Figure 4 – Example V representation of the lifecycles demonstrating the role of validation and verification for functional safety performance in respect of electromagnetic disturbances

8.2 Verification

The objective of verification is to confirm and to demonstrate that the deliverables of each phase meet in all respects the requirements of that phase. Hence verification is performed within the individual phase and is related to the levels below the overall system level, for example equipment level or component level.

The verification shall take into account all the relevant electromagnetic disturbances and the electromagnetic characteristics that are correspondingly required. It shall address specific pass/fail criteria (for example particular performance criteria taking into account functional safety aspects), a positive choice of verification methods and activities as well as the need for particular EMC provisions.

Verification may be performed by only one activity or by a combination of several activities. In most cases, however, verification will include testing (see Clause 9) on the basis of standardized test methods, in combination with appropriate performance criteria taking into account functional safety aspects (see 9.3 and 9.4). Compliance with the test requirements is demonstrated by fulfilling the technical, quantitatively stated requirements of the standards defining these test methods (for example the IEC 61000-4 series) and documented by means of test reports, test certificates or equivalent documents.

On the element level, any relevant generic, product family or product standard related to functional safety shall be applied.

Further verification activities can include:

- reviews on completion of each lifecycle phase to ensure compliance with the objectives and requirements of this phase, taking into account the specific inputs to that phase;
- appropriate non-standardized tests performed on the designed products to ensure that they perform according to their specification;
- individual and/or integrated hardware tests performed where different parts of a system are put together in a step-by-step manner and by the performance of environmental tests to ensure that all the parts work together in the specified manner.

The results of verification shall be described in a verification report (which could be for example a test report) or in a technical construction file.

8.3 Validation

The objective of validation is to get a final confirmation that the entire safety-related system meets all the required objectives. This involves a mixture of several activities such as predictions, reviews or tests. In order to demonstrate that all safety requirements have been fully addressed, it is recommended to plan ahead as to how the reviews, tests, etc., will be structured. This validation (or quality) plan may be part of the EMC plan or a separate document.

The validation shall take into account all the phases of the lifecycle and show audit points. It shall address specific pass/fail criteria, a positive choice of validation methods and activities and a clear handling of non-conformances.

Validation activities include:

- demonstration that the safety requirements are fully addressed and correctly implemented;
- checklists (e.g. to ensure that EMC measures are adequately observed, applied and implemented);
- inspections (e.g. concerning observance of the installation guidelines);
- reviews and audits (e.g. close-out audit at the completion of the project);

- assessments;
- testing (e.g. factory acceptance test or on-site testing).

The process of validation is described in the validation plan. It contains the structure and schedule of the validation activities, as well as the technical rationale as to how the chosen activities demonstrate that the safety requirements are met.

In cases where there are changes in the system, its use or in the electromagnetic environment, the appropriate phases of the lifecycle shall be revisited and revalidation carried out if necessary.

The results of the validation process are described in a validation report.

8.4 Test philosophy for equipment intended for use in safety-related systems

8.4.1 General

Equipment performing or intended to perform safety functions or parts of safety functions shall behave in a specified manner. The specified behaviour of a safety-related system is to achieve or maintain safe conditions of the equipment and the related equipment under control. To achieve this, the behaviour of the equipment shall be known under all specified conditions. The E/E/PE system safety requirements specification developed for the system under consideration shall specify the safety function and the required behaviour in case of failure or occurrence of a fault.

8.4.2 Performance criterion DS for safety applications

A specific performance criterion designated as DS and applicable to functions contributing to or intended for safety applications taking into account functional safety aspects is defined as follows:

The functions of the EUT intended for safety applications are not affected outside their specification or may be affected temporarily or permanently if the EUT reacts to a disturbance in a way that detectable, defined state or states of the EUT are maintained or achieved within a stated time. Also, destruction of components is allowed if a defined state of the EUT is maintained or achieved within a stated time.

NOTE 1 In consequence it will be possible for the defined state to be outside normal operating limits or otherwise detectable.

NOTE 2 Some EMC publications related to functional safety use the abbreviation FS for this performance criterion.

The functions not intended for safety applications may be disturbed temporarily or permanently.

NOTE 3 Generalized performance criteria A, B and C as defined in generic EMC standards and also more precise performance criteria as defined in EMC product or product family standards were not specifically created for use in functional safety applications. However, performance criterion A is always acceptable.

8.4.3 Application of the performance criterion DS

This performance criterion DS, only applicable for functions contributing to or intended for safety applications, shall be considered for all electromagnetic phenomena. There is no differentiation required between continuous and transient electromagnetic phenomena.

Where a device or system performs both safety and non-safety functions the requirements for functional safety apply in context with the safety functions only.

8.4.4 Relationship to “normal” EMC standards

Even though functional safety requires the correct functioning of the complete system, for example comprising sensors, logic solver and actuators, it is possible to test its devices individually. To allow this, the individual devices intended to be used to construct a safety-related system shall be sufficiently specified. This specification comprises the intended function and the defined behaviour in case of failure. The objective of the immunity tests is to help demonstrate that the specification is fulfilled for the considered electromagnetic disturbances.

Elements intended for use in safety-related systems shall have a specification of their intended functions included in the safety manual for compliant items. It is difficult to quantify the impact of all disturbed functions as it is application dependent, however the designer shall duly take into account all foreseeable use in the development of the SSRS. Therefore the test shall show the behaviour of the equipment under test. Deviations from the undisturbed functions shall be detectable and shall be documented in the test report.

The performance criteria for functional safety define specific requirements on the equipment that is intended for use in safety-related applications. In this case both the normal requirements and the specific requirements for functional safety apply. The performance criteria for normal immunity tests within their associated limits and the performance criteria for EMC safety tests are considered separately, which could result in different tests.

NOTE Normal immunity tests/requirements are those tests/requirements, which are carried out according to specifications given in generic or product standards where those specifications do not consider functional safety aspects.

The general approach is shown in Table 4.

Figure C.1 illustrates the application of the relevant performance criteria for equipment in more detail by showing which effects due to specific electromagnetic disturbances are allowed.

Table 4 – Applicable performance criteria and observed behaviour during test of equipment intended for use in safety-related systems

Normal EMC tests	EMC safety tests
A B + pre-defined behaviour, detectable and documented + recovery time to be documented C + pre-defined behaviour, detectable and documented	A or DS
Performance criterion A is always acceptable. The potential of performance criteria B and C to result in misuse of the safety function (for example disablement of the safety function) should be assessed. NOTE 1 The description of the performance criteria A, B and C is given in generic standards such as IEC 61000-6-1 and adapted accordingly in product standards. NOTE 2 For more detailed information about allowed effects during immunity testing, see Figures C.1 and C.2.	

8.5 Test philosophy for safety-related systems

The intended functions and possible safe states are specified for a safety-related system. The aim of the immunity tests is to help demonstrate that the system as a whole behaves as specified and required by the E/E/PE system safety requirements specification.

The performance criteria for functional safety define additional requirements for safety-related systems. The performance criteria for normal EMC tests within their associated limits and the performance criteria for EMC safety tests are considered separately.

Figure C.1 illustrates the application of the relevant performance criteria for functions of safety-related systems in more detail by showing which effects due to specific electromagnetic disturbances are allowed.

System testing should be performed at the highest practicable level of assembly, if necessary using appropriate on-site or in-situ test methods.

It may be difficult at times to separately assess safety-related functions and normal functions of a system. When the separation of EMC tests for both types of functions is not practical, it is acceptable to combine the EMC tests for both types of functions.

9 EMC testing with regard to functional safety

9.1 Electromagnetic test types and electromagnetic test levels with regard to functional safety

9.1.1 Considerations on testing

In most cases there is no simple or practical way to verify by means of testing alone that the specified electromagnetic characteristics have been achieved (see Clause 7). EMC testing for functional safety requires some special considerations.

9.1.2 Types of immunity tests

Usually, the functional immunity tests in a product or generic standard do not consider all of the possible electromagnetic phenomena (as listed in Table A.1). It is also conceivable that a high level electromagnetic disturbance that has not been taken into account could have a safety implication.

With regard to safety, it is therefore necessary to evaluate whether disturbances that may not have been considered in the product or generic standards can occur. If their relevance has been demonstrated, their impact shall be analysed and the corresponding tests shall be carried out.

9.1.3 Testing levels

Immunity testing levels specified in the EMC product or generic standards are related to normal environmental disturbance levels.

For safety purposes, system designers shall specify test levels that are based on the maximum levels of the electromagnetic disturbances where the safety-related systems are intended to be employed. Product committees or manufacturers shall specify tests and levels that are based on the maximum levels likely to occur in the most probable environments where the equipment is intended to be installed (see IEC 61000-6-7 for example).

When possible, that is, when the experience or the knowledge of the environment is sufficient, it is recommended to take the statistical distribution of the disturbance levels into consideration.

It might therefore be necessary to enhance the functional immunity test levels by a value derived from the assessment of the electromagnetic environment. It is not always possible to give general advice on this value, which depends on numerous conditions including uncertainty (see 9.4). Test levels shall be specified on a case by case basis. The test level assigned to each electromagnetic phenomenon may differ depending on its occurrence. In certain circumstances, it will be necessary that this value is specified so that it leads to a greater test level than for performance reasons.

For equipment or systems with specific safety-related parts, three series of tests may be considered:

- a series of tests for system parts not relevant for safety;
- a series of tests for system parts relevant for safety;
- a series of tests for complete safety-related systems where practical.

9.2 Determination of test methods with regard to functional safety

With regard to the variety of equipment, of environmental conditions, and of conditions specific to the installation under consideration, it is difficult to provide exact rules for how to select the tests. Basically the selection of tests shall take into account all the electromagnetic phenomena that have been identified as occurring in the electromagnetic environment. This environment comprises both the electromagnetic phenomena due to external conditions and electromagnetic phenomena resulting from processes inside the installation. The tests shall be selected and determined in such a way that they reflect and simulate the influence of the electromagnetic phenomena upon the safety-related system and its components.

NOTE 1 In some cases it is impractical to apply tests on a safety-related system as a whole and tests will be applied to the individual equipment separately. In these cases the tests are performed in such a way that their application on individual equipment represents the effect which the electromagnetic phenomena have on the whole safety-related system.

When determining a test method for an immunity test, the test uncertainty shall be assessed and taken into account, both with respect to the test performance as well as with respect to the applicable immunity test parameters.

There are several possibilities for determining the appropriate test methods:

- a) Use of standardized test methods, for example the basic immunity test standards of the IEC 61000-4 series or other more applicable standards

In most cases electromagnetic phenomena such as electrical fast transients (bursts) or electrostatic discharges (ESD) have to be considered as they are to be expected in typical installations. But in addition some other electromagnetic phenomena will have to be considered due to the situation at the particular installation, for example, the occurrence of relatively strong power frequency magnetic fields or the presence of a bad power supply showing significant voltage unbalances or frequent voltage interruptions. These phenomena have been well understood for several decades, and test methods have been worked out to represent the effect of the disturbances on the equipment under test. Corresponding test methods are described in the IEC 61000-4 series. Valuable experience has been obtained regarding the test performance and test parameters in order to represent the effect of disturbances as realistically as possible.

- b) Use of variants of standardized test methods

Although standardized test methods, for example described in the basic immunity test standards of the IEC 61000-4 series or in other more applicable standards, and the test parameters described therein cover a wide range of electromagnetic phenomena there may be situations where an electromagnetic phenomenon actually expected in the installation differs to some extent from that one as covered by a standardized test. In these cases it is useful to assess the deviation of the actual phenomenon from that defined in a standardized test method and to check the applicability of the standardized test method when tailored accordingly.

NOTE 2 An example may demonstrate this approach. When looking at the immunity against power frequency magnetic fields the test methods and parameters as described in IEC 61000-4-8 can be applied. This standard mainly focuses on the effects of 50 Hz/60 Hz magnetic fields. If, however, the assessment of the electromagnetic environment shows that there are significant harmonics to be considered, the basic test method of this standard can also be used for testing the immunity against magnetic fields at harmonic frequencies.

- c) An electromagnetic phenomenon is not covered by existing standards or variants of it

In some particular installations electromagnetic phenomena occur which are neither covered by standardized test methods, such as the basic immunity test standards of the

IEC 61000-4 series, nor could they be modelled by accordingly tailored standardized test methods. This may be the situation when for example new technologies have emerged showing electromagnetic phenomena that are not yet considered by the standardized test methods. In these cases particular test methods, whose performance and parameters shall reflect the effect of the electromagnetic phenomenon under consideration as realistically as possible, have to be developed. Verification and validation are necessary in order to demonstrate that new test methods produce accurate and reliable test results.

9.3 Considerations on test methods and test performance with regard to systematic capability

9.3.1 General

Immunity tests and immunity test levels shall be selected for the various electromagnetic phenomena by taking into account:

- the characteristics of the electromagnetic environment where the installation under consideration is intended to be operated;
- the maximum amplitude of the actual electromagnetic disturbance to be expected at the various locations of the installation;
- the maximum uncertainty due to test method and test equipment.

The second and third considerations given above in 9.3.1 are based on the fact that for electromagnetic phenomena it is normally not possible to establish a simple, evident and provable correlation between applicable immunity test requirements and SIL due to the probabilistic aspects of a SIL determination. Since these maximum amplitudes are not correlated with the SIL, they shall be used to determine the test levels.

Beside the immunity test levels there are further parameters that may determine the suitability of immunity tests. Such parameters are for example:

- testing period;
- number of tests with different test set-ups or test samples;
- variation of test settings (e.g. direction of incident electromagnetic field, phase relationship between test impulse, type of modulation of RF field);
- environmental factors (e.g. temperature, humidity or the appearance of different electromagnetic phenomena at the same time);
- performance criteria.

For standardized immunity tests, for example the basic immunity test standards of the IEC 61000-4 series, these parameters are determined in such a way as to reflect typical interference situations or typical conditions. The parameters are derived on a technical/economical basis. For example, the test period is limited to one that represents a compromise between the amount for testing time and the confidence that the testing time is considered as long enough for typical stress conditions.

Hence these parameters may be modified in order to increase the level of confidence that an accordingly modified immunity test reflects the effect of an electromagnetic disturbance with a higher probability than using the parameters given for example in the basic immunity test standards of the IEC 61000-4 series. In this regard the parameters may be modified according to the required SIL. Some examples of modification of parameters are given in Table 5.

NOTE As in the case of the immunity levels, it will not be possible to establish a simple, evident and provable correlation between the accordingly modified immunity test and the required SIL. Hence the modification or variation of immunity tests will mainly rely on technical judgement.

Table 5 – Examples for methods to increase level of confidence

Type of electromagnetic phenomena	Example of standards	Some examples of methods to increase test severity compared to the requirements in the basic standard
Continuous audio frequency (AF)/radio frequency (RF)	IEC 61000-4-3 IEC 61000-4-6 IEC 61000-4-8 IEC 61000-4-13 IEC 61000-4-16 IEC 61000-4-19 IEC 61000-4-20 IEC 61000-4-21	Frequency of modulation (e.g. 2 Hz, 400 Hz, 1 kHz, 1 Hz to 10 kHz) Different test set-ups (testing of different combination of equipment / versions / cabling) Type of modulation (for example amplitude-modulated AM, frequency-modulated FM, pulse-modulated PM) Different carrier frequencies at the same time
Transient phenomena	IEC 61000-4-4	Increasing test time (no change in normative parameters) Changing repetition frequency of pulses Changing packet length / repetition time of pulses Different test set-ups (testing of different combinations of equipment / versions)
	IEC 61000-4-12 IEC 61000-4-18	Different test set-ups (testing of different combinations of equipment / versions) Different carrier frequencies at the same time
	IEC 61000-4-2 IEC 61000-4-5	Number of pulses Changing repetition rate / time between pulses / phase angle Different test set-ups (testing of different combinations of equipment / versions)
NOTE 1 Some methods may not be applicable to some of the test methods given in the basic standards. NOTE 2 The parameters mentioned under the methods only apply if these parameters of electromagnetic phenomena could really occur in the electromagnetic environment under consideration. NOTE 3 For particular products different sets of standards can be applicable instead of the IEC 61000-4 series. NOTE 4 Equipment can be exposed to multiple angles of incidence and polarizations in IEC 61000-4-21.		

9.3.2 Testing period

Some of the electromagnetic phenomena to be considered may be related to an operating state of equipment in a statistical way only, for example the simultaneous occurrence of an impulse peak with respect to the momentary state of a digital circuit or a digital signal transmission.

In order to increase the level of confidence regarding immunity against electromagnetic disturbances for a higher SIL, it may be required to perform immunity tests against such electromagnetic phenomena with a greater number of pulses or by using a longer test time compared to the requirements of the corresponding basic standards.

NOTE Example of a modification of the electrical fast transients immunity test (IEC 61000-4-4): the coupling of pulses is normally applied for a period of 1 min for each polarity. This period can be increased depending on the SIL.

9.3.3 Number of tests with different test set-ups or test samples

There may be a variation in the immunity behaviour of equipment, for example due to tolerances in the devices used in the equipment or due to tolerances in manufacturing the equipment. Further uncertainties may result from various possibilities concerning a test set-up. Hence it may be reasonable to expand the immunity tests by

- testing more samples of the product under consideration, or
- testing a sample several times with variations in the test set-up.

These may be done alternatively and/or in combination.

9.3.4 Variation of test settings

Standardized immunity tests, for example the basic immunity test standards of the IEC 61000-4 series, describe a detailed test set-up as well as settings to be applied during the immunity test. These settings may be modified to increase the level of confidence. By doing this rather than by using the settings of the basic immunity standards, a broader range of possible effects of the electromagnetic phenomenon upon the equipment is considered. Examples of such modifications include

- modifications concerning the coupling of an electromagnetic phenomenon on the equipment under test,
- modifications concerning the physical placement of the equipment under test.

NOTE 1 Example of a modification of the surge immunity test (IEC 61000-4-5): coupling of pulses on AC lines at phase angles in addition to those given in the basic standard.

NOTE 2 Example of modifications of the radiated, radio-frequency, electromagnetic field immunity test (IEC 61000-4-3): the incident field faces not only to the main sides but also to tilted orientations of the equipment under test; the equipment is tested with different types of modulation frequencies (for example 2 Hz to 10 kHz) or different carrier frequencies at the same time.

9.3.5 Environmental factors

Beside the variation in the immunity behaviour of equipment due to tolerances in the devices used, or in its assembly, there might be the possibility that the immunity is affected by environmental parameters. Such factors are, for example, the temperature or humidity, which may vary in a broad range at the final location of the installation. The possible impact of these factors on the immunity should be considered taking into account stresses, ageing, foreseeable misuse, etc., on the electromagnetic characteristics of the equipment or system.

There are many kinds of possible stresses, including physical (e.g. bending, twisting, etc.) and climatic (e.g. air pressure, temperature, humidity, etc.). After the initial electromagnetic functional testing has been performed as described above, and the equipment passes those tests, ageing testing should be performed, if it can be reasonably and foreseeably expected that the electromagnetic characteristics will change during the lifetime of the equipment. This testing should include, for example, the evaluation of the reduction in effectiveness of electromagnetic mitigation measures associated with the equipment or product due to corrosion or mechanical movement during the anticipated lifetime of the system. As appropriate during or after these stress/ageing tests, the electromagnetic characteristics should be measured to determine whether the equipment's electromagnetic characteristics has been excessively degraded. The results of such testing and its impact on the electromagnetic characteristics during the anticipated lifetime of the equipment or system shall also be documented for each electromagnetic phenomenon considered. All physical stresses and ageing aspects within the specification of the equipment/system shall be evaluated and documented.

Alternatively, where the equipment is protected from its electromagnetic and physical environment by an external enclosure, it is permissible to test the finished enclosure for its reduction in electromagnetic characteristics due to physical stresses, ageing, foreseeable misuse, etc., over its anticipated lifetime. The tested enclosure should include the same types of cable entries, door and panel fixings, etc., as the one that is supplied with or specified for the equipment. There is no requirement to test the products and other equipment that are installed within an enclosure to the external environment.

9.4 Testing uncertainty

The required immunity of products or items of equipment to electromagnetic phenomena is in most cases demonstrated by means of immunity testing based on basic EMC standards. The results of the tests are used to conclude whether the equipment under test fulfils the requirements and consequently whether it can be used in a safety-related system.

Hence it is important to have some indications of the quality of the results, that is, the extent to which they can be relied on for the purpose in hand. One of the means to demonstrate the quality of the immunity test performance and of the test results is the evaluation and the assessment of the associated uncertainty.

Whether an immunity test is a standardized or a modified one, it shall be developed so that reproducible results are obtained if different parties perform the same test with the same EUT. Beside this fact of repeatability, an immunity test set-up and the adjusted immunity test level shall reflect the specified levels as closely as possible. Hence special attention has to be given to any factors that can cause a deviation from the specified levels and the impact of which can quantitatively be described by means of the uncertainty. Substantial information about all the aspects related to uncertainty and its determination are given in IEC TR 61000-1-6 and CISPR 16-4 series of standards.

As a consequence, the uncertainty associated with an immunity test shall be determined and assessed with respect to its impact on the test results.

NOTE 1 The type of uncertainty to be considered and the value of uncertainty not to be exceeded depend on the particular immunity test.

NOTE 2 Other factors of testing uncertainty can be considered in addition to the instrumentation uncertainty.

10 Documentation

The documentation shall be written according to the requirements given in the appropriate standard for functional safety (i.e. IEC 61508). The ERS can contain additional requirements concerning documentation. Information shall be provided by an equipment manufacturer in the form of a clearly documented specification of the maximum characteristics of relevant electromagnetic phenomena that the equipment is intended to be used in. This can be achieved by specifying EMC standards and levels to which the equipment has been tested. In the case of elements, this information should be included in the safety manual for compliant items, see 7.2, 7.3 and 8.4.3 and IEC 61000-6-7.

Annex A (informative)

Selection of electromagnetic phenomena

Table A.1 lists the electromagnetic phenomena described in IEC TR 61000-2-5. It shows the immunity test levels from IEC 61000-6-2 and gives some guidance on how to assess them when considering the phenomena for functional safety purposes.

**Table A 1 – Example of selection of electromagnetic phenomena
for functional safety in industrial environments**

No.	Phenomena according to IEC 61000-2-5 Test level according to IEC 61000-6-2	Basic standard	Comments
1	ESD 4 kV (contact) 8 kV (air)	IEC 61000-4-2	Levels should be applied in accordance with the environmental conditions described in IEC 61000-4-2. Levels specified in the generic standard may only be chosen if the appropriate environmental conditions exist.
2	RF field 10 V/m (80 MHz to 1 000 MHz) 3 V/m (1,4 GHz to 2,0 GHz) 1 V/m (2,0 GHz to 2,7 GHz)	IEC 61000-4-3	An increased level should be applied in frequency ranges used for mobile transmitters in general, except when reliable measures are realised to avoid the use of such equipment nearby. ISM frequencies have to be taken into account on an individual basis.
3	EFT/B 1 kV (I/O) 2 kV (AC/ DC)	IEC 61000-4-4	Higher levels can be expected in industrial applications compared with the levels specified in applicable standards for functional reasons.
4	Surge AC: 2 kV (L-G) 1 kV (L-L) DC 0,5 kV (L-G) 0,5 kV (L-L) I/O: 1,0 kV (L-G)	IEC 61000-4-5	Increased requirements may be adequate, but additional external EMC measures have to be considered.
5	HF conducted 10 V (0,15 MHz to 80 MHz)	IEC 61000-4-6	An increased level should be applied in frequency ranges used for mobile transmitters in general, except when reliable measures are realised to avoid the use of such equipment nearby. ISM frequencies have to be taken in to account on an individual basis.
6	Power frequency magnetic field 30 A/m	IEC 61000-4-8	Applicable in accordance with the common exceptions given in the generic standard. No increased level in general. An increased level may be adequate in an environment as defined in IEC 61000-6-5 or similar such as an industrial switchyard.
7	Pulse magnetic field	IEC 61000-4-9	No increased level in general. An increased level may be adequate in an environment as defined in IEC 61000-6-5 or similar such as an industrial switchyard.

No.	Phenomena according to IEC 61000-2-5 Test level according to IEC 61000-6-2	Basic standard	Comments
8	Damped oscillatory magnetic field	IEC 61000-4-10	No increased level in general. An increased level may be adequate in an environment as defined in IEC 61000-6-5 or similar such as an industrial switchyard.
9	Voltage dips 0 % for 1 period 40 % for 10/12 periods 70 % for 25/30 periods	IEC 61000-4-11	To be decided case by case.
10	Voltage short interruptions 0 % for 250/300 period	IEC 61000-4-11	To be decided case by case.
11	Voltage variations	IEC 61000-4-11	Voltage variations are considered as functional aspects and not EMC related.
12	Ring wave	IEC 61000-4-12	To be decided case by case.
13	Harmonics	IEC 61000-4-13	To be decided case by case.
14	Interharmonics	IEC 61000-4-13	To be decided case by case.
15	Mains signalling	IEC 61000-4-13	To be decided case by case.
16	Conducted, common mode, 0 Hz to 150 kHz	IEC 61000-4-16	Increased level for short time power frequency phenomena only. Limited to the rated voltage of the power supply.
17	Damped oscillatory wave	IEC 61000-4-18	To be decided case by case.
18	Conducted, differential mode, 2 kHz to 150 kHz	IEC 61000-4-19	To be decided case by case.
19	HEMP radiated	IEC 61000-4-23	To be decided case by case.
20	HEMP conducted	IEC 61000-4-24	To be decided case by case.
21	HEMP immunity tests	IEC 61000-4-25	To be decided case by case.
22	Unbalance three-phase mains	IEC 61000-4-27	To be decided case by case.
23	Variation of power frequency	IEC 61000-4-28	Not applicable in general, but may be considered for special applications like UPS, emergency power supply systems and so on.
24	Voltage dips on DC power ports	IEC 61000-4-29	To be decided case by case.
25	Short interruption on DC power ports	IEC 61000-4-29	To be decided case by case.
26	Voltage variations on DC power ports	IEC 61000-4-29	To be decided case by case.
27	Voltage dips, short interruptions and voltage variations for equipment with mains current more than 16 A per phase	IEC 61000-4-34	To be decided case by case.
28	DC in AC networks		To be decided case by case.
29	DC magnetic field		Not applicable in general, but may be considered for special applications (e.g. traction systems, aluminium process).
30	16 2/3 Hz magnetic field		Not applicable in general, but may be considered for special applications like traction systems.

No.	Phenomena according to IEC 61000-2-5 Test level according to IEC 61000-6-2	Basic standard	Comments
31	Non-power system related magnetic field		To be decided case by case.
32	Power system harmonics magnetic field		To be decided case by case.
33	DC electric field		
34	16 2/3 Hz electric field		
35	50/60 Hz electric field		
36	Transient electric field		
37	ESD field		
38	Transients milliseconds		

Annex B (informative)

Measures and techniques for the achievement of functional safety with regard to electromagnetic disturbances

B.1 General principles

The aim of Annex B is to give an informative overview of a range of mitigation and other design techniques and measures that are available for the achievement of appropriate levels of resilience to electromagnetic disturbances (“electromagnetic resilience”).

NOTE Electromagnetic resilience is the capability to maintain adequate performance for safety functions when exposed to electromagnetic disturbances.

Appropriate techniques and measures for the achievement of functional safety with respect to electromagnetic disturbances should be identified and applied as necessary throughout the lifecycle of a safety-related system. Information on the range of techniques and measures applied on the element level as required to facilitate system integration activities should be included in the safety manual.

The selection of the techniques and measures to be applied for a particular system will depend upon a large number of factors. For a safety-related system, an appropriate range of techniques and measures should be selected and applied to achieve electromagnetic resilience, in order to ensure that the overall functional safety specifications are met with respect to electromagnetic resilience. The selection of the techniques and measures should be justified for that system. The following Tables B.1 to B.3 include a range of suggested techniques and measures together with guidance solely as to their importance for electromagnetic resilience purposes.

Depending on the nature of the project, different or additional techniques and measures may be applied to achieve electromagnetic resilience. Other techniques and measures than those listed in Tables B.2 and B.3 may provide an equivalent level of protection from impacts of electromagnetic disturbances. Designers of a system or item of equipment of functional safety should be aware of the recommendations given in Tables B.2 and B.3, but they may choose other techniques and measures when appropriate and the reasons are documented.

For example, in the case that no software is used in a system, then no software design techniques and measures would be selected for any of the project's stages. In the case where sufficiently rugged, high-specification electromagnetic mitigation measures are employed, other design techniques and measures may not be required to achieve electromagnetic resilience appropriate to the SIL.

Table B.1 below summarizes recommendations for system lifecycle techniques and measures. (For the explanation of the abbreviations HR, R and M see Table 3.)

Table B.1 – Overview of lifecycle techniques and measure recommendations for the achievement of functional safety with regard to electromagnetic disturbances

Practice	Overview	Reference for further information
EMC project management and safety planning	The processes for the management, planning, selection, design, implementation, commissioning, modification and verification of each safety function should explicitly include electromagnetic resilience measures.	–
	The electromagnetic resilience of the system should be managed as appropriate throughout the lifecycle using appropriate expertise.	–
Safety-related system design documentation	The system design documentation should provide sufficient information to enable the selection of techniques and measures to be used for achieving adequate electromagnetic resilience for the operational environment.	–
Implementation and integration measures	Procure materials, components and products according to their specifications for achieving electromagnetic resilience.	–
	Assemble according to the design, using the correct materials, components and products according to their specifications for achieving electromagnetic resilience.	–
	Install according to the design for achieving electromagnetic resilience.	B.2.2.4
Verification and validation measures	Verify and validate the effectiveness of the implemented measures.	B.2.2.5
Operation and maintenance techniques and measures	Comprehensive user instructions including operating procedures necessary to maintain adequate electromagnetic resilience.	–
	Maintenance procedures and planning related to achieving electromagnetic resilience (e.g. preventative and corrective maintenance).	–
Assessment of modifications to system or operational environment	Assessment of changes in the external electromagnetic environment (e.g. to consider new electromagnetic conditions that were not taken into account in the original design).	–
	Assessing the effect of proposed modifications and upgrades on the electromagnetic resilience of the system concerned.	–
	Ensuring that modifications and upgrades do not reduce electromagnetic resilience below acceptable levels, for the system concerned.	–

B.2 Choosing design techniques and measures

B.2.1 Introduction to design techniques and measures against electromagnetic disturbances

These design techniques and measures have been developed specifically to help overcome the following difficulties that have been found when attempting to deal with all of the electromagnetic disturbances that could occur during a lifecycle when trying to achieve functional safety to IEC 61508 or its related standards.

It has been generally found to be impractical to perform anything more than a general assessment of the electromagnetic disturbances that could possibly occur over a complete lifecycle. General assessments of electromagnetic disturbances and levels typically make up the manufacturer's specification for the maximum electromagnetic environment of their equipment.

These assessments are good enough for determining which of the many published EMC emissions and immunity standards for functionality should be applied, but cannot determine what electromagnetic disturbances, and combinations of them, could foreseeably occur over the lifecycle.

It is necessary to maintain adequate electromagnetic resilience in the operational environment despite all foreseeable faults, misuse, ageing, component tolerances, assembly errors, physical and climatic conditions, etc., that could occur over the lifecycle.

The traditional, and very effective, approach to dealing with these difficulties is to use very rugged, high-specification electromagnetic mitigation techniques and measures (shielding, filtering, surge protection, galvanic insulation, etc.) that:

- have a sufficiently high confidence that they can be expected to protect what they enclose from any/all electromagnetic disturbances over the lifecycle;
- are sufficiently rugged that they can be expected not to suffer significant degradation in their protection over the complete lifecycle, despite all foreseeable faults, misuse, ageing, component tolerances, assembly errors, physical and climatic conditions, etc., that could occur;
- ensure that both of these characteristics are achieved with the degree of confidence that is necessary for the achievement of functional safety according to the SIL.

As the use of electronic technologies in functional safety engineering expands rapidly into more sectors (e.g. aircraft, motor vehicles, portable or implanted medical devices, etc.), this traditional approach may be found to be impractically large, heavy and costly. This is especially the case for safety-related systems that are manufactured in high volumes.

These issues may make it desirable to achieve adequate electromagnetic resilience by employing an appropriate set of design techniques and measures. Design techniques and measures that may assist in demonstrating adequate electromagnetic resilience include (but may not be limited to) those listed in Table B.2 and Table B.3.

The range of design techniques and measures used in respect of a particular system should be identified and justified by the system designer. The precise selection of the electromagnetic resilience techniques and measures used depends on the application, as well as the technology employed. Equipment manufacturers may also wish to demonstrate compliance with an appropriate range of techniques and measures in a product's safety manual for compliant items.

Many of these techniques and measures are also employed in order to achieve systematic integrity in respect of causes of system failure not relating to electromagnetic disturbances. The application of particular techniques and measures (e.g. those relating to software) may have a significant effect on overall system performance. The precise selection of techniques and measures for systematic integrity therefore should consider a range of factors that are not limited to the demonstration of electromagnetic resilience.

Figure B.1 shows the general principles recommended for design to achieve electromagnetic resilience, (where the 'rugged high-specification electromagnetic mitigation' approach is not used). Some elements of a safety-related system could employ the 'rugged high-specification electromagnetic mitigation' approach, while other elements employed different combinations of techniques and measures (such as those summarized in Table B.2 and Table B.3).

It is important to understand that an overall safety-related system cannot be said to achieve electromagnetic resilience simply on the basis of the elements from which it is composed.