EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 50155

July 2021

ICS 45.060.01

Supersedes EN 50155:2017 and all of its amendments and corrigenda (if any)

English Version

Railway applications - Rolling stock - Electronic equipment

Applications ferroviaires - Équipements électroniques utilisés sur le matériel roulant

Bahnanwendungen - Fahrzeuge - Elektronische Betriebsmittel

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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Ref. No. EN 50155:2021 E

Contents

European foreword

This document (EN 50155:2021) has been prepared by CLC/SC 9XB, “Electrical, electronic and electromechanical material on-board rolling stock, including associated software”.

The following dates are fixed:

• latest date by which this document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2022-06-28
• latest date by which the national standards conflicting with this document have to be withdrawn	(dow)	2024-06-28

This document supersedes EN 50155:2017 and all of its amendments and corrigenda (if any).

EN 50155:2021 includes the following significant technical changes with respect to EN 50155:2017:

a) Revision of Clause 1 Scope;

   1) Precision about definition of electronic equipment and his components;

   2) Precision about covered scopes;

   3) Precision about applicability of this standard to electronic equipment or systems performing safety-related functions.

b) Updating of Clause 2 Normative references;

c) Revision of Clause 3 Terms, definitions and abbreviations”, new definitions and reorganisation of subclauses;

   1) Definition added for “performance”;

   2) Definition added for “adjacent circuit”;

   3) Definition added for “specification”;

   4) Definition added for “procedure”.

d) Improvement of Clause 4 General requirements, in terms of better wording, requirement expansion and reorganisation of subclauses;

   1) Precision about concept of normal performance level and concept of deviation of the normal performance level;

   2) Wording improvements of 4.3.2 to 4.3.4 “Performance criterion A, B and C”;

   3) Wording improvement of “4.6.4 Thermal compatibility”;

   4) Wording improvement of “4.6.6 Cabling inside vehicle” and “4.6.7 Wiring inside equipment”.

e) Improvement of Clause 5 Electrical service conditions, with reorganisation of subclauses;

   1) Subclause “DC supply” is renamed “5.1.1 DC Supply system”;

2) Subclause “5.1.2 AC supply system” is added;

3) Precisions added and editorial improvements of 5.2.1 to 5.2.8;

4) Concept of “rated voltage” is clarified in 5.2.2;

5) Wording improvement of subclause “5.2.6 Grouping of supply voltages”;

6) Subclause added: “5.3 Supply by another source than the vehicle battery”.

f) Improvement and simplification of Clause 6 Reliability, maintainability and expected useful life, with reorganization of subclauses and introduction of explicative figures;

g) Wording improvements and precision added to Clause 7 Design;

h) Clause 8 is renamed “Electronic equipment not designed for use on rolling stock application”;

i) Improvement of Clause 9 Components, revised requirement regarding the compliance with a quality system;

j) Wording improvements and precisions added for Clause 10 Construction;

k) Revision of Clause 11 Safety, reorganisation of subclauses;

l) Revision of Clause 12 Documentation;

1) In addition to the datasheet and user manual, equipment installation and commissioning information have to be provided to the user;

2) Typical content of the datasheet, is moved to Annex J;

3) The acronyms UPIC is used to designate User Programmable Integrated Circuit.

m) Improvements of texts and figures of Clause 13 Testing;

1) Generation, access and delivery of type test and routine test reports, are clarified.

2) Access or delivery of test reports, and tests subject to agreement must be agreed at tender stage.

3) Equipment used for type tests shall be already submitted to routine test procedure and shall be identified in the type test report by its part number and serial number.

4) Added : For “Prototype testing”, see Annex F – F.2.6

5) Table 11 — List of tests is rearranged;

6) Conditions during testing is moved in a new 13.3.2;

7) Improvements and clarification of 13.4.3 DC Power supply test;

8) Precisions added to 13.4.4 Low temperature test;

9) Precisions added to 13.4.5 Dry heat test - including use of rated voltage;

10) Precisions added to 13.4.7 Insulation test;

11) Precisions added to 13.4.8 Cyclic damp heat test;

12) Precisions added to 13.4.10 Shock and vibration test;

13) Precisions added to 13.4.12 Rapid temperature variation test;

14) Precisions added to 13.4.13 Salt mist test.

n) Improvement of the following informative Annexes:

1) Annex A - List of default requirements of EN 50155 and related subclauses;

2) Annex B - System Testing approach;

3) Annex C - Severity level of service conditions in different vehicle locations;

4) Annex D - Example for a summary of equipment type test compliance;

5) Annex E - User programmable integrated circuit life cycle example;

6) Annex F - Design suggestions for electronic hardware used on rolling stock;

7) Annex G - Electronic equipment not designed for use on rolling stock;

8) Annex H – Paragraphs with agreement with the involved parties.

o) Introduction of the following informative Annexes;

1) New Annex I – Electronic equipment supplied from AC supply system;

2) New Annex J – Typical content of datasheets;

3) New Annex K – Insulation test and testing matrix example.

p) Bibliography (extended and corrected).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC shall not be held responsible for identifying any or all such patent rights.

This document has been prepared under a Standardization Request given to CENELEC by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s) / Regulation(s).

For relationship with EU Directive(s) / Regulation(s), see informative Annex ZZ, which is an integral part of this document.

Any feedback and questions on this document should be directed to the users' national committee. A complete listing of these bodies can be found on the CENELEC website.

Introduction

This document specifies the requirements for the design, the manufacturing, the documentation and testing of any electronic equipment installed on-board of rolling stock.

It also describes the electrical and environmental operating conditions.

The aim of this document is not to be a detailed guideline for the design of the electronic equipment. The design is the supplier´s responsibility, however some recommendations are given in informative annexes in order to draw the attention of the designer on known design aspects. The supplier should take into account the requirements resulting from the specific location of the on-board installation (see Annex C).

This document specifies the requirements for the design, the manufacturing, the documentation and testing of any electronic equipment installed on-board rolling stock.

The roles of user and/or supplier are shown in Figure 1 below.

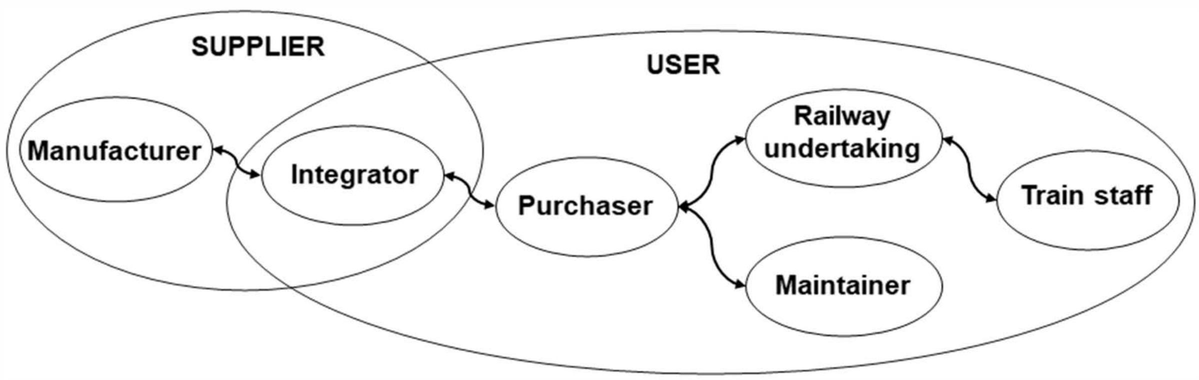


Figure 1 — Roles and relationship of user and/or supplier

1 Scope

This document applies to all electronic equipment for control, regulation, protection, diagnostic, energy supply, etc. installed on rail vehicles.

For the purpose of this document, electronic equipment is defined as equipment composed of electronic components (e.g. resistors, capacitors, transistors, diodes, integrated circuits, hybrids, application specific integrated circuits, wound components and relays), and recognized associated components (e.g. connectors, mechanical parts). These components are mainly mounted on printed circuit boards.

Sensors (e.g. current, voltage, speed) and semiconductor drive units for power electronic devices are covered by this standard. Complete semiconductor drive units and power converters are covered by EN 61287-1.

This document covers the requirements for operating conditions, design, documentation, testing and integration of electronic equipment, as well as hardware and software requirements considered necessary for compliant and reliable equipment.

Specific requirements related to practices necessary to ensure defined safety integrity level or functional safety are not covered by this document. Nevertheless, this document applies to the hardware of all rolling stock electronic equipment or systems performing safety-related functions.

The software requirements for on-board railway equipment are specified by EN 50657.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE 1 The IPC normative references are acceptable only until an equivalent standard from an official International or European Standardisation body will become available which cover the same requirements now covered by the referenced IPC standard.

NOTE 2 The version of IPC normative references, herein after listed, is identified by the last letter of the identification code, e.g. the letter J in IPC-A-600J identify the version J which was published in May 2016. However, the publication date is reported, even though implicit in the last letter. Consequently, the date is not repeated in the text of this document when the IPC normative references appear.

EN 45545-1:2013, *Railway applications - Fire protection on railway vehicles - Part 1: General*

EN 45545-2:2020, *Railway applications - Fire protection on railway vehicles - Part 2: Requirements for fire behavior of materials and components*

EN 45545-5:2013+A1:2015, *Railway applications - Fire protection on railway vehicles - Part 5: Fire safety requirements for electrical equipment including that of trolley buses, track guided buses and magnetic levitation vehicles*

EN 50121-3-2, *Railway applications - Electromagnetic compatibility - Part 3-2: Rolling stock - Apparatus*[1], Railway applications — Electromagnetic compatibility — Part 3-2: Rolling stock - Apparatus

EN 50124-1:2017, *Railway applications - Insulation coordination - Part 1: Basic requirements - Clearances and creepage distances for all electrical and electronic equipment*

EN 50125-1:2014, *Railway applications - Environmental conditions for equipment - Part 1: Rolling stock and on-board equipment*

1) Document impacted by EN 50121-3-2:2016/A1:2019.

EN 50126-1:2017, *Railway Applications - The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS) - Part 1: Generic RAMS Process*

EN 50153, *Railway applications - Rolling stock - Protective provisions relating to electrical hazards*2)

EN 50163, *Railway applications - Supply voltages of traction systems*3)

EN 50343, *Railway applications - Rolling stock - Rules for installation of cabling*4)

EN 50533, *Railway applications - Three-phase train line voltage characteristics*5)

EN 50657:2017, *Railways Applications - Rolling stock applications - Software on Board Rolling Stock*

EN 60068-2-1:2007, *Environmental testing - Part 2-1: Tests - Test A: Cold*

EN 60068-2-2:2007, *Environmental testing - Part 2-2: Tests - Test B: Dry heat*

EN IEC 60068-2-11:2021, *Environmental testing - Part 2: Tests - Test Ka: Salt mist*

EN 60068-2-30:2005, *Environmental testing - Part 2-30: Tests - Test Db: Damp heat, cyclic (12 h + 12 h cycle)*

EN 60297-3-100:2009, *Mechanical structures for electronic equipment - Dimensions of mechanical structures of the 482,6 mm (19 in) series - Part 3-100: Basic dimensions of front panels, subracks, chassis, racks and cabinets*

EN 60297-3-101:2004, *Mechanical structures for electronic equipment - Dimensions of mechanical structures of the 482,6 mm (19 in) series - Part 3-101: Subracks and associated plug-in units*

EN 60529, *Degrees of protection provided by enclosures (IP Code)*6)

EN 61373, *Railway applications - Rolling stock equipment - Shock and vibration tests*7)

EN ISO 13732-1:2008, *Ergonomics of the thermal environment - Methods for the assessment of human responses to contact with surfaces - Part 1: Hot surfaces (ISO 13732-1:2006)*

ISO/IEC/IEEE 15289:2019, *Systems and software engineering — Content of life-cycle information items (documentation)*

IPC-A-600J, *Acceptability of Printed Boards (Published date: May 2016)*

IPC-A-610G, *Acceptability of Electronic Assemblies (Published date: October 2017)*

IPC-7711C/7721C, *Rework, Modification and Repair of Electronic Assemblies (Published date: January 2017)*

2) Document impacted by EN 50153:2014/A1:2017 and EN 50153:2014/A2:2020.

3) Document impacted by EN 50163:2004/A1:2007 and EN 50163:2004/A2:2020.

4) Document impacted by EN 50343:2014/A1:2017.

5) Document impacted by EN 50533:2011/A1:2016.

6) Document impacted by EN 60529:1991/A1:2000 and EN 60529:1991/A2:2013.

7) Document impacted by EN 61373:2010/AC:2017-09.

3 Terms, definitions and abbreviations

3.1 Terms and definitions

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

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

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

3.1.1
printed board
printed circuit board
PCB
base material which is cut to size containing all required holes and incorporating at least one conductive layer

Note 1 to entry: Printed circuit boards are typically subdivided according to:

— their structure (e.g. single and double sided, multilayers);

— the nature of the base material (e.g. rigid, flexible).

Note 2 to entry: In some standards instead of printed circuit board the synonym printed board is used.

[SOURCE: IEV 541-01-03, modified]

3.1.2
printed board assembly
PBA
printed circuit board with electrical and mechanical components and/or other printed board assemblies attached to it with all manufacturing processes, soldering, coating, etc., completed

3.1.3
operating temperature, <of electronic equipment>
temperature range in which the electronic equipment is operating (e.g. cubicle temperature, rack temperature, roof box temperature) in full conformity with its performance criteria

Note 1 to entry: Outside of the operating temperature range there can be temporary or permanent degradation of the equipment performances

3.1.4
plug-in unit
unit which plugs into a subrack and is supported by guides

Note 1 to entry: Plug-in units can be of various types, e.g. a PBA with or without enclosure designed with a plug-in connection to be inserted into a subrack.

3.1.5
subrack
structural unit for housing PBA/PBAs and plug-in units

3.1.6
rack
free-standing or fixed structure for housing electrical and electronic equipment

[SOURCE: IEV 581-25-03]

3.1.7
enclosure
adequate housing for electrical and/or electronic equipment, provided by the equipment manufacturer to mount the equipment and to protect it from accidental damage, and occasionally from electromagnetic fields or environmental effects

Note 1 to entry: The equipment housing can offer protection to personnel, e.g. from electric shock.

Note 2 to entry: Several enclosure types are given in Figure 2

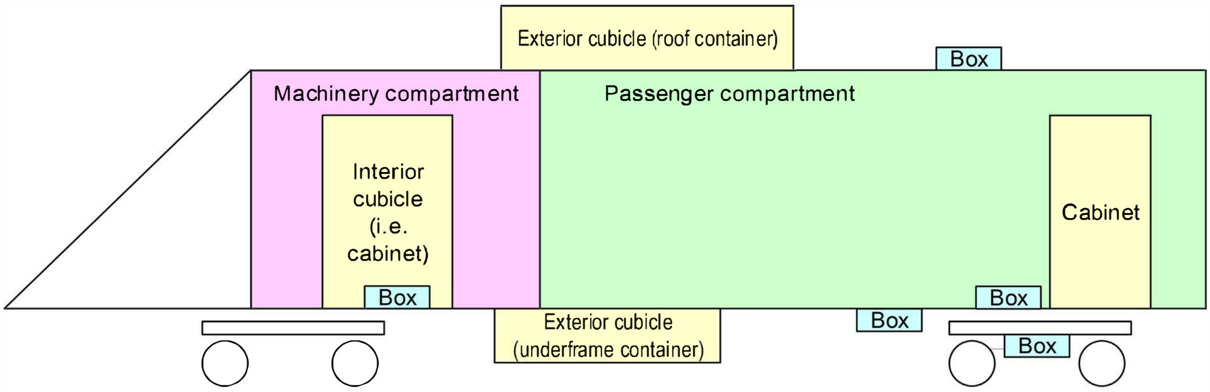


Figure 2 — Types of enclosures

3.1.8
cubicle
enclosure for whole equipment, including electrical, electronic and mechanical parts (e.g. converter, inverter)

EXAMPLE cabinet, roof container, underframe container

3.1.9
box
enclosure for smaller equipment, including electrical, electronic and mechanical parts

3.1.10
line replaceable unit
LRU
unit which can be removed from a railway system and replaced by an operating unit with the same function in order to restore the operational capability of the system

3.1.11
performance test
test in which all functions of the equipment are stimulated and verified in accordance with the specified functional requirements

Note 1 to entry: The performance test is carried out according to the performance test specification and performance test procedure provided by the supplier.

3.1.12
operational check
tailored performance test which is carried out during and/or after environmental tests or stress screening sufficient to prove that the equipment is still functioning within its operational limits

Note 1 to entry: Each environmental test or stress screening can use a different operational check.

Note 2 to entry: Operational checks are carried out according to operational check specifications and operational check procedures provided by the supplier.

3.1.13
system power supply
combination of vehicle battery and battery charger to provide the DC on-board supply voltage

Note 1 to entry: see Figure 3.

3.1.14
power supply
unit used to supply the electronic equipment with electrical energy

Note 1 to entry: The power supply can be also part of the equipment

Note 2 to entry: see Figure 3 and Figure 4.

3.1.15
supply voltage <of electronic equipment>
voltage at the supply terminals of the electronic equipment

3.1.16
vehicle cabling
all cabling which can be connected to the power supply, and all other cabling outside of the electronic equipment

3.1.17
supply overvoltage
disturbance to the system power supply (e.g. caused by battery charger malfunction or by load drop)

Note 1 to entry: A supply overvoltage will occur as an increase in the level of the supply voltage.

3.1.18
energetic transient pulses
non-periodic and relatively short positive and negative pulse or sequence of pulses of voltage and/or current

3.1.19
failure
loss of ability to perform as required

Note 1 to entry: “Failure” is an event, as distinguished from “fault”, which is a state.

Note 2 to entry: Attention is drawn to the possibility of a consequential failure of a second item of equipment resulting from a temporary malfunction of an item of equipment connected to it.

Note 3 to entry: A temporary malfunction will not be considered as a failure provided that the equipment recovers normal operation automatically following malfunction.

[SOURCE: IEV 192-03-01, modified – other notes to entry]

3.1.20
damage <to an electronic equipment>
change in visual appearance or alteration of electrical or mechanical integrity

3.1.21
useful life <of an item>
time interval, from first use until user requirements are no longer met, due to economics of operation and maintenance, or obsolescence

Note 1 to entry: In this context, “first use” excludes testing activities prior to hand-over of the item to the end-user.

Note 2 to entry: For a repairable item the individual useful life may be ended by a failure which is not considered as repairable for any reason.

[SOURCE: IEV 192-02-27, modified – Note 2 to entry has been added]

3.1.22
fault <of an item>
inability to perform as required, due to an internal state

Note 1 to entry: A fault of an item results from a failure, either of the item itself, or from a deficiency in an earlier stage of the life cycle, such as specification, design, manufacture or maintenance. See latent fault (IEV 192-04-08).

Note 2 to entry: Qualifiers, such as specification, design, manufacture, maintenance or misuse, may be used to indicate the cause of a fault.

Note 3 to entry: The type of fault may be associated with the type of associated failure, e.g. wear-out fault and wear-out failure.

Note 4 to entry: The adjective “faulty” designates an item having one or more faults.

[SOURCE: IEV 192-04-01]

3.1.23
performance
quantitative characteristics defining the ability of an equipment to achieve the intended functions

[SOURCE: IEV 311-06-11, modified]

3.1.24
performance classes
classification applied to an electronic equipment and specifying different performance levels for a performance requirement

3.1.25
performance criterion
performance class (A, B or C) specified for validation of the operation of the electronic equipment throughout the environmental test conditions

[SOURCE: Based on EN 50121-1:2017 Clause 4 – modified]

3.1.26
user
person or organization that receives and specifies equipment or software for further use, and that can be:

— a system integrator in relationship to the manufacturer;

— a purchaser;

— a maintainer;

— a railway undertaking.

3.1.27
manufacturer <of electronic equipment>
party who develops and manufactures the electronic equipment

3.1.28
system integrator
party who is responsible for the specification and/or the integration of the electronic equipment into the railway vehicle or vehicle subsystem

3.1.29
system
set of interrelated elements considered in a defined context as a whole and separated from their environment

[SOURCE: IEV 351-42-08, modified — The notes to entry have been omitted.]

3.1.30
equipment
single apparatus or set of devices or apparatuses, or the set of main devices of an installation, or all devices necessary to perform a specific task

[SOURCE: IEV 151-11-25, modified — The note to entry has been omitted.]

3.1.31
apparatus
device or assembly of devices which can be used as an independent unit for specific functions

Note 1 to entry: In English, the term "apparatus" sometimes implies use by skilled persons for professional purposes.

[SOURCE: IEV 151-11-22]

3.1.32
component
constituent part of a device which cannot be physically divided into smaller parts without losing its particular function

[SOURCE: IEV 151-11-21]

3.1.33
device
material element or assembly of such elements intended to perform a required function

Note 1 to entry: A device may form part of a larger device.

[SOURCE: IEV 151-11-20]

3.1.34
package
case
enclosure for one or more chips, film elements or other components, that allows electrical connection and provides mechanical and environmental protection

[SOURCE: IEV 521-05-31, heading modified]

3.1.35
item
part, component, device, subsystem, functional unit, equipment or system that can be individually considered

3.1.36
event
something that occurs in a certain place during a particular interval of time

3.1.37
supplier
organization which has the responsibility for the supply of an individual item of equipment or groups of the equipment to the user.

Note 1 to entry: This can be:

— a manufacturer;

— a system integrator in relation to railway undertaking or maintainer.

3.1.38
commercial off-the-shelf equipment/components
item purchased from a supplier's catalogue, available on the domestic and foreign market, according to a supplier reference, and for which the user has no control over the design definition or on the production

Note 1 to entry: This item can be modified, and manufacturing or maintenance can be discontinued without the user being notified.

3.1.39
equipotential area
area of electronic components and electric connections referenced to the same potential and without insulation between the electronic components

3.1.40
DC ripple factor
ratio of half the difference between the maximum and minimum value of a pulsating voltage to the mean value of this voltage

Note 1 to entry: With low values of the DC ripple factor this quantity is approximately equal to the ratio of the difference to the sum of the maximum and the minimum values.

[SOURCE: IEV 551-17-29, modified – "direct current" has been replaced by "voltage"]

3.1.41
Extra Low Voltage circuit
ELV circuit
secondary circuit with voltages between any two conductors of the circuit, and between any one such conductor and earth, not exceeding AC 25 V or DC 60 V, under normal operating conditions, which is separated from hazardous voltage by basic insulation

Note 1 to entry: The values AC 25 V and DC 60 V are taken from band I of EN 50153:2014+A2:2020.

3.1.42
functional earth
terminal for earthing in a system or in an installation or in equipment, for purposes other than electrical safety

[SOURCE: IEV 195-01-13, modified]

3.1.43
terminal
conductive part of a device, electric circuit or electric network, provided for connecting that device, electric circuit or electric network to one or more external conductors

[SOURCE: IEV 151-12-12, modified – Note which is not relevant in the context of this standard omitted]

3.1.44
adjacent circuit
circuit next to the circuit under consideration having a requirement for functional, simple or protective insulation

[SOURCE: IEC 62477-1, ed. 1.0 (2012-07)]

3.1.45
specification
document stating requirements

Note 1 to entry: A specification can be related to activities (e.g. test specification) or products (e.g. product specification, interface specification, performance specification).

[SOURCE: ISO 9000 2015, 3.8.7, modified – Example and Note 2 which are not relevant in the context of this standard omitted, Note1 modified]

3.1.46
procedure
specified way to carry out an activity or a process

[SOURCE: ISO 9000:2015, 3.4.5 - modified – Note which is not relevant in the context of this standard omitted]

3.2 Abbreviations

For the purposes of this document, the following abbreviations apply.

AC	Alternating Current
ASIC	Application Specific Integrated Circuit
ATE	Automatic Test Equipment
CAN	Controller Area Network bus
CMRR	Common Mode Rejection Ratio
CPLD	Complex Programmable Logic Device
CPU	Central Processing Unit
CTR	Current Transfer Ratio
DC	Direct Current
ELV	Extra Low Voltage
EMC	Electromagnetic Compatibility
ESD	Electrostatic Discharge
FPGA	Field Programmable Gate Array
GBWP	Gain–Bandwidth Product
IEV	International Electrotechnical Vocabulary
I/O	Input Output

IP Code	International Protection Code
LED	Light Emitting Diode
LRU	Line Replaceable Unit
MTBF	Mean Time Between Failures
MVB	Multifunction Vehicle Bus
NA	Not Applicable
PBA	Printed Board Assembly
PCB	Printed Circuit Board
PLD	Programmable Logic Device
PPS	Polyphenylene Sulfide
PTE	Portable Test Equipment
RAMS	Reliability Availability, Maintainability and Safety
RF	Radio Frequency
RH	Relative Humidity
RMS	Root Mean Square (value of a quantity)
TCMS	Train Control and Management System
TFT	Thin-Film-Transistor (display)
UPIC	User Programmable Integrated Circuit
UV	Ultraviolet

4 General requirements

4.1 Requirement for equipment characteristics

The requirements for equipment characteristics (e.g. functional, electrical, mechanical, appearance, interfaces) shall be defined by the user or derived from market needs for a generic equipment.

The supplier will generate a technical specification how to fulfil these requirements.

4.2 Classes of environmental, constructional and service conditions

The standard specifies a set of default performance classes of requirements; different classes may be requested at tender stage.

The summary of default requirements is given in Annex A.

4.3 Performance criteria

4.3.1 General

The normal performance level (i.e. the equipment is functioning as specified), expected from the equipment under test, shall be specified.

If agreed between the involved parties, the normal performance level of the equipment under test can be replaced by a defined deviation of the specified performance.

If the deviation of the normal performance of the equipment under test is not specified by the manufacturer/supplier, either of these may be derived from the product description and documentation and what the user may reasonably expect from the equipment if used as intended.

No damage to any connected equipment is allowed when the electronic equipment does not operate as intended during or after the test. Possible causes of failure are incorrect timing of output signals, overvoltage outside specifications, etc.

4.3.2 Performance criterion A

The equipment shall continue to operate as intended during and after the test and/or during and after an environmental disturbance.

No degradation of performance or loss of function is allowed.

Changes of actual operating state or stored data are not allowed.

Performance criterion A also satisfies performance criteria B and C.

4.3.3 Performance criterion B

The equipment shall continue to operate as intended after the test or after an environmental disturbance.

However, during the test or an environmental disturbance, degradation of performance is allowed.

Changes of actual operating state or stored data are not allowed.

Performance criterion B also satisfies performance criterion C.

4.3.4 Performance criterion C

During the test or during an environmental disturbance, temporary loss of function is allowed.

The equipment:

— shall automatically restart. The normal performance shall be obtained within a maximum defined time. After this time the equipment shall retain the previous operating state and shall work as intended. The loss of significant stored data is not allowed;

  NOTE Significant stored data are application dependent and stated in the equipment documentation.

  or:

— shall be manually restarted or process-controlled restarted. In this case the restart process shall be clearly defined in the user manual and agreed between user and supplier at tender stage.

4.4 Environmental service conditions

4.4.1 Altitude

The altitude at which the equipment is normally to function should not exceed the values called for in EN 50125-1:2014, Table 1 “Classes of altitude range”. If the required altitude exceeds the one specified in EN 50125-1:2014, Table 1 class A1, compliance with the requirements shall be agreed between the involved parties.

Unless otherwise specified, the requirements of EN 50125-1:2014, Table 1 class A1 apply.

4.4.2 Operating temperature

In order to fulfil the general environmental requirement stated in EN 50125-1:2014, Table 2, the electronic equipment shall be designed and manufactured to meet the specification for the selected operating temperature classes (OTx) as stated in Table 1 below:

Table 1 — Operating temperature classes

Class	Operating temperature range (°C)
OT1	−25 to +55
OT2	−40 to +55
OT3	−25 to +70
OT4	−40 to +70
OT5	−25 to +85
OT6	−40 to +85

Temperature classes OT1 and OT2 are mainly applicable for equipment in passenger compartments and the driver's cab with a reference permanent temperature of 25 °C for which the effects on the material ageing correspond to the surrounding temperature of the equipment during lifetime. Temperature classes OT3 and OT4 are mainly applicable for equipment in cabinets / cubicles with a reference permanent temperature of 45 °C for which the effects on the material ageing correspond to the surrounding temperature of the equipment during lifetime.

It is not recommended to use classes OT5 and OT6 as a general requirement for operating temperature. Classes OT5 and OT6 can be applicable for PBA inside a subrack or inside an enclosure when it is necessary because of the internal enclosure temperature, for semiconductor drive units or for combustion engine control units (see also Figure C.1).

Unless otherwise specified, the requirements of class OT3 apply.

The design should take into account temperature rises within cubicles and enclosures to ensure that the components do not exceed their specified temperature ratings. It is expected, that the air temperature surrounding the individual PBA can increase, for example between 10 °C … 15 °C (this temperature rise depends significantly on the power dissipation of the PBA itself and on the power dissipation of other PBAs in the vicinity of it, on the natural or forced air flow, etc.). This should be taken into account for the design of the PBA, particularly when individual PBAs are intended to be horizontally or vertically juxtaposed or when sub-racks containing the PBAs are superposed.

The supplier should take into account the requirements resulting from the specific on-board installation constraints. Examples therefore are given in Annex C, Figure C.1.

The supplier of the electronic equipment shall specify its power dissipation and the thermal integration constraints (e.g. natural convection cooling, forced air cooling, cooled plate, mounting position, free space inside integration volume, preheating, air outlet) to respect a correct integration of this electronic equipment into its operating environment.

The user of the electronic equipment shall respect the thermal integration constraints specified by the supplier and shall design the integration environment in order to ensure an operational temperature compliant with the operational temperature class of the electronic equipment to be integrated.

The requirements for active or assisted cooling system shall be described in accordance with 12.5.

"Electronic equipment" and "Integration environment" are generic designations applicable to several levels; some examples are listed below:

— an "Enclosed" or "Open frame" piggyback module integrated on a PCB;

— a "PBA" or a "Plug-In unit" integrated into a "Sub-rack";

— a "PBA" integrated into an "Enclosure";

— a "Sub-rack" integrated into a "Container"; "Cubicle" or "Cabinet";

— a "Rack" or a "Box" integrated into a "Vehicle".

The ambient temperatures outside vehicle are defined in EN 50125-1:2014, Table 2, column 1.

4.4.3 Increased operating temperature at switch-on

In some situations (e.g. dissipation of part with important thermal inertia that continues to dissipate energy inside the cubicle when forced ventilation is switched off, effect of solar radiation on equipment, assisting cooling system shutdown), it is possible that the temperature of the equipment at switch-on is above the maximum temperature defined by the operating temperature class.

Depending on the severity of these effects, there are three classes of switch-on at increased operating temperatures which are described by the corresponding type test cycles.

Table 2 — Classes for increased operating temperature at switch-on

Class	Increased operating temperature at switch-on	Thermal test cycle See 13.4.5
ST0	OTx (no increased temperature)	Test cycle A
ST1	OTx +15 °C	Test cycle B
ST2	OTx +15 °C	Test cycle C
NOTE "OTx +15 °C" = maximum temperature of OTx operating temperature range +15 °C (with "OTx" classes = OT1, OT2, OT3, OT4).		

Class ST1 and ST2 do not apply to classes OT5 and OT6.

Unless otherwise specified, the requirements of class ST1 apply.

The equipment shall pass the continuous operational checks applied during the increased operating temperature for classes ST1 and ST2.

4.4.4 Rapid temperature variations

Rapid external ambient temperature variations resulting from running through tunnels shall be taken into account depending on the installation location.

The temperature variation seen by the equipment depends on the installation location (see Figure C.1 and Table C.1 ; locations 4, 5, 6, 7 are particularly exposed).

The following classes define the requirements that the equipment shall fulfil:

Table 3 — Temperature variation classes

Class	Column 1	Column 2	Column 3
	Cold air temperature surrounding the equipment (RH not relevant)	**Hot air temperature surrounding the equipment**	**External temperature gradient**
H1	No requirements	No requirements	No requirements
H2	−25 °C	+15 °C / 95 %RH	±3 K/s [a]
	+10 °C	+40 °C / 60 %RH	±3 K/s [a]

[a] The temperature gradient might be higher than ±3 K/s dependent on the special installation condition of the equipment and the speed of the vehicle. If it is different from ±3 K/s, it should be specified.

NOTE 1 The H2 class takes into account the situation of a vehicle entering into a tunnel from low temperature environment (rapid change from −25°C to +15°C) or exiting from a tunnel into a hot and wet environment (rapid change from +10°C to +40°C). Condensation phenomena occur in both cases.

NOTE 2 The unit Kelvin [K] is used in case of a temperature variation or temperature difference or temperature gradient.

The values given in Table 3, Class H2 are worst case values which will typically not occur regularly throughout the year. Both directions of the rapid temperature change shall be taken into account.

Class H2 cannot be used as a general requirement for temperature and humidity change in vehicle (e.g. can be used for equipment mounted outside vehicle body).

If class H2 is required, the duration of the exposure to temperature from column 1 and column 2 shall be specified (typical and worst case).

Furthermore, the frequency of occurrence of the rapid temperature change shall be specified.

Unless otherwise specified, the requirements of class H1 apply.

4.4.5 Shock and vibration

The equipment shall be able to withstand, without deterioration or malfunction, vibrations and shocks that occur in service.

The level of shock and vibration that the equipment can withstand in normal operation shall be specified. This shall be done using the Categories and Classes as specified by EN 61373:2010. The supplier shall specify the permitted orientation for mounting the equipment on the vehicle according to the definitions of EN 61373:2010.

Unless otherwise specified, the requirements of EN 61373:2010 category 1 class B apply.

4.4.6 Electromagnetic compatibility

All electronic equipment shall comply with EN 50121-3-2:2016.

4.4.7 Relative humidity

External relative humidity values and duration exposure to consider are specified in EN 50125-1:2014.

The following shall be taken into account in order to avoid malfunction or failure due to relative humidity (see also Annex C):

— air temperature surrounding the electronic equipment;

— service conditions (e.g. pollution degree of EN 50124-1);

— rolling stock installation location;

— type of enclosure (IP Code of EN 60529:1991).

4.5 Special service conditions

4.5.1 General

Special arrangements shall be agreed between the involved parties when service conditions can be proved different from those mentioned in 4.4 (e.g. bogie mounted equipment or equipment integrated into a power converter). For checking the functionality and the performance level of such arrangements, optional type tests can be carried out on the vehicle itself in accordance with methods to be agreed between the involved parties.

4.5.2 Atmospheric pollutants

It is to be expected that the equipment is exposed throughout its life to various pollutants (e.g. oil mist, salt spray, conductive dust, sulphur dioxide, microorganism like fungi and mould). The types of pollutants, their concentration, test procedures and test specifications should be defined in the tender documents.

4.6 Installation requirements

4.6.1 General

The manufacturer shall provide the installation manual of the equipment.

The integrator shall ensure that the installation requirements are taken into account.

The requirements in the following 4.6.2 to 4.6.8 are necessary for the installation to maintain the full functionality of the equipment.

4.6.2 Installation instructions

The installation manual of the equipment shall contain the specific installation instructions, see 12.5 for details.

4.6.3 Battery voltage supply system

The battery voltage supply system for the electronic equipment should be provided by a separate conductor connected as directly as possible to the source or the main battery line. The separated conductor should only be used for the supply to electronic circuits.

EN 50343:2014 provides additional recommendations.

Calculations for the cabling of the battery voltage supply system and the protection against overcurrent shall take into account the power demand and the inrush current specified in the datasheet or in the installation manual of the equipment.

4.6.4 Thermal compatibility

When integrating the electronic equipment into its operating environment, the thermal integration constraints specified in the equipment datasheet or in the installation manual shall be taken into account. In addition, the integration environment shall be designed to ensure that the operating temperature matches the operating temperature class of the integrated electronic equipment.

4.6.5 Electromagnetic compatibility

The installation of the electronic equipment shall be arranged to reduce, as far as possible, the effects of electrical/electromagnetic disturbances to the electronic equipment and as far as possible the effect of emissions by the equipment to the electrical/electronic system of the rolling stock in accordance with EN 50121-3-2:2016.

4.6.6 Cabling inside vehicle

The vehicle cabling shall be done in accordance with EN 50343:2014.

Requirements for special cabling (e.g. for sensors, transducers and communication lines) should be taken into account.

4.6.7 Wiring inside equipment

As far as possible, wiring inside equipment should be done in accordance with the rules of EN 50343:2014. Useful hints are available in Annex F.

Requirements for special wiring (e.g. for sensors, transducers and communication lines) should be taken into account.

The installation requirements of devices/equipment intended to be integrated into another equipment shall be respected.

4.6.8 Insulation of the installation

The insulation coordination requirements are defined in EN 50124-1:2017. Test voltages are specified in EN 50343:2014.

5 Electrical service conditions

5.1 General

5.1.1 DC supply system

A typical topology of on-board DC supply system of rolling stock is given in Figure 3:

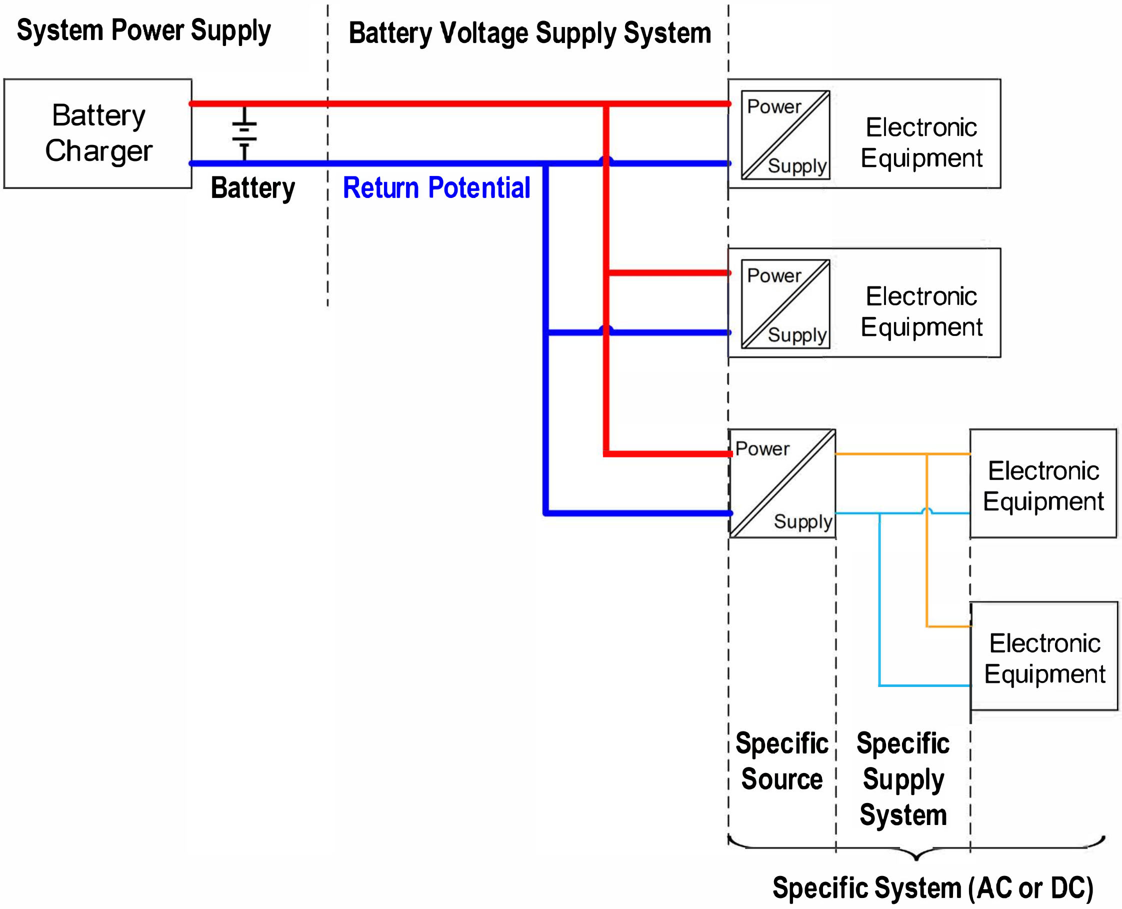


Figure 3 — Topology of on-board DC supply system

The system power supply is composed by the vehicle battery and the battery charger. Normally the battery is charged from battery chargers, auxiliary inverters or motor-generators with associated electronic regulations.

5.1.2 AC supply system

A typical topology of on-board AC supply system of rolling stock is given in Figure 4:

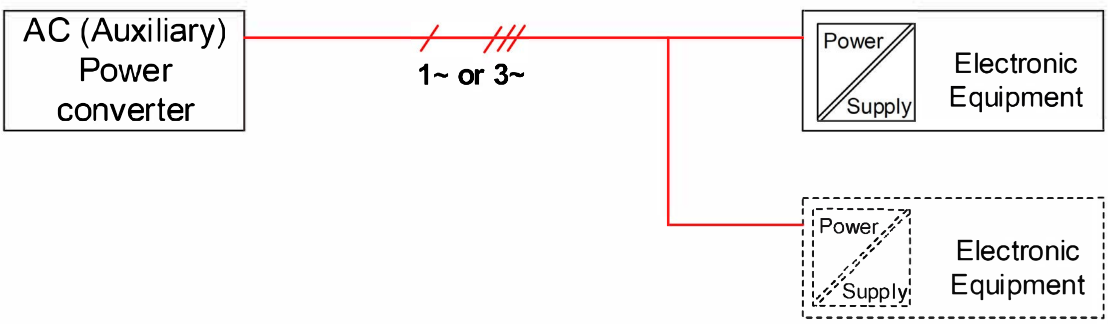


Figure 4 — Topology of on-board AC supply system (1~ or 3~)

5.2 Battery voltage supply system

5.2.1 General

The battery voltage supply system can be of the following types:

— Battery voltage supply system referred to vehicle body: One of the poles of the battery voltage supply system is connected (directly or by an impedance) to the vehicle body;

— Floating battery voltage supply system: No galvanic connection between the battery voltage supply system and the vehicle body.

In general, the electronic equipment has to work with both types of battery voltage supply systems unless the system integrator specifies the type of battery voltage supply system.

The battery referenced ports of the equipment shall be insulated from earth and from other internal circuits of the equipment which are not referenced to the battery voltage supply system (See Annex K).

5.2.2 Supply voltage range

The nominal voltage (U_n) of the electronic equipment shall be selected from amongst the following values:

24 V, 28 V, 36 V, 48 V, 72 V, 96 V, 110 V.

The recommended values are the following:

24 V, 72 V, 110 V.

These **nominal voltage** values are given as standardized values for the design of equipment.

The nominal voltage should not be considered as the off-load battery voltage as it is determined by the type of battery, the number of cells and the operating conditions. The nominal voltage represents approximately the output voltage of a charged battery with low load.

The **rated voltage** value represents the charging voltage of a battery powered supply system under normal conditions.

All requirements related to power supply (with possible exception for interruptions of supply voltage in 5.2.4 and supply change-over in 5.2.5) shall be applied to all I/O ports referenced to the battery voltage supply system.

In case of variation of the supply voltage between maximum and zero (e.g. opening of a circuit breaker) the equipment shall neither fail, nor be the cause of failure of other equipment. The equipment shall restart in normal operating mode when the supply voltage is within the continuous voltage range.

Within the range defined in Table 4, electronic equipment shall operate satisfactorily for all the values of the supply voltage, which are measured at the terminals of the equipment.

Table 4 — Supply voltage limits and performance criteria

Designation	Limit	Duration	Performance Criterion
Minimum temporary supply undervoltage	0,6 U_n	≤ 0,1 s	A
Minimum continuous voltage	0,7 U_n	Permanent	A
Nominal voltage	U_n		
Rated voltage	1,15 U_n		
Maximum continuous voltage	1,25 U_n		
Maximum temporary supply overvoltage	1,4 U_n	≤ 0,1 s	A
Maximum temporary supply overvoltage	1,4 U_n	≤ 1,0 s	B

If the supply voltage is permanently below 0,7 U_n, see 7.2.6.

If the supply voltage is permanently over 1,25 U_n, equipment may be damaged.

For thermal design the most stringent values in the voltage range shall be considered.

5.2.3 Temporary supply voltage variation

Electronic equipment shall operate at the values of the DC supply voltage, which are measured at the terminals of the equipment, within the variation range defined in Table 4.

Voltage variations can be either positive (overvoltage) or negative (undervoltage).

Temporary supply overvoltage up to 1,4 U_n and not exceeding 0,1 s shall not cause deviation of function (performance criterion A).

Temporary supply overvoltage up to 1,4 U_n and not exceeding 1 s shall fulfil performance criterion B.

Temporary supply undervoltage down to 0,6 U_n and not exceeding 0,1 s shall not cause deviation of function (performance criterion A).

Temporary supply overvoltages shall be assumed to be generated with respect to the system power supply return potential and to be present only as an increase to the level of the supply voltage, which shall be assumed to be present before and after the application of the overvoltage.

Overvoltage of reverse polarity to the system power supply need not be considered, see also design requirements in 7.2.7.

Voltage dips (temporary undervoltages) are mainly caused by faults in the battery voltage supply system, or by sudden large changes of load.

In the case of combustion engines, see also 5.2.8.

5.2.4 Interruptions of supply voltage

For the interruption of supply voltage, the equipment shall be validated for the nominal voltage for which it is designed for operation.

Due to a short circuit on the battery voltage supply system and subsequent operation of fuse/circuit breakers, input voltage may reduce to 0 V for a short period.

The supply voltage interruption classes are listed in Table 5:

During a short interruption, the battery voltage supply system presents a "**low impedance**" (short circuit) condition due to the clearing of an overload or fault condition on the battery voltage supply system. This condition can cause reverse current (negative peak inrush current) from the load.

Regarding interruptions on supply voltage, there are three classes of interruptions:

Table 5 — Supply voltage interruption classes

Class	Interruption time	Performance criterion
S1	> 0 ms	C
S2	≤ 10 ms	A
	> 10 ms	C
S3	≤ 20 ms	A
	> 20 ms	C

The requirements of this table shall be fulfilled for nominal voltage.

The system integrator should define the supply voltage interruption class. Unless otherwise specified, the requirements of class S2 apply.

Unless otherwise specified, the requirements for interruption of supply voltage apply to the power supply input ports only.

The requirements for interruption of supply voltage on I/O ports, supplied from the same battery voltage supply system, shall be handled as described in the specification of the equipment.

5.2.5 Supply change-over

In the case of equipment supplied with power alternatively from a battery and a DC stabilized source switched with dead time (e.g. mechanical switch), the voltage supply system presents a “high impedance” condition due to switching from one source to another.

During supply change-over, the equipment shall operate satisfactorily under the conditions stated in 5.2.1, 5.2.2 and 5.2.6.

The supply change-over classes are listed in Table 6:

Table 6 — Supply change-over classes

Class	Starting Condition	Condition during change-over	Change-over time	Performance criterion
C1	U_n	0,6 U_n	≤ 100 ms	A
C2	U_n	Supply break (open circuit)	≤ 30 ms	B

Unless otherwise specified, the requirements of class C1 apply.

Unless otherwise specified, the requirements for interruption of supply voltage only apply to the power supply input ports of the electronic equipment.

The requirements for interruption of supply voltage on I/O ports, supplied from the same battery voltage supply system, shall be handled as described in the specification of the equipment.

5.2.6 Grouping of supply voltages

It is permitted to group different nominal voltages for equipment designed for a wide input voltage range. In case of grouping, the principle (for compliance with performance and power supply type test) is to consider the most stringent values in the voltage range:

— In case of supply voltage variation within the continuous voltage range (see Table 4) the following applies:

The minimum continuous voltage shall be 0,7 U_n of the lowest nominal voltage and the maximum continuous voltage shall be 1,25 U_n of the highest nominal voltage;

EXAMPLE 1 Considering the voltage variation for equipment designed to operate at nominal voltages from 24 V up to 110 V, the minimum continuous voltage is 0,7 × 24 V and the maximum continuous voltage is 1,25 × 110 V.

— In case of temporary supply overvoltage and undervoltage, interruption, change-over the following applies:

The most stringent nominal voltage shall be considered.

EXAMPLE 2 For the interruption of the supply voltage, the supply voltage for equipment designed for operation with nominal voltages from 24 V up to 110 V is 24 V.

EXAMPLE 3 For the maximum and minimum temporary supply voltage the minimum temporary supply voltage to consider is 0,6 × 24 V and the maximum temporary supply voltage to consider is 1,4 × 110 V

5.2.7 DC ripple factor

The DC ripple voltage, and frequency, on a supply voltage is dependent on the type of power generator or converter that produces the stabilised supply voltage. The DC ripple normally consists of a small AC waveform superimposed on the supply voltage once the generator or converter output has been rectified and filtered. In practice, there are three common ways to produce a stabilised supply voltage, as follows:

— rectified single-phase AC (50 Hz or 60 Hz) that produces a DC ripple at frequencies of 100 Hz or 120 Hz, respectively;

— rectified 3 phase AC (50 Hz or 60 Hz) that produces a DC ripple at frequencies of 300 Hz or 360 Hz, respectively;

— inverter which generates single phase AC (1 kHz or higher) with a DC ripple frequency twice the inverter switching frequency, here 2 kHz or higher, respectively (e.g. for a full bridge topology).

The simplified formula to calculate the DC ripple factor is given below:

$$\text{DC ripple factor (\%)} = \frac{U_{\max} - U_{\min}}{U_{\max} + U_{\min}} \times 100$$

where U_{max} is the maximum peak voltage and U_{min} is the minimum peak voltage.

EXAMPLE A supply voltage has a value of 50 V. The maximum peak voltage is 51,5 V. The minimum peak voltage is 49,5 V. This gives a DC ripple factor of 2 V / 101 V ≈ 1,98 %.

The equipment shall be designed to operate properly taking into account a maximum 5% DC ripple factor on its supply voltage. The minimum temporary supply undervoltage and the maximum temporary supply overvoltage as defined in Table 4 shall, however, not fall below 0,6 Un or rise above 1,4 Un.

NOTE 1 The value of 5% for the maximum DC ripple factor is specified in EN 60077-1.

NOTE 2 For high frequency switch mode battery chargers a DC ripple factor significantly smaller than 5% can be expected.

This is only a design requirement and a type test is not required.

5.2.8 Behaviour of system power supply during start of combustion engine

If a combustion engine is started by a starter motor which is supplied over the battery voltage supply system by the battery, this can generate voltage drop and variation on the battery voltage supply system.

The system power supply, the battery voltage supply system and the starter motor shall be designed in such a way that the electronic equipment being involved in this starting process shall work as intended.

The behaviour of essential electronic equipment, if relevant, shall be agreed between user and supplier.

5.3 Supply by another source than the vehicle battery

5.3.1 Supply by a specific source

In the case of electronic equipment supplied by a specific DC or AC source, not directly connected to the battery voltage supply system (e.g. stabilized DC-DC-converter) the technical specification of this local source (e.g. voltages, currents, tolerances) shall be met.

Characteristics (e.g. range, variation, ripple factor) of the output voltage of the supply and input voltage of the equipment shall fit together and be agreed between the involved parties.

Regarding EMC, all ports connected to the specific supply system (see Figure 3) can be considered equivalent to the battery referenced ports of the equipment. However, the surge requirements are only relevant for extended cabling over more than one carbody / coach.

5.3.2 Supply by an AC auxiliary power converter

If the electronic equipment is supplied directly by the AC auxiliary power converter (see Figure 4), it shall operate satisfactorily for the voltage characteristics given in EN 50533:2011.

5.3.3 Supply with overhead line or third rail

If the electronic equipment (e.g. control electronics of a self-starting static converter) is supplied directly by a contact line, it shall operate satisfactorily for the contact line voltage characteristics given in EN 50163:2004.

NOTE According to national conditions, specific cases of contact line voltage characteristics are possible.

6 Reliability, maintainability and expected useful life

6.1 Equipment reliability

6.1.1 Predicted reliability

The user may require the manufacturer to predict reliability figures or meet the user's reliability targets.

The method of calculation shall be agreed between the manufacturer and the user at tender stage and shall be in accordance with a recognized standard.

IEC 61709 is an example of a recognized standard.

6.1.2 Proof of reliability

If the proof of reliability is required, it shall be agreed between the involved parties at tender stage.

The proof of reliability can be a costly process. Thus, the reliability evaluation plan and the associated procedure should be clarified in an early stage between the involved parties.

The reliability evaluation plan and associated procedure shall be agreed between the involved parties.

In order to show whether the equipment meets its stated reliability requirements, the equipment should be subjected to a reliability evaluation.

The manufacturer and the user shall agree how to monitor and to record all actions carried out on the equipment.

To demonstrate the reliability level of the equipment a reliability report will be presented at the end of a mutually agreed period (km or hours) identifying at least the components replaced (circuit reference number, type, manufacturer, number of manufacturing lot, kilometres and/or hours etc.), the definition and cause of faults (design weakness, software, component problems etc.).

Examples of standards providing guidance on this topic:

— For collection of dependability data from the field: EN 60300-3-2;

— For reliability growth programs: EN 61014;

— For performing accelerated ageing tests: EN 62506.

6.2 Useful life

The useful life of the electronic equipment shall be specified according to one of the following classes:

Table 7 — Useful life classes

Life Class	Useful Life (years)
L1	5
L2	10
L3	15
L4	20
LX	As agreed by the involved parties

Unless otherwise specified, the life class L4 applies.

If the supplier uses items that have known operational life shorter than the useful life of the electronic equipment, this shall be declared by the supplier at tender stage and specified in the documentation of the equipment.

If certain components of the electronic equipment should become unavailable during the useful life, the supplier of the electronic equipment shall inform the user and propose an alternative solution to the user in accordance with the equipment supply contract.

EN 62402 can be used as a guide.

NOTE The calculation of the MTBF has nothing to do with the useful life and are values for random statistic faults.

6.3 Maintainability

6.3.1 General

The presence of any non-repairable items in the equipment shall be declared in the equipment documentation.

At tender stage the supplier shall provide the essential information about the maintenance and, if requested, about the life cycle costs to the user.

PBAs and/or subracks and/or LRUs shall be capable of being individually tested.

NOTE Maintenance processes such as ultrasonic cleaning, connecting of diagnostic test equipment, electrical insulation testing, and transportation packaging arrangements, can reduce the equipment reliability level, through additional stressing of the assembly and components.

6.3.2 Preventive maintenance

Equipment should be designed such that regular periodic maintenance should not be necessary. If this is not possible, then maintenance requirements shall be specified in the datasheet of the equipment.

6.3.3 Corrective maintenance

6.3.3.1 On-vehicle diagnosis and repair

The user and the supplier shall agree on the type of LRU, if appropriate. These units shall be designed to be easily exchanged.

Equipment shall be designed such that a failed LRU can be identified by the use of either suitable portable test equipment or built-in diagnostics, both with associated test instructions.

The supplier shall specify in the documentation of the equipment the necessary information to allow the identification of the LRU as a result of on-vehicle fault diagnosis.

The supplier shall also declare in the documentation if any specialized tools are required in this maintenance procedure.

Maintenance or diagnostic procedures at this level shall not require the removal or replacement of any component of the LRU.

6.3.3.2 Off-vehicle diagnosis and repair

Equipment shall be designed such that test equipment with associated test instructions shall enable the full diagnosis and validation of performance of on-board electronic equipment in repair centres by qualified personnel.

Repairable Equipment shall be constructed such that access necessary for diagnosis and repair can be achieved without damage or undue stress to the components or wiring.

Repairable PBAs shall have test facilities (e.g. test plugs, test pads, etc.) to aid the diagnosis and repair process.

6.3.4 Built-in diagnostics

Communication interface or indicators to assist diagnostic maintenance should be used where appropriate, in order to provide status of input data, output data, main control functions, power supplies, etc.

Self-test routines shall be capable of providing a clear indication of the operational status of the equipment.

The design of electronic equipment shall ensure that the built-in diagnostic facilities cannot be activated unintentionally during normal operation of the equipment. The use of extra components for built-in diagnostic facility shall be taken into account in the calculation of the reliability prediction of the equipment.

6.4 Automatic test equipment

The user may require the use of a specific type of automatic test equipment for fault location either on or off vehicle.

It is permitted to remove plug-in units which do not contribute to the function of the equipment to facilitate the connection of automatic test equipment.

If it is required, details of such test equipment and its interfacing with on-board electronic equipment or equipment connector shall be provided by the user at tender stage.

6.5 Purpose-built test equipment and special tools

The prior approval of the user shall be obtained regarding the use of items requiring tools other than readily available industrial tools.

Where purpose-built test equipment and/or special tools are required to carry out the user's formal maintenance procedures, this equipment, or alternatively the manufacturing and procurement details for it, shall be offered by the supplier to the user at tender stage.

Where on-board electronic equipment has been developed or tested using proprietary test equipment the supplier may offer this as an alternative for fault diagnosis within repair centres, provided that such test equipment is easy to install and to use, and all support details are made available to the user.

Purpose-built test equipment does not necessarily have to comply with this standard.

7 Design

7.1 General

7.1.1 Quality management

The design shall follow a quality management system.

Examples of a quality management system are EN ISO 9001 and ISO/TS 22163.

The design process shall be visible and auditable.

If the user requires details of this process for tender evaluation, this shall be defined in the tender documents.

The quality management system applies to the design process of the system, hardware and software which shall be carried out according to unambiguous functional and interface specifications.

7.1.2 System life cycle model

The design process shall follow a tailored life cycle model which shall be laid down in the quality plan.

It is recommended to use the life cycle model given in EN 50126-1:2017.

7.2 Detailed practices - Hardware

7.2.1 Insulation coordination

The insulation requirements in accordance with EN 50124-1:2017 shall be defined by the user at tender stage.

Unless otherwise specified, the pollution degree PD2 of the EN 50124-1:2017 applies.

Unless otherwise specified, only the insulation tests (13.4.7) including the withstand test voltage specified in Table 13 shall be applied.

7.2.2 Interfacing

All interfaces shall be so implemented as to allow the equipment to meet its requirements in respect of:

a) personnel safety;

b) potential differences;

c) electromagnetic interferences.

and to restrict propagation of damage arising from external faults/failures.

The user may require galvanic isolation to meet the above-mentioned. In this case the requirements and particular areas for its application shall be declared at tender stage.

An example of system interfacing with various areas and galvanic isolation is given in Figure 5.

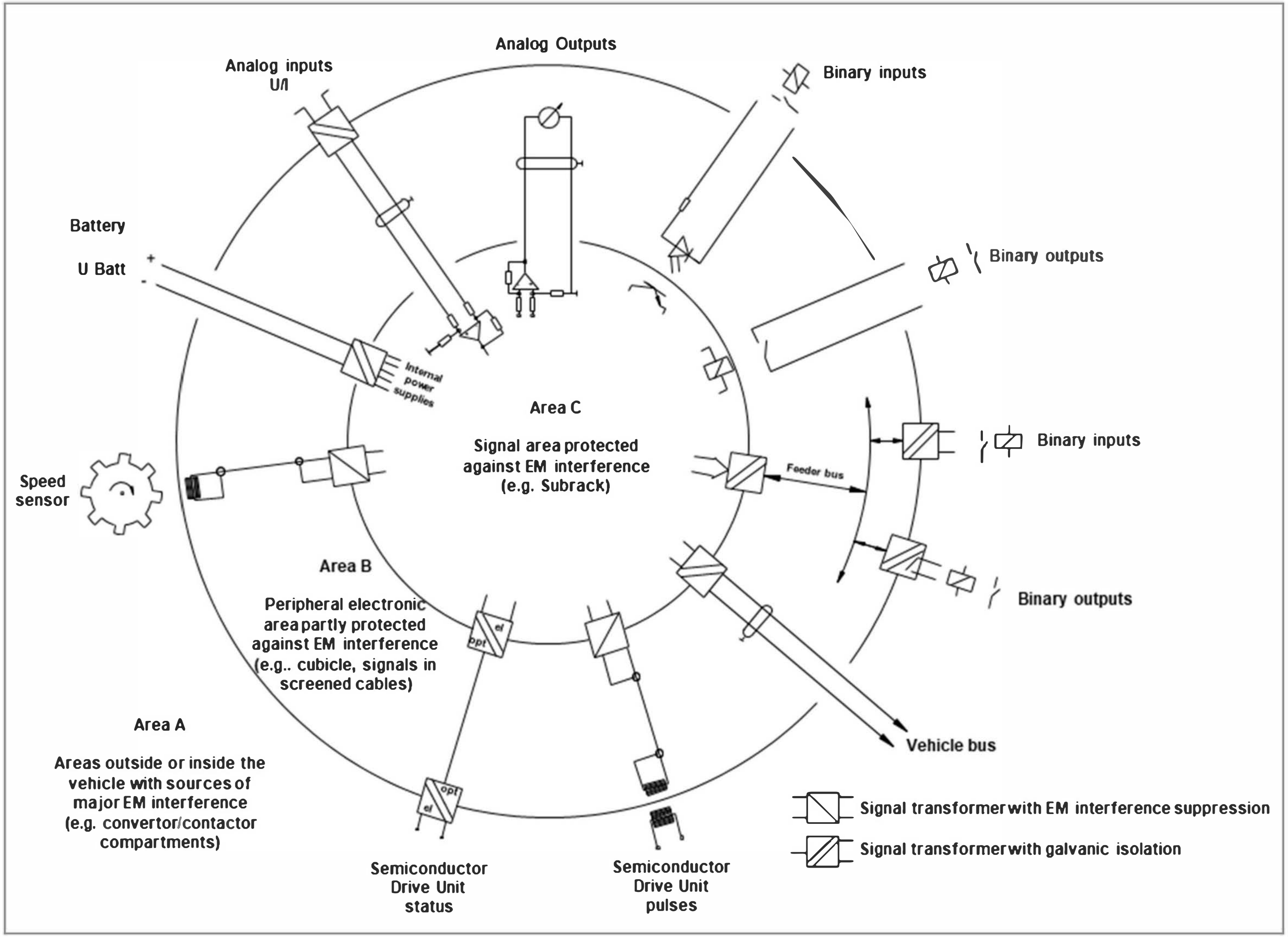


Figure 5 — System interfacing with typical areas A, B and C

7.2.3 Fault protection

Outgoing cables of the equipment and the corresponding protective devices shall match (short circuit behaviour and thermal behaviour). As an example, the cables shall be rated to at least the current limit specification of the protective device for the electric circuit considered. Equipment shall be protected against external faults/failures (e.g. short circuit or open circuit conditions) as appropriate.

Power supplies for electronic equipment shall incorporate current limiting to minimize the use of fuse elements.

If the equipment uses electromechanical relays and the contacts are provided as potential free and not short-circuit protected, an external device to limit the current or an overcurrent protection should be installed by the system integrator.

Where protective devices with manual or automatic resetting are incorporated, the available current under short circuit/overload conditions shall be sufficient to trip them. In addition, protective devices with manual resetting shall be easily accessible.

Any protective devices used shall be so arranged that the risk of fire within the equipment is minimized.

7.2.4 Reference potential of power supplies

The outputs of galvanically isolated power supplies should not be allowed to float for various reasons (e.g. EMC, functional, insulation, electrical safety).

If the outputs are not connected to the battery supply, one pole of the output supply rails should be connected either directly or via an impedance (e.g. resistor, capacitor or a combination of these) to the vehicle frame or a defined earthing point.

This reference point and the means of connection should be defined by the system integrator.

The voltage bands of EN 50153:2014 shall be taken into account.

7.2.5 Interchangeability

Unless otherwise agreed, all individual PBAs or LRUs forming part of a system shall be functionally complete and fully interchangeable with any other unit of the same functional type without the need for any recalibration of the hardware after the PBA or LRU has been inserted in the system.

7.2.6 Reduction of supply voltage and ON/OFF phases

The equipment shall not suffer damage, when the supply voltage is, or falls, below the lowest value of its specified supply voltage, irrespective to the value of the supply voltage and the voltage change rate. The voltage can fall down to 0 V.

In addition, the equipment shall not generate any spurious output which could lead to consequential failure of any other equipment under these conditions, including during power on/off phases.

7.2.7 Reverse polarity protection

To prevent any damage to the equipment, electrical or mechanical means shall be provided to ensure protection against reverse polarity of the power supply input voltage.

7.2.8 Inrush currents

The design of the equipment shall take into account inrush currents that can occur at the time of switch-on, so that protective devices do not trip and so that no damage occurs.

The datasheet of the electronic equipment shall include its inrush current characteristics to enable the integrator to select the appropriate circuit breaker.

7.2.9 Energetic transient pulses

Energetic transient pulses, occurring mainly at the battery voltage supply system, might cause ageing of the components. A guideline on how to cope with this is given in Annex F, F.2.2.

7.2.10 Capacitance to earth

To avoid failure or tripping of earth fault detection systems, the total value of the capacitance between equipment battery referenced ports and earth should be as small as possible.

A guideline how to cope with is given in Annex F, F.2.3.

7.2.11 Spare capacity

If the user requires spare capacity (e.g. spare inputs, spare outputs, CPU loading, etc.) for system expansion or changes during the equipment life cycle, the user shall specify this at tender stage. If required, this requirement shall be included in the design process.

The user may only request spare capacity for system expansion if it is very likely that this capacity will be needed during the life of the rolling stock (e.g. TCMS) and not if such expansion is improbable (e.g. Battery charger computational power).

7.2.12 User Programmable Integrated Circuit

The design development process of a User Programmable Integrated Circuit (UPIC) shall follow a tailored life cycle model according to EN 50126-1:2017, which shall be laid down in the quality plan, e.g. in Annex E.

7.3 Detailed practices - Software

7.3.1 General

The design process shall be visible and auditable in accordance with EN 50657:2017. If the user requires details of this process for tender evaluation, he shall define this in the tender documents.

7.3.2 Life cycle

Software design shall proceed in accordance with a tailored life cycle model according to EN 50657:2017. The tailored life cycle model shall be laid down in the quality plan.

7.4 Features of software-controlled equipment

7.4.1 General

Software-controlled equipment, unless very simple, shall be constructed with the following features, intended to provide operation under all conditions.

7.4.2 Self-test

The equipment should include self-test function(s), which verify that the system is operational at each initialization (e.g. memory checking, I/O test, configuration test, communication interfaces, and redundant functionalities). As far as possible diagnostic information shall be made available by self-test function(s) to localize a fault. Where possible, the system shall enter the recovery state.

7.4.3 Watchdog

The equipment/system shall include a watchdog function, to cause it to enter a recovery state in the case of failure of the operational software (e.g. software entering an unintended loop due to abnormal transient disturbances).

7.4.4 Failure indication

As far as possible, on detection of failure the processor shall record or indicate that such an event has occurred. It shall then enter a recovery state.

7.4.5 Recover from fault or error state

The equipment shall, as far as possible, recover from any fault or error state, into which it may be forced, with the minimum deviation to its functions. This recovery process may require the processor to reinitialize. Where it is not safe or practicable to recover from this state, the supplier shall declare the effect on the equipment.

8 Electronic equipment not designed for use on rolling stock

Electronic equipment not designed for use on rolling stock is outside of the scope of this standard. However, in some special cases, it might be necessary to use equipment that is not designed for use on rolling stock, because it is the only way to achieve the required function.

In this case, the use of such electronic equipment shall be submitted to an agreement between the involved parties and the acceptability conditions for use on rolling stock shall be evaluated case by case at the sub-system or system level by the user.

The informative Annex G provides a list of relevant acceptability conditions that should be fulfilled to expect a positive evaluation for the installation of such electronic equipment on rolling stock.

Electronic equipment compliant with the acceptability conditions for use on rolling stock cannot be considered as compliant with the EN 50155 standard, if all the mandatory type tests (see Table 11) are not passed and if all other requirements of this standard are not fulfilled.

9 Components

9.1 Procurement

Only components manufactured in accordance with a quality system (EN ISO 9001 or an equivalent quality system) shall be used.

Components with a multiple source of supply should be used. For the purpose of this standard, “multiple sourcing” shall imply complete interchangeability in respect of fit and function according to the specification.

Components to be used should be chosen on the basis of a high probability that further supplies will be available for a time equivalent to the life of equipment. If, despite this precaution, certain components should become unavailable during the period covered by the equipment supply contract, the supplier of the electronic equipment shall provide an alternative solution.

For specialized components such as custom hybrid circuits and application specific integrated circuits (ASIC), programmable components (e.g.: FPGA, CPLD) see 12.7.8.3.

The specialized component documentation is delivered only under specific request of the user and is subject to a contract agreement between supplier and user regarding the confidentiality and the rights of use of those documents.

9.2 Application

All selected components shall be appropriate for use in the application, and subject to the requirements (e.g. environment, quality, life expectancy, etc.) described in this standard.

All components shall be used in such a way that:

— they are used in accordance with the component manufacturer’s specifications;

— the life or performance of the equipment is not compromised; for this reason, tolerances and ageing of components shall be taken in due consideration during the design process and the choice of the component shall be properly documented (e.g. varistors, transient voltage suppressor diodes, fuses, electrolytic capacitors, relays, mechanical components, optocouplers, connectors) and components shall not be used outside the recommended operating conditions stated by their manufacturer;

— a percentage of logic gates inside of programmable components is available for future use.

The choice of temperature range, derating, packaging and screening, etc. of components is the complete responsibility of the supplier.

If required by the user, the supplier shall show (e.g. by calculations or other applications), at tender stage, that the equipment fulfils all the requirements given in this standard with particular reference to reliability and the life of components as described in Clause 6. The life expectancy of components shall not be less than the useful life of the equipment except for components with a known life as defined in 6.2.

10 Construction

10.1 Equipment construction

10.1.1 General

Equipment shall comply with the constructional requirements specified by the following subclauses.

10.1.2 Mechanical protection

It shall be possible to lay down an LRU on a flat surface on any of its sides without causing mechanical damage to any component. Where necessary, mechanical guards shall be fitted.

10.1.3 Polarization or coding

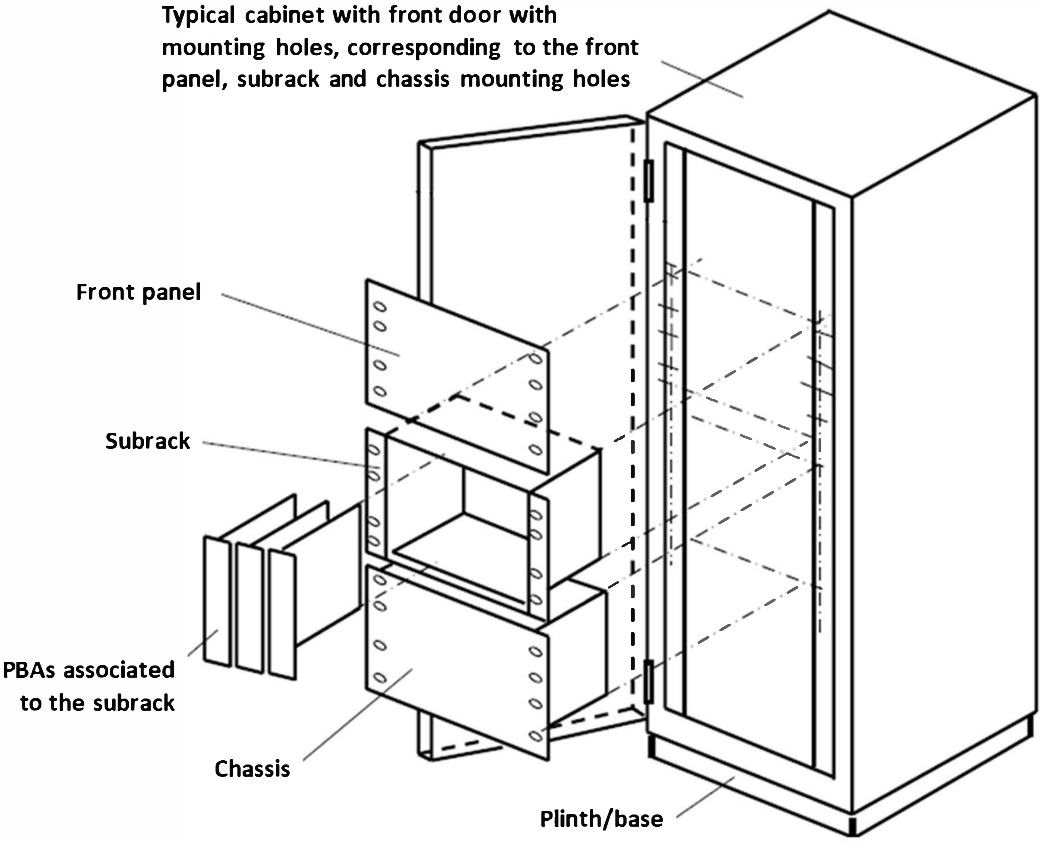
If required by the user, LRUs and PBAs used for racks and/or subracks shall incorporate mechanical means of polarization or coding to prevent incorrect insertion.

10.1.4 Dimensional requirements

The mechanical dimensions of the electronic equipment and the related installation requirements (e.g. free space for connectors, cable's routing and ventilation requirements) shall be stated in the documentation.

If the electronic equipment is designed for mounting in a 19-inch chassis or rack, the front panel, subrack and/or plug-in unit shall comply with dimensional requirements of EN 60297-3-100:2009 and EN 60297-3-101:2004. In such cases PCB sizes of 3U or 6U, and 160 mm or 220 mm length are preferred.

Figure 6 illustrates the relationship of front panels, subracks, chassis, rack and cabinet.



NOTE Figure taken from EN 60297-3-100:2009, modified

Figure 6 — Typical cabinet arrangement overview

10.2 Component mounting

10.2.1 General

PBA acceptability shall at least comply with IPC-A-610G class 2 and the constructional requirements specified by the following subclauses.

10.2.2 Layout

Components and parts of the repairable equipment shall be arranged, secured and placed in relation to each other and to mechanical structures in a way that they can be inspected and/or tested, removed and replaced without damaging other parts or wiring.

Wherever possible and applicable, the component identification and the marking on the fitted component shall be visible.

Heat dissipating components shall be mounted so that they will not cause damage to a PCB or any other components.

10.2.3 Fixing

Components which do not have specific mechanical fixings and whose weight can cause stress or damage to the soldered connections, through vibration during the life of the equipment, shall be fixed to the PCB.

The method of fixing shall be such that components can be replaced without damage to the PCB.

All components shall be mounted in accordance with the component manufacturer's recommendations or, in the absence of such recommendations, in such a way that the method of fixing has no adverse effect on the performance of the component, including the soldered joints.

10.2.4 Component lead terminations

Lead terminations of components shall be treated in such a way that no mechanical or thermal stress exceeds the limits specified for the component and/or the PCB.

Bending of lead terminations shall not cause damage or permanent stress to the component body/lead junction.

10.2.5 Integrated circuit sockets and edge connectors

There are two classes for the equipment according to Table 8 below:

Table 8 — Use of integrated circuit socket or edge connector - Permission classes

Class	Requirement
K1	Integrated circuit sockets and/or edge connectors are allowed
K2	Integrated circuit sockets and edge connectors are not allowed

Unless otherwise specified, the class K2 applies.

10.2.6 Pre-set controls

Where pre-set controls have been deemed necessary for operating adjustments (e.g. not internal calibration), they shall be accessible with the complete equipment and adjacent equipment in operation. Such controls shall retain their settings in normal operation and shall be protected against accidental adjustment.

For on-board adjustment, mechanical potentiometers are not recommended.

10.2.7 Select-on-test components

If selected-on-test components are used, they shall be mounted on solder posts to facilitate removal.

10.3 Electrical connections

10.3.1 General

The connection type shall be selected and meet the requirements of the following subclauses.

10.3.2 Soldered connections

Soldered connections shall be made only to components specially designed for that purpose. Flexible/stranded conductors and metallic braiding designed for flexible bending shall not be soldered but fitted with crimped tags or ferrules and strain relieved before the electrical connections.

Silver- or gold-plated wires or components should not be soldered, unless the plating is thin enough to avoid any adverse effect on the joints.

Soldered wires and components shall, as far as possible, be capable of disconnection without damaging the other connections.

Solder fluxes shall be non-corrosive.

10.3.3 Crimped connections

Crimped connections shall be in accordance with IPC-A-610G.

10.3.4 Wire wrap connections

All wire wrap connections shall be in accordance with the wire wrapped connection specified in IPC-A-610G. Soldered and wire wrapped connections on the same post are not allowed. The wire used shall be suitable for the chosen wrapping process, and at least three turns of the wire shall be in close contact to the post.

All wrapped connections shall, as a minimum, comply with the modified wire wrapped connection specified in IPC-A-610G.

10.3.5 Other connections

Other methods of connection (e.g. insulation displacement, press-fit) may be used. If required by the user, the supplier shall justify which ones are appropriate for use in the application, and state that they fulfil the requirements (e.g. environment, quality, life expectancy) given in this standard.

10.4 Internal flexible wiring (electrical and optical)

Wiring which could be subjected to flexing shall be provided with suitable clamps, sheaths or supports adjacent to the terminations and at suitable locations along its route.

Wiring shall be so arranged that its performance shall not be affected by extremes of temperature.

Wiring shall not be bent to a radius less than the minimum permissible value specified by its manufacturer.

If a minimum radius is not specified for an electrical wire, the inside radius of the bend shall not be less than twice the overall diameter of the wire, including its insulation, depending on the type of wire.

Grommets, bushes or edge protections shall be fitted where wiring passes through any material likely to cause abrasion damage. Internal wiring shall be adequately supported by clamping, looming, troughing, or similar means.

Wiring shall be clamped into plugs and sockets in such a way that the connections inside the connector cannot be subjected to detrimental tensile or torsional stress by normal operation and handling.

Wiring foreseen for flexible bending shall be protected against damage at or near to the connector (bending protection).

Where practical, sufficient wire shall be provided to enable a re-connection to be made at each end of the wire.

All wiring shall be readily traceable to a point-to-point wiring diagram or list.

10.5 Flexible printed wiring

The base material shall have suitable temperature ranges and mechanical properties to suit the application.

Wherever possible, sharp bends shall be avoided. The minimum bending radius shall not be so small that it results in cracking or deterioration of the base material or the overlay.

Adequate support at the connection points of the flexible printed wiring at the PCB shall be provided to ensure that there is no separation of the base material to any layer.

Any termination using this technique shall be capable of re-connection without damage to the wiring system.

10.6 Printed circuit boards - flexible and rigid

10.6.1 General

Printed circuit board procurement and manufacturing shall be in accordance with recognized standard from, for example IEC, CENELEC and IPC.

10.6.2 Holes

All the holes used for soldered connections shall be plated through, with pads on both sides.

10.6.3 Printed circuit board acceptability

PCB acceptability shall comply with IPC-A-600J class 2 as a minimum. Alternative standards of equivalent scope may be used with prior approval of the user.

10.6.4 Layout

PCB layout shall be carried out in accordance with a recognized international standard, e.g. EN 62326-1, EN 62326-4, EN 62326-4-1 and IPC-2222, IPC-2223, IPC-2226 as appropriate with due regard to the service conditions defined in this standard.

10.6.5 Materials

The base material shall be an epoxy woven glass fabric laminated sheet of defined flammability (vertical burning test) for rigid PCBs and for use in the fabrication of multilayer PCBs, in accordance with a recognized international standard (e.g. EN 61249 series and / or IPC-4101), as appropriate.

For flexible and rigid-flexible printed boards the base material shall be in accordance with a recognized international standard (e.g. EN 61249 series and / or IPC-6013), as appropriate.

10.7 Protective coatings for printed board assemblies

The following classes are defined for the protective coatings and they define the requirements that the equipment shall fulfil:

Table 9 — Protective coating classes

Class	Protective coatings requirement
PC1	No protective coatings. This is only applicable for special modules where protective coating is not feasible (e.g. TFT display, camera module, hard disk, RF modules). In this case rapid temperature variation class requirement for electronic equipment shall be H1, see 4.4.4. Protective coating is also not required for equipment inside a sealed enclosure which fulfils the requirements for IP 65 or better (according to EN 60529:1991).
PC2	All PBAs shall be protected on both sides with a protective transparent fluorescent pigment coating, in order to prevent deterioration or damage due to such causes as moisture and atmospheric contaminants. The coating shall not have any adverse reaction with any other materials or components used. The protective coating shall not be applied to integrated circuit sockets, test points or to connector contact mating surfaces, etc.
PCX	As agreed between user and supplier

Unless otherwise specified, class PC2 applies.

When the PBA is considered not repairable, the coating may be opaque.

When the PBA is considered repairable, it shall be possible to repair it without the need for complete removal of the coating.

After repairing, the PBA shall be locally recoated.

Coating types and thickness shall be according IPC-A-610G.

10.8 Identification

10.8.1 Bare PCB identification

The bare PCB shall reproduce sufficient information to enable its correct identification including its revision.

10.8.2 Identification of subracks and printed board assemblies

Identification of subracks and PBAs shall be adequate to enable their correct identification including serial number and revision. All markings/labelling shall be clear, bold, concise and durable. Identification of LRU shall also include its identification name, manufacturer's name or trade mark, and serial number.

Means shall be provided on the subracks and PBAs to record any change to fit, form or function.

Where possible the identification label shall be placed on the front panel of plug-in units.

For maintenance purposes the modification status label should be fitted to this front panel.

10.8.3 Mounting position of subracks and printed board assemblies

Each mounting position should be marked to indicate the type of subrack, PBA or cable connectors to be located in that position.

10.8.4 Fuse and battery identification

All fuse ratings should be indicated adjacent to the fuse.

If batteries are used, the front panel of the plug-in unit or LRU in which the batteries are placed should be marked to indicate their presence and to show the recommended date of their replacement.

10.9 Mounting

The equipment shall be mounted in some way to ensure its ability to operate in the specified service conditions. For mounting locations see examples in Figure C.1.

In each case, the enclosure shall provide the necessary protection (IP code according to EN 60529:1991) from the service conditions, and permit dismantling and repair of the contained equipment.

Potting (the covering of, for example, a PBA with silicone rubber, resin or other material) to provide additional protection is not recommended and should only be used if it is necessary for special environmental reasons (e.g. in case of a remotely mounted transducer).

If the supplier intends to use potting, the user shall be informed at the earliest possible stage.

The requirements of this subclause do not apply to individual components such as hybrid circuits, ASICs, etc.

10.10 Cooling and ventilation

Cooling shall not be achieved by the forced induction of air into the equipment enclosure, unless precautions agreed between involved parties are taken to ensure that the life of the equipment is not thereby adversely affected by the introduction of contaminants.

When a cooling system is used (e.g. fan, pump), the equipment shall be so protected that no damage can occur due to a failure of the cooling system.

The full performance shall be maintained until the related protective device operates. The lifetime of the fans or pumps should be taken into account.

NOTE Damage in this context includes negative effects on the equipment life due to the operation of any component beyond its maximum specified ratings.

10.11 Materials and finishes

Materials and finishes shall be suitable for the conditions of use, and shall be chosen with respect to the environmental, wear and ageing factors, as well as to the risk of toxic influences on persons.

All materials shall be dimensionally stable and should be non-hygroscopic. Materials with limited hygroscopicity (e.g. polyamide, ABS (Acrylonitrile butadiene styrene copolymers), polycarbonate) may be used in applications where they are proven in use and their hygroscopicity is expected not to cause any problem.

The supplier shall specify the method of disposal of any component which contains toxic material.

10.12 Reworking, modification and repair of electronic assemblies

Reworking, modification and repair of electronic assemblies are allowed and shall be executed in accordance with IPC-A-610G and IPC-7711C/7721C.

11 Safety

11.1 General

These requirements relate to all equipment installed on rolling stock and any maintenance equipment, tools or procedures.

11.2 Personnel safety

11.2.1 General

The user shall identify any special requirements related to personnel safety, with respect to equipment, construction and use of materials, at tender stage.

The safety requirements for rolling stock equipment applied in design, manufacturing and installation are given in the following subclauses.

11.2.2 Personnel safety against electric shock

Personnel safety against electric shock shall be in accordance with EN 50153:2014+A2:2020. If applicable, the earth continuity of the equipment shall be taken into account.

Insulation coordination shall be in accordance with EN 50124-1:2017.

11.2.3 Personnel safety against effects of excessive temperature

Personnel safety against effects of excessive temperature shall be in accordance with EN ISO 13732-1:2008.

11.3 Functional safety

The safety related functions for the equipment or system are not covered by this standard, nevertheless this standard shall also be applied to the hardware of all rolling stock safety related equipment and systems.

RAM and functional safety are covered by standards EN 50126-1:2017 and EN 50126-2:2017.

11.4 Fire behaviour requirements

For protection against spread of fire, EN 45545-1:2013, EN 45545-2:2020 and EN 45545-5:2013+A1:2015 shall be used.

Fire behaviour testing shall be in accordance with EN 45545-2:2020.

12 Documentation

12.1 General

As referenced in Clause 7, the equipment design shall be documented.

This should be done according to the provisions of EN ISO 9001 or an equivalent quality system.

12.2 Supply and storage of documentation

As a minimum the datasheet and the user manual, as well as installation and commissioning information of the equipment, shall be provided to the user.

The following documentation requirements, shall be agreed between the involved parties at tender stage:

— the quantity, scope, content, language, presentation, medium and updating process of documentation required by the user;

— the scope, conditions and duration applying to the storage of documentation by the supplier.

12.3 Datasheet

The datasheet is a document that describes the electronic equipment.

This document shall contain all information which the user needs to evaluate whether the electronic equipment fulfils the requirements.

Typical datasheet content is given in Annex J.

12.4 User and maintenance manual

This document shall contain all relevant information for the user and the maintainer of the electronic equipment.

For simple electronic products without or with only few number of human interfaces, this content may be integrated into the datasheet.

12.5 Equipment installation documentation

This document shall contain all relevant information for system integrator of the electronic equipment. For simple electronic products with only few mechanical and electrical interfaces, this content may be integrated into the datasheet.

The following check list for equipment installation requirements (not complete) should be considered:

— type of mechanical frame needed for mounting the electronic equipment: mounting frame, mounting plate, rack, subrack, enclosure, etc. (with references and characteristics);

— mechanical drawing (dimension, fixing, mounting points);

— orientation constraints for mounting the equipment;

— natural cooling or forced ventilation constraints for the equipment;

— free space required for natural cooling within integration volume;

— need of preheating or air outlet;

— need of free space for access to parts, for mounting or dismounting of the equipment;

— mechanical protection constraints (e.g.: against shock and hazard, solar screen);

— (EMC or protective) earthing terminal location(s);

— shielding requirements for input or output cables;

— possible recommendations or requirements for cable cross section;

— mechanical polarization or coding where applicable;

— external filters for EMC compliance;

— external overcurrent protections (e.g.: fuses or micro circuit breakers for power supply circuits or for output circuits);

— external overvoltage protections (e.g.: overvoltage suppressor, ESD protection);

— interconnection diagrams and charts;

— interface information.

12.6 Commissioning documentation

This document shall provide all relevant information and instructions for the person in charge of the commissioning of the electronic equipment.

For simple electronic products with only few human interfaces, the following topics may be integrated into the datasheet document:

— commissioning instructions and pre-setting data;

— test points;

— on/off vehicle diagnostic procedures and test equipment required.

12.7 Design documentation

12.7.1 General

The design documentation describes the detailed design of the electronic equipment and includes all detailed information about its internal functionalities.

The design documentation is delivered only as a specific request of the user and is subject to a contractual agreement between the involved parties.

12.7.2 Block diagrams

Block diagrams shall show the flow of information between the identifiable parts of a system and should have symbols in accordance with IEC 60617 series and EN 61082-1.

12.7.3 Wiring diagrams

Wiring diagrams and charts shall show the inter-unit wiring within equipment enclosures and, in addition, the functions provided (e.g. power supplies, distribution, alarms).

12.7.4 Cabling diagrams

In case of system or subsystem delivery by the supplier, cabling diagrams and charts shall show the inter-equipment cabling at vehicle level, and in addition, the functions provided (e.g. power supplies, distribution and alarms).

12.7.5 Interface specification

The interface specification shall include all the information that is needed to replace the equipment by another functionally equivalent equipment.

12.7.6 Internal interface specification

Internal interface specification shall include all the information that is needed to replace a part of the equipment by another functionally equivalent part.

12.7.7 Equipment drawings

Equipment drawings shall show the layout of equipment mounted in racks or subracks, the distribution of units and sub-units within an enclosure, and the essential mechanical features of all cubicles, racks, subracks, plug-in units, and PBAs.

12.7.8 Documentation – Hardware

12.7.8.1 General

The following items provide a check list for hardware documentation:

12.7.8.2 Manufacturing data

The manufacturing data includes all necessary information for the manufacturing and the assembly of the PBA or electronic equipment. The manufacturing data are delivered only under specific request of the user and are subject to a contractual agreement between supplier and user regarding the confidentiality and the rights of use of those documents.

The generic requirements for PBA product manufacturing description data and the transfer methodology should include:

— bill of materials (PCB, electronic parts, mechanical parts, etc.) with component reference and sourcing (i.e. manufacturer) information;

— manufacturing documents (e.g. circuit diagrams, wiring diagrams);

— bit stream codes for programmable components (e.g. CPLD, FPGA) with programming instructions, documentation, references of programming tools;

— drawings, mounting instructions and specifications;

— in circuit testing specifications, test programs (boundary scan programs, where appropriated).

12.7.8.3 User Programmable Integrated Circuits (UPIC, e.g. FPGA, PLD, ASIC)

The list of documents required for a user programmable integrated circuit, shall be defined according to class M0 or M1:

— Class M0: The documents listed in the column “Class M0” of Table 10 shall be available according to the contractual agreement between the involved parties. These documents shall be sufficiently precise to allow subsequent redesign of a ‘functionally equivalent component at interface level’.

— Class M1: The documents listed in the column “Class M1” of Table 10 shall be available according to the contractual agreement between the involved parties. These documents shall be sufficiently precise to allow a modification of the design. For this purpose, the supplier shall demonstrate that the delivered source code (with design constraints and procedure) allows the correct generation of the programming file. If the user requests specific verification activities for those deliveries, it shall be specified at tender stage.

Table 10 — List of required documentation according to the class

Documentation	Class M0	Class M1
Quality plan	X	X
UPIC Requirement specification	X	X
UPIC Architecture and interface specification	X	X
UPIC Programming file	X	X
UPIC Programming procedure	X	X
UPIC Architecture & Design specification UPIC Requirements & Integration test specification		X
Source Code and supporting documentation (e.g. design constraint file, project file)		X
UPIC Placement & Routing, Synthesis		X
UPIC Testing/simulation report & supporting files (e.g.: Test bench files)		X
UPIC Integration/validation report & supporting files (e.g.: simulation report)		X
UPIC Programming file generation procedure		X
Development tools (e.g.: simulation, generation tools) shall be specified into UPIC Programming file generation procedure.		
NOTE 1 This UPIC Quality plan can be integrated into the general "Design process" quality plan (see 7.1.2). NOTE 2 Architecture and interface specification document is an output of the Hardware design documentation; this document is an entry document for the UPIC design phase. NOTE 3 UPIC Programming file and UPIC Programming procedure can be integrated into the general manufacturing data (see 12.7.8.2).		

Unless otherwise specified, the requirements of class M0 apply.

12.7.9 Non-repairable items list

The manufacturer/integrator shall provide the list of all the declared non-repairable items.

12.7.10 Repair documentation

12.7.10.1 General

All documents submitted to the user shall bear an appropriate drawing number, date, version/release and title indicating the particular item shown and the type of drawing.

All documents and component lists shall have an issue or revision index and a record of modification.

The repair documentation is delivered only under specific request of the user and is subject to a contractual agreement between supplier and user regarding the confidentiality and the rights of use of this documentation.

12.7.10.2 Circuit diagrams

Circuit diagrams shall be generated for each PBA and plug-in unit of the complete equipment.

Where practicable, all circuit diagrams shall be drawn so that the main sequence of events on the signal path is from left to right (and where necessary for arrangement purposes, from top to bottom).

Where practicable, the circuit diagram for any one unit shall be completely self-contained, self-explanatory, readily related to other circuit diagrams and shall show:

— voltage levels and interconnections;

— connections between the low voltage circuits;

— connections between these circuits, the electronic equipment, the transducers and the controlled or monitored devices;

— earth connections of the metallic parts;

— connections between the electronic zero-volt lines (reference potentials);

— enclosures and their connections;

— features of used cables (e.g.: screened and/or twisted).

Discrete components external to a PBA or plug-in unit but essential to its operation shall be shown in dotted outline on the circuit diagram and be appropriately identified.

All component symbols shall be marked with their identifier in the circuit and the nominal value of components shall be marked on the circuit diagram where the component list is not included on the same diagram.

Components with three or more connections shall have the connection points identified or marked.

The function of all controls, switches and indicating items shall be indicated in accordance with the inscriptions marked on the equipment.

Relays shall always be shown in the de-energized position.

12.7.10.3 Component list (Bill of material)

All component lists shall unambiguously identify each component, i.e. its identifier in the circuit and the specification or part number(s)/manufacturer(s) indication(s) of that component.

12.7.10.4 Component layout

Component layout drawings shall show the location of each individual component used in a PBA or plug-in unit, marked with its identifier in the circuit, outline and polarizing details if needed.

12.7.10.5 Special maintenance tool

The list, the description and references of special tools (Hardware and/or Software) associated to the electronic equipment shall be provided.

12.7.11 Documentation – Software

The documentation of the software design is delivered only under specific request of the user and is subject to a contractual agreement between supplier and user regarding the confidentiality and the rights of use of this documentation.

Depending on the chosen software life cycle model according to 7.3.2, the supplier shall determine and list which information items are deliverable documents, consultable documents and non-deliverable documents and which information items are to be archived. The list shall be included in the quality plan.

All identified information items (documentation) shall be in accordance with EN 50657:2017.

At least the highly recommended documents (HR) in EN 50657:2017, Table A.1 column basic integrity shall be provided for non-safety related on-board equipment.

12.7.12 Documentation – System

This subclause is applicable only if the supplier's scope includes delivery of equipment which consists of several interconnected apparatus or devices, and which constitutes a system or a sub-system.

All identified information items (documentation) shall be in accordance with ISO/IEC/IEEE 15289:2019, Clauses 7 and 10. For each identified information item, the generic contents as specified in ISO/IEC/IEEE 15289:2019, Clause 7 shall be applied.

At least the following identified information items according to the ISO/IEC/IEEE 15289:2019, Clause 10 shall be available:

10.58	System architecture description
10.59	System element description
10.60	System requirement specification
10.67	User documentation
10.71	Validation report
10.74	Verification report

13 Testing

13.1 General

A test specification shall list all the tests to be performed on the equipment and shall define the test acceptance criteria. The test specification and the test procedures to apply shall be written by the supplier.

Equipment, as single apparatus or set of devices or apparatus, shall pass the appropriate routine and type tests.

The supplier (manufacturer or integrator) shall generate the following reports for his equipment:

— a type test report;

— a routine test report.

The access and delivery of type test and routine test reports shall be agreed between the involved parties at tender stage.

During the type tests and routine tests, the item shall not malfunction or produce a performance which is outside its specification. For type test, the equipment should be tested in the manner in which it is expected to be used, i.e. protective covers should be in position and the equipment arranged, as nearly as possible, in the position it will occupy in operating conditions.

The requirements not associated with a test procedure shall be verified at the design review level. Additional requirements, acceptance criteria and the related verification/test shall be agreed between the involved parties at tender stage.

Since some of the tests subject to agreement can be costly, it is advisable to carry out only necessary tests. The user may require to observe and check the results of any tests. This shall be agreed between the involved parties.

13.2 Categories of tests

13.2.1 General

There are three categories of tests:

— type tests;

— routine tests;

— investigation tests.

At tender stage, the user shall identify any tests subject to agreement (see Table 11 — List of tests).

13.2.2 Type tests

Type tests shall be carried out to verify that a product will meet the specified requirements.

Type tests shall be performed on a single equipment of a given design and manufacturing procedure.

Equipment used for type tests shall be already subjected to routine test procedure.

NOTE If automatic test routines are not ready at this step, they can be replaced by equivalent procedure.

Equipment used for type tests shall be identified in the type test report by its part number and serial number.

For prototype testing, see Annex F, F.2.6

If an equipment is not identical to one tested previously the supplier shall provide documents justifying that the change does not alter the validity of existing previous type test report; otherwise a complete re-test or a subset of type tests shall be performed.

The type test sequence starts with visual inspection and a performance test. After all type tests have been performed the visual inspection and performance test shall be repeated.

According to an agreement between the user and the supplier, some or all tests may be repeated from time to time on samples drawn from current production or deliveries, to confirm that the quality of the product still meets the specified requirements.

In addition, the user may request the supplier to repeat a type test either totally or in part in case of:

— modification of equipment likely to affect its function or method of operation;

— failure or variations established during type or routine tests;

— resumption of production after an interruption of more than five years;

— change of manufacturing site.

The type test reports shall be produced and managed according to the implemented quality system.

Equipment used for type test shall not be delivered to the user.

13.2.3 Routine tests

Routine tests shall be carried out to verify that the properties of a product meet the specification after the manufacturing process and correspond to those measured during the type tests.

Routine tests shall be performed on each manufactured equipment by the supplier.

A complete routine test report shall be generated for each equipment and managed according to the implemented quality system.

13.2.4 Investigation tests

Investigation tests are carried out to obtain additional information about the performance of the electronic equipment outside the specified requirements.

If investigation tests are requested by the user, they shall be agreed between the involved parties.

The results of investigation tests may not be used as reasons for refusing acceptance of the equipment.

These tests are not described in this standard.

13.3 List of tests and test conditions

13.3.1 List of tests

Table 11 lists the type and routine tests for electronic equipment; the test sequence is not mandatory. The test specification shall indicate the tests to be performed and the test sequence to be followed.

The complete test is carried out according to the test specification and the test procedure written by the supplier.

Table 11 — List of tests

	Test	Type	Routine	Test subclause	Requirement subclause
1	Visual inspection	M	M	13.4.1	4.1
2	Performance test	M	M	13.4.2	4.2 and 4.3
3	DC Power supply test	M	O	13.4.3	5.2
4	Low temperature test	M	O	13.4.4	4.4.2
5	Dry heat test	M	O	13.4.5	4.4.2 and 4.4.3
6	Low temperature storage test	O	NA	13.4.6	4.1
7	Insulation test	M	M	13.4.7	4.6.8 and 7.2.1
8	Cyclic damp heat test [a]	M	O	13.4.8	4.4.2 and 4.4.7
9	Electromagnetic compatibility test	M	O	13.4.9	4.4.6
10	Shock and vibration test	M	NA	13.4.10	4.4.5
11	Enclosure protection test (IP code)	O	O	13.4.10.5	4.4.7 and 10.9
12	Stress screening test	O	O	13.4.11	
13	Rapid temperature variation test	O	NA	13.4.12	4.4.4
14	Salt mist test	O	NA	13.4.13	4.5.2
Tests marked “M” are mandatory. Tests marked “O” are optional and subject to contract agreement between the user and the supplier. Tests marked “NA” are not applicable.					
[a] The cyclic damp heat test is not applicable to class PC1, see 10.7, Table 9 — Protective coating classes.					

13.3.2 Conditions during testing

If not otherwise defined, tests in Table 11 shall be carried out at room temperature of +25 °C ± 10 °C.

A test specification shall define performance criteria for each test.

For type test, if the electronic equipment has a large number of ports, which are identical regarding the electronic circuit, then a representative number of ports shall be selected to simulate actual operating conditions and to ensure that all the different types of termination are considered. In that case, the technical justification of this reduction of tested ports shall be provided in the test specification.

13.4 Test specification

13.4.1 Visual inspection

The visual inspection verifies the mechanical, dimensional and appearance conformance of the electronic equipment; see 4.1.

The visual inspection shall be carried out before and after tests to check whether any damage or deterioration has occurred resulting from the tests.

13.4.2 Performance test

The performance test verifies that the functional requirements for the electronic equipment are fulfilled with the specified performance criteria (see 4.3).

The performance test is carried out according to the performance test specification and performance test procedure written by the supplier either for type test or for routine test.

The performance test shall be carried out at room temperature, see 13.3.2.

The performance test shall consist of a comprehensive series of measurements of the functional characteristics of the equipment to verify that its performance criteria are in accordance with the functional requirements of the concerned equipment, including any special requirements of its individual specification, and general requirements of this standard.

The performance test carried out during the type test may differ from the one carried out during the routine test.

13.4.3 DC Power supply test

13.4.3.1 General

The test verifies the performance of the electronic equipment connected to the battery voltage supply system, see 5.2.

To carry out the DC power supply tests, EN 61000-4-29 may be used as a guide. The rated voltage noted in EN 61000-4-29 has to be replaced by the nominal voltage.

If the electronic equipment has a large number of similar battery referenced I/O ports, which are electrically identical, then a sufficient number shall be selected to simulate actual operating conditions and to ensure that all the different types of termination are considered. In that case, the technical justification of this reduction of tested ports shall be provided in the test plan.

In all cases, the voltage and time duration of the test waveform shall be monitored at the input of the equipment during the test.

The rising/falling edge of the waveforms in the figures below are only indicative and can differ in detail.

13.4.3.2 Supply voltage variations

Tests shall be performed to prove correct functioning at nominal supply voltage and at the specified upper and lower voltage limits (see Table 4).

Tests shall be performed to prove correct functioning for the continuous supply voltage range between 0,7 U_n and 1,25 U_n.

13.4.3.3 Temporary supply overvoltages

Temporary supply overvoltages shall be assumed to be generated with respect to the system power supply return potential.

Electronic equipment shall be tested, for each duration (0,1 s and 1 s), with a sequence of 10 overvoltage events. The repetition time should be between 10 s minimum and 1 min maximum (between each test event). If the equipment needs more than 1 min recovery time between test events, this shall be justified in the test specification, noted in the test report and defined in the datasheet of the equipment.

Temporary supply overvoltages up to 1,4 U_n and not exceeding 0,1 s shall not cause deviation of function **(performance criterion A)**, see Figure 7.

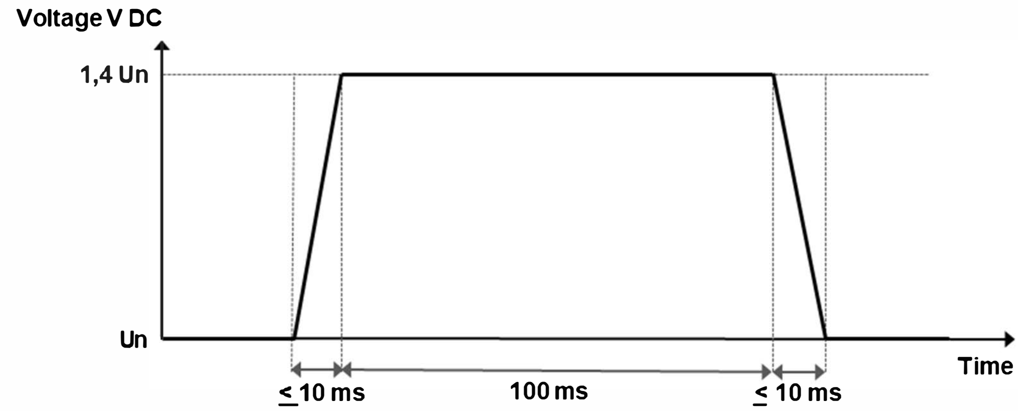


Figure 7 — Temporary supply overvoltages up to 0,1 s

Temporary supply overvoltages up to 1,4 U_n and not exceeding 1 s the equipment shall fulfil **performance criterion B**, see Figure 8.

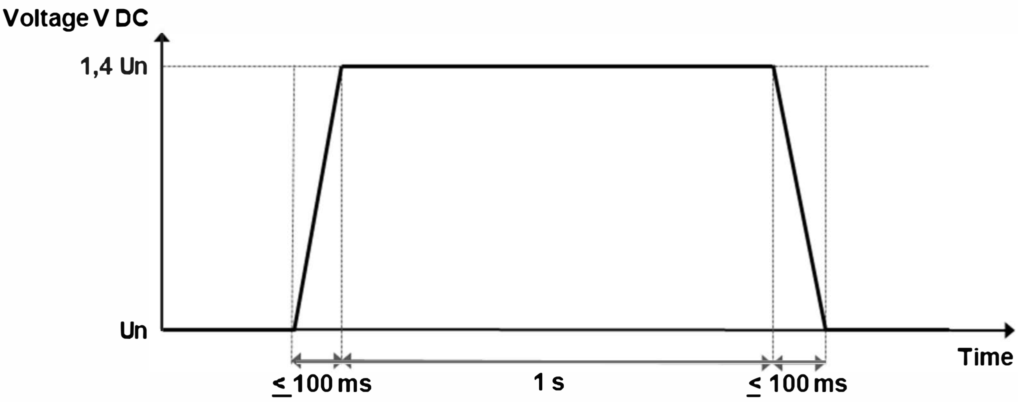


Figure 8 — Temporary supply overvoltages up to 1 s

If the equipment is specified for a wide input voltage range, temporary supply overvoltage shall be tested according to the highest specified nominal input voltage.

EXAMPLE 1 Equipment specified for a grouping of the nominal input voltages 24 V and 28 V: temporary supply overvoltage test is carried out at 28 V x 1,4 = 39,2 V.

EXAMPLE 2 Equipment specified for a grouping of the nominal input voltages from 48 V to 110 V: temporary supply overvoltage test is carried out at 110 V x 1,4 = 154 V.

13.4.3.4 Temporary supply undervoltage

Those tests cover requirements specified in 5.2.3 related to temporary supply undervoltage. Electronic equipment shall be tested, for the duration of 0,1 s, with a sequence of 10 undervoltage events. The repetition time should be between 10 s minimum and 1 min maximum (between each test event). If the equipment needs more than 1 min recovery time between test events, this shall be justified in the test specification, noted in the test report and defined in the datasheet of the equipment.

Temporary supply undervoltage down to 0,6 U_n and not exceeding 0,1 s shall not cause deviation of function **(performance criterion A)**, see Figure 9.

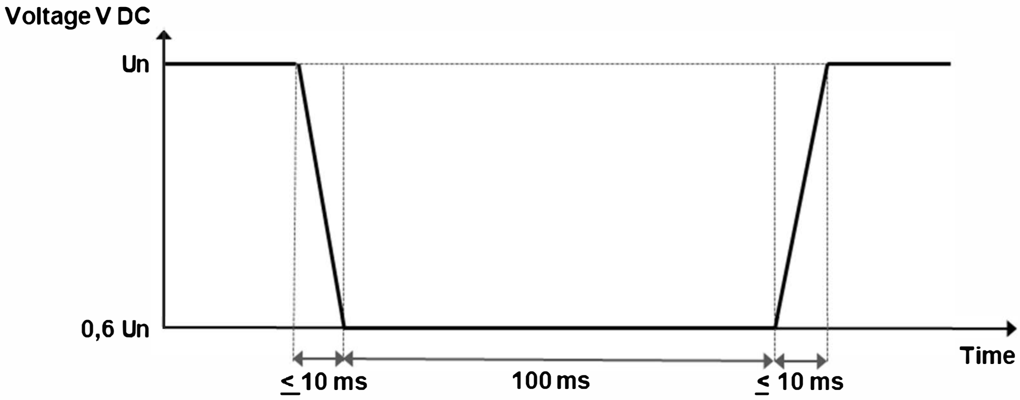


Figure 9 — Temporary supply undervoltage

If the equipment is specified for a wide input voltage range, temporary supply undervoltage shall be tested according to the lowest specified nominal input voltage.

EXAMPLE 1 Equipment specified for a grouping of the nominal input voltages 24 V and 28 V: temporary supply undervoltage test is carried out at 24 V x 0,6 = 14,4 V.

EXAMPLE 2 Equipment specified for a grouping of the nominal input voltages from 48 V to 110 V: temporary supply undervoltage test is carried out at 48 V x 0,6 = 28,8 V.

13.4.3.5 Interruptions of supply voltage

Possible causes of the physical phenomena and the supply voltage interruption classes are given in 5.2.4.

In order to realize the low impedance condition, a test generator shall be used which is able to supply both current directions (to source and sink current). Specific characteristics for the generator operating in "low impedance" conditions can be found in EN 61000-4-29.

To verify that performance criterion A is fulfilled, the maximum interruption time for the relevant class shall be applied. Electronic equipment shall be tested with a sequence of 10 interruption events.

The repetition time should be between 10 s minimum and 1 min maximum (between each test event).

If the equipment needs more than 1 min recovery time between test events, this shall be justified in the test specification, noted in the test report and defined in the datasheet of the equipment.

To verify that performance criterion C is fulfilled it is suggested to test with different interruption times greater than the time given in the relevant class.

Tests shall be carried out at nominal voltage and nominal load / operating conditions.

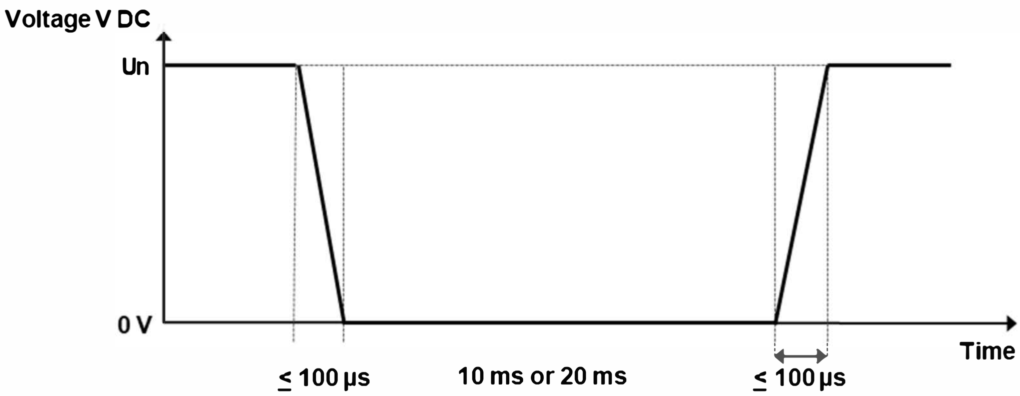


Figure 10 — Interruption of supply voltage

If the equipment is specified for a wide input voltage range, interruption of supply voltage shall be tested at the lowest specified nominal input voltage.

EXAMPLE 1 Equipment specified for a grouping of the nominal input voltages 24 V and 28 V: interruption test of supply voltage is carried out at 24 V.

EXAMPLE 2 Equipment specified for a grouping of the nominal input voltages from 48 V to 110 V: interruption test of supply voltage is carried out at 48 V.

13.4.3.6 Supply change-over

During supply change-over, the equipment shall operate satisfactorily under the conditions stated in 5.2.5.

The requirements and performance criteria are listed in Table 12:

Table 12 — Supply change-over classes

Class	Requirements	Performance criterion	Duration of supply undervoltage
C1	From U_n to 0,6 U_n and back to U_n (without interruptions)	A	100 ms (See Figure 11)
C2	During a supply break starting at U_n NOTE The supply break is an open circuit and not a short circuit (“High impedance” condition)	B	30 ms (See Figure 12)
In case of class C1, no additional test is required if the undervoltage test has passed.			

Electronic equipment shall be tested with a sequence of 10 change-over events.

The repetition time should be between 10 s minimum and 1 min maximum (between each test event).

If the equipment needs more than 1 min recovery time between test events, this shall be justified in the test specification, noted in the test report and defined in the datasheet of the equipment.

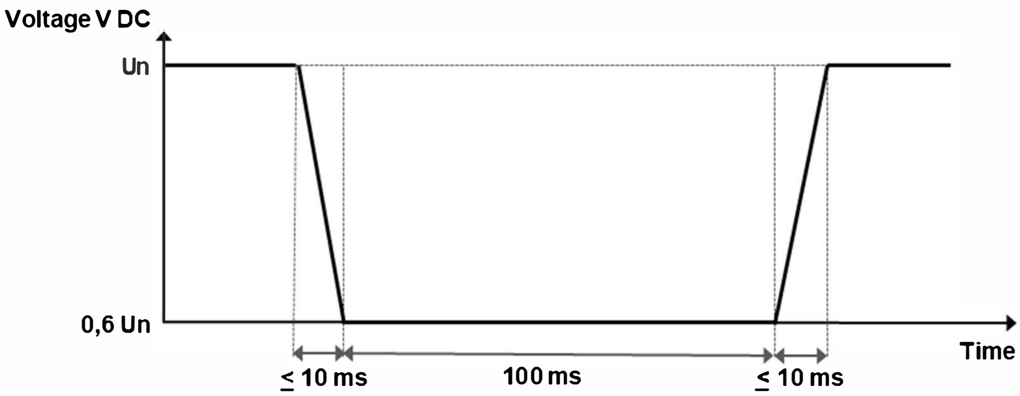


Figure 11 — Supply change-over Class C1

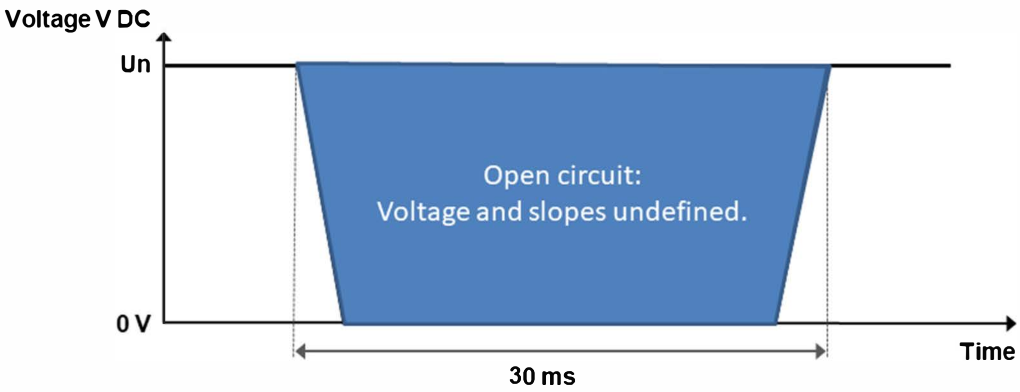


Figure 12 — Supply change-over Class C2

Tests shall be carried out at nominal load / operating conditions.

If equipment is specified for a wide input voltage range, supply change-over of voltage supply shall be tested at the lowest specified nominal input voltage, see examples in 13.4.3.5.

13.4.4 Low temperature test

This test shall be carried out in accordance with EN 60068-2-1:2007 (test Ad), using low-air velocity.

Equipment shall be tested according to its operating temperature class; low operating temperature (T_{TEST}) shall be taken from Table 1 of this standard.

After the initial performance test, the equipment is placed in a test chamber at room temperature (see 13.3.2), without any voltage applied.

After the chamber has cooled down, the equipment is thermally stabilized by leaving it for a sufficient period of time at test temperature (T_{TEST}).

In any case, the stabilization time period shall not be less than 2 h, see Figure 13.

At the end of this period the equipment shall be switched on and continuous operational checks shall be carried out, keeping the equipment at low temperature according to EN 60068-2-1:2007 not less than 30 min.

The continuous operational checks should also include some on/off cycles.

After the recovery period, the initial performance test shall be repeated.

Test acceptance requirements:

During and after the test, the equipment is checked and shall work as intended within its specified limits **(performance criterion A)**.

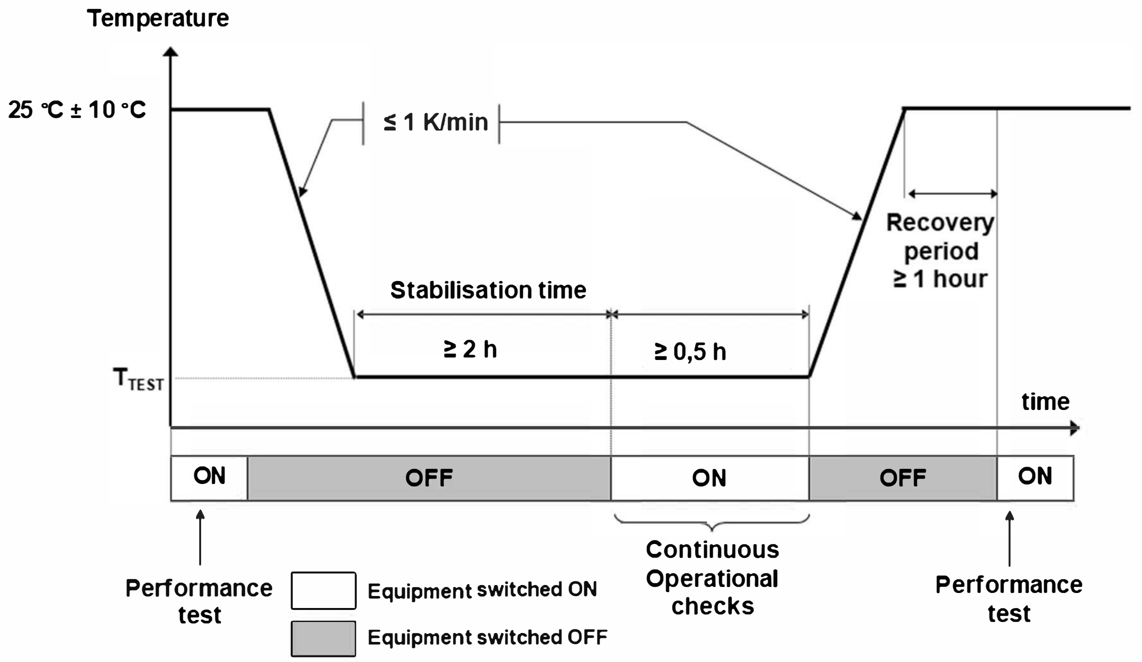


Figure 13 — Low temperature test

Equipment start-up condition shall be at its nominal voltage.

Equipment specified for a wide input voltage range shall be tested at the lowest specified nominal input voltage and at the highest nominal input voltage specified for this equipment.

Tests at lowest and highest nominal input voltage can be sequenced in a single cycle, providing that the stabilisation time and that the continuous operational checks time are respected at T_{TEST} temperature for both test voltages.

EXAMPLE 1 Equipment specified for a grouping of nominal input voltages from DC 72 V to DC 110 V: the low temperature test is carried out at DC 72 V and at DC 110 V.

EXAMPLE 2 Equipment specified for a grouping of nominal input voltages from DC 24 V to DC 72 V: the low temperature test is carried out at DC 24 V and at DC 72 V.

13.4.5 Dry heat test

13.4.5.1 General

This test shall be carried out in accordance with EN 60068-2-2:2007, (test Bd), using low-air velocity unless a different type of cooling is normally used for the equipment (internal or external cooling). In that case, the normal configuration of the equipment shall be replicated.

The temperature value for this test is:

— dependent on the operating temperature class (OTx);

— for cycle B and C dependent on the classes of increased operating temperature at switch-on (STx).

See Table 1 and Table 2 for details.

Equipment shall be tested at its rated voltage.

NOTE The rated voltage is representing the realistic situation during operation of the equipment and can cause more power dissipation than the nominal voltage.

Equipment specified for a wide input voltage range shall be tested at rated voltage corresponding to the lowest specified nominal input voltage and to the highest nominal input voltage specified for this equipment.

Tests at lowest and highest nominal input voltage can be sequenced in a single cycle, providing that the stabilisation time and that the continuous operational checks time are respected at T_{TEST} temperature for both test voltages.

EXAMPLE Equipment specified for a grouping of the nominal input voltages between DC 24 V and DC 110 V: the dry heat test is carried out at DC 24 V x 1,15 = DC 27,6 V and at DC 110 V x 1,15 = DC 126,5 V.

13.4.5.2 Dry heat thermal test — Cycle A

After the initial performance test, the switched off equipment is placed in a test chamber at room temperature which will be progressively raised to the maximum operating temperature (T_{TEST}) according to the selected temperature class (OTx), see Figure 14.

The temperature of the whole equipment (internal and external) shall be stabilized for a time of at least 2 h. Then the equipment is switched on and left in the test chamber for a minimum period of 6 h, in which operational checks shall be carried out at the maximum operating temperature (T_{TEST}).

The continuous operational checks should also include some on/off cycles.

The switched off equipment is then cooled down to room temperature and a further performance test shall be carried out after the stabilization time of at least one hour.

Test acceptance requirements*:*

During and after the test, the equipment shall work as intended within its specified limits **(performance criterion A)**.

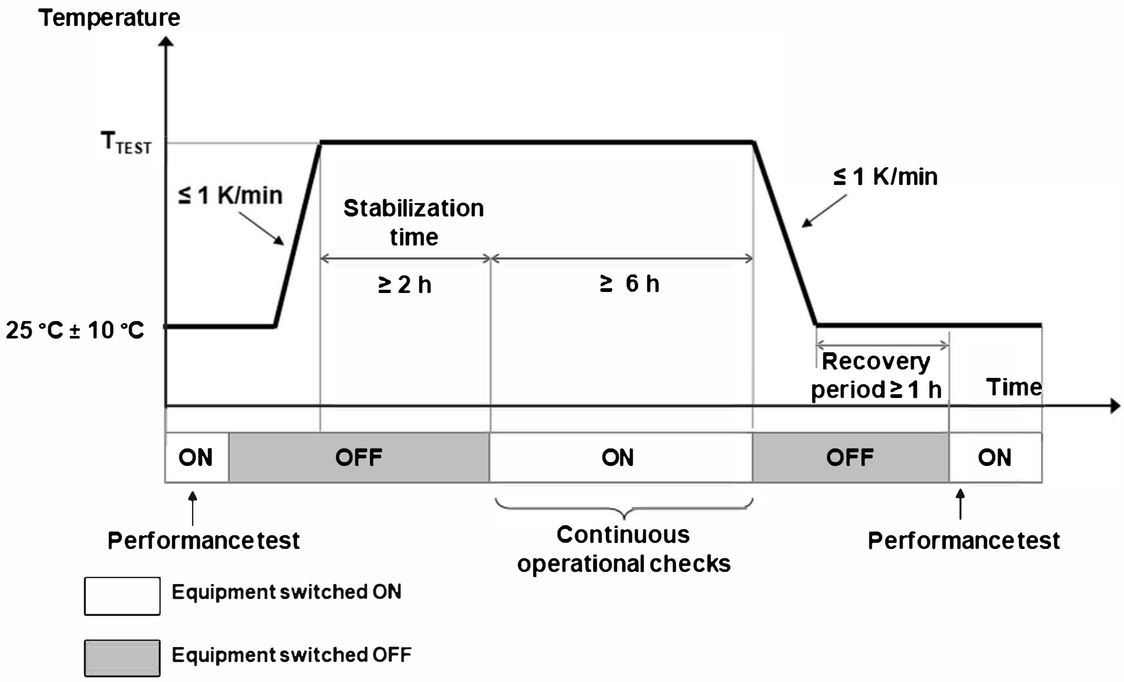


Figure 14 — Dry heat thermal test — Cycle A

13.4.5.3 Dry heat thermal test — Cycle B

After the initial performance test, the switched off equipment is placed in a test chamber at room temperature which will be progressively raised to the maximum operating temperature (T_{TEST}) according to the selected temperature class (OTx), see Figure 15.

The temperature of the whole equipment (internal and external) shall be stabilized for a time of at least 2 h. Then the equipment is switched on and left in the test chamber for a minimum period of 6 h, in which operational checks shall be carried out at the maximum operating temperature (T_{TEST}).

These continuous operational checks should also include some on/off cycles.

Once this test phase is complete, the equipment is switched off and operating temperature is gradually increased to the “Switch-on extended” operating temperature (T_{TEST}+15 °C). Then the equipment is switched on and additional start-up continuous operational checks shall be carried out.

This “Switch-on extended” operating temperature shall be maintained at least for 10 min (see Figure 15 for details).

The switched off equipment is then cooled down to room temperature and a further performance test shall be carried out after the stabilization time of at least one hour.

Test acceptance requirements:

During and after the test, the equipment shall work as intended within its specified limits **(performance criterion A)**.

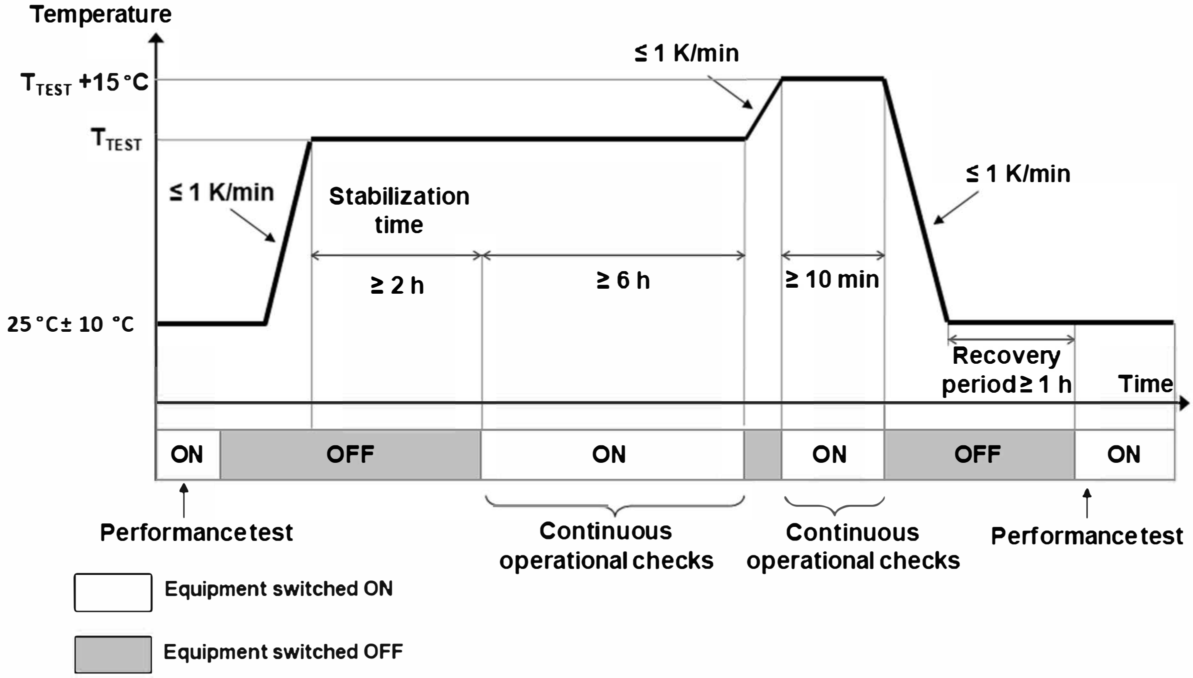


Figure 15 — Dry heat thermal test — Cycle B

13.4.5.4 Dry heat thermal test - Cycle C

After the initial performance test, the switched off equipment is placed in a test chamber at room temperature which will be progressively raised to the “Switch-on extended” operating temperature (T_{TEST} + 15°C) according to the selected temperature class (OTx), see Figure 16.

The temperature of the whole equipment (internal and external) shall be stabilized for a time of at least 2 h. Then the equipment is switched on.

The "Switch-on extended" operating temperature value shall be maintained for at least 10 min. Then, the equipment is gradually cooled down to the maximum continuous operating temperature (T_{TEST}) and maintained for at least 6 h. Operational checks shall be carried out over the whole switched ON time.

These continuous operational checks should also include some on/off cycles. The switched off equipment is then cooled down to room temperature and a further performance test shall be carried out after the stabilization time of at least one hour.

Test acceptance requirements:

During and after the test, the equipment shall work as intended within its specified limits **(performance criterion A)**.

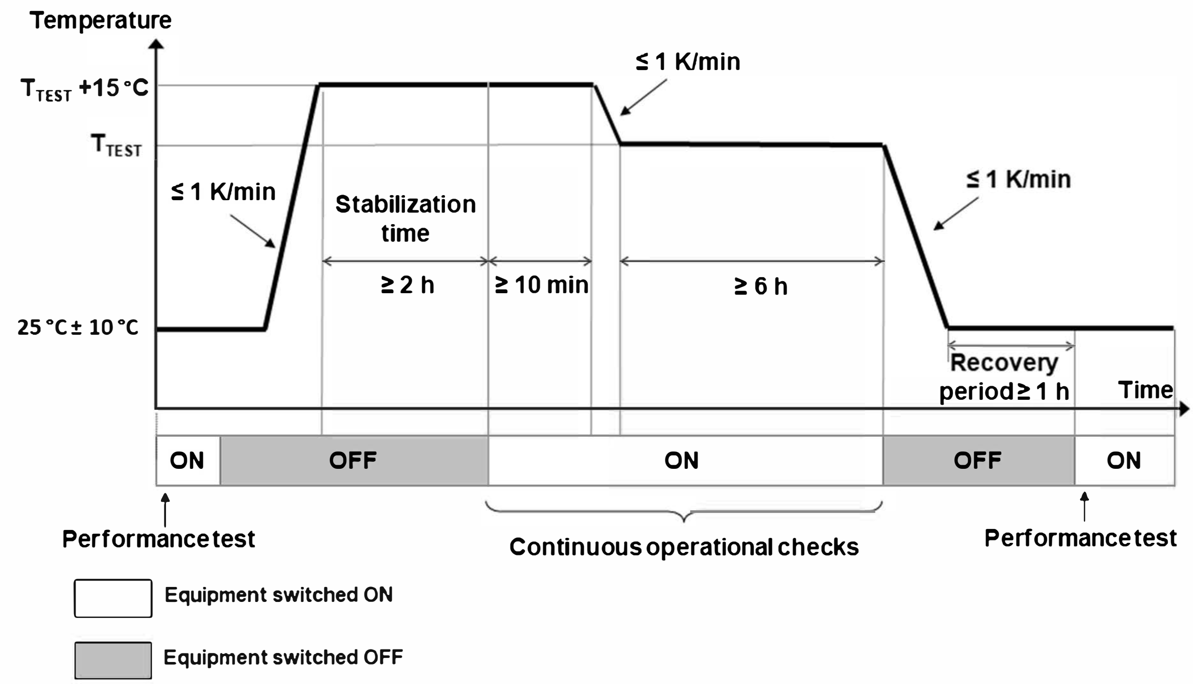


Figure 16 — Dry heat thermal test — Cycle C

13.4.6 Low temperature storage test

Where the equipment is to be exposed to temperatures less than its minimum operating temperature, then a low temperature storage test may be carried out. This test shall be carried out in accordance with EN 60068-2-1:2007 (test Ab).

Equipment without transportation packaging is placed, without any voltage applied, in a test chamber.

The temperature value for the test shall be −40 °C and the time period after stabilization shall be 16 h minimum.

After the recovery period, a performance test shall be carried out at room temperature.

Test acceptance requirements:

After the recovery period, the equipment shall work as intended within its specified limits **(performance criterion A)**.

13.4.7 Insulation test

13.4.7.1 General

The aim of this test (insulation resistance test and voltage withstand test) is to ensure that the mounted components, their metal connections and enclosures, and the routing of printed circuit board tracks and wires (if any), are not located too close to surrounding metal parts or fixings.

The test verifies that the design of circuits meets the requirements for galvanic isolation.

The test shall be carried out on fully assembled parts of equipment, and/or complete equipment dependent upon the scope of supply. For this test no alteration of the original equipment is permitted (e.g. component removal).

The insulation test consists of three parts:

- an insulation resistance test before the voltage withstand test;
- the voltage withstand test;
- an insulation resistance test after the voltage withstand test.

After the insulation test the equipment shall work as intended and within its specified limits. All measured values shall be recorded in the test report.

Where galvanic isolation is required, test voltages shall be applied between the two sides of the isolation barrier and the measured insulation resistance values shall be recorded.

Each equipotential area shall be defined and tested against functional earth and against all adjacent equipotential areas.

An equipotential area can be formed by ELV circuits that have internal electronic earth potential (0 V) electrically connected to the functional earth (see Annex K). In this case, insulation test against functional earth is not required.

The voltage withstand test procedure shall be arranged such that equipotential areas are subjected to the minimum number of applications of the dielectric test voltage.

The earth continuity shall be ensured for subracks and PBAs with exposed metal parts which can be touched.

13.4.7.2 Insulation resistance test

The insulation resistance test shall be carried out at DC 500 V and the resistance values shall be recorded for all the equipotential areas defined for the insulation test. During the test, the equipment shall not be powered on.

Test acceptance requirements:

For a single equipotential area on a fully assembled part of equipment (e.g. on a single PBA), the minimum value of the insulation resistance after the voltage withstand test shall be higher than 20 MΩ.

For assembled equipment (e.g. control electronics in traction converter), the minimum value of the insulation resistance of equipotential areas depends on the extent of the complete circuit. The insulation resistance at the interfaces to the vehicle shall be agreed between the involved parties.

In the case of high-impedance bleeder resistors between adjacent equipotential areas or between an equipotential area and functional earth, the effect of these resistors shall be deducted.

13.4.7.3 Voltage withstand test

The test shall be performed with AC test voltage (50 Hz or 60 Hz) according to Table 13. If not applicable (e.g. when EMC filter capacitors are mounted between active signals and functional earth) DC test voltage according to the same table shall be used.

Each equipotential area shall be defined and tested against functional earth and against all surrounding equipotential areas.

The test voltage shall be applied by gradually increasing the voltage amplitude to the test voltage (i.e. in more than 1 s), and maintained at the specified level for:

— Type test: 1 min;

— Routine test: 10 s.

For type test always the initial test voltage shall be applied.

For routine test, in case of repetition of the voltage withstand test during the life cycle of the same equipment, the test voltage may be reduced to 80 % of the initial test voltage to avoid pre-damages by partial discharges. For the same reason, if the same electronic equipment integrated into a subsystem is used, it may be disconnected or removed from the subsystem during the voltage withstand routine test or type test carried on this subsystem.

During the test, the equipment shall not be powered on.

An insulation resistance test shall be carried out before and after the voltage withstand test. Significant differences in the results shall be analysed and justified in the test report.

The nominal battery voltage and/or I/O voltage of each equipotential area define the test voltage according to Table 13.

For equipment powered by voltage not covered by this standard, see the applicable standards (e.g. EN 61287-1, EN 60077-1).

The test shall be applied to all insulated ports including power supply, I/O-ports and communication ports.

Table 13 — Test voltages of voltage withstand test

Nominal battery voltage and/or I/O voltage	Test voltage
< DC 72 V or AC 50 V_{RMS}	AC 500 V or DC 750 V
DC 72 V ≤ DC V < DC 125 V or from AC 50 to 90 V_{RMS}	AC 1 000 V or DC 1 500 V
DC 125 V ≤ DC V < DC 315 V or from AC 90 to 225 V_{RMS}	AC 1 500 V or DC 2 200 V

Where part of the electronic equipment is galvanically connected to a power circuit, then this part of the equipment shall be subject to the same dielectric tests as that circuit.

Attention is drawn to the fact that for battery referenced ports, a higher impulse withstand voltage is applicable, in respect of EN 50121-3-2:2016 surge requirements.

Test acceptance requirements:

Neither disruptive discharge nor flashover shall occur.

13.4.8 Cyclic damp heat test

This test shall be carried out in accordance with EN 60068-2-30:2005 (test Db variant 2); see Figure 17 and Figure 18.

During the 2 cycles of the test, the equipment under test shall not be powered except during the operational check at the beginning of the 2nd cycle.

Temperatures:	+ 55 °C and + 25 °C
Number of cycles:	2 (breathing effect)
Time:	2 × 24 h

Initial measurement:

- a performance test shall be carried out.

Intermediate measurements:

- at the rise of temperature during the beginning of the 2nd cycle (see Figure 17), during the appearance of condensation on the equipment at 35 °C ± 2 °C, the equipment is temporarily switched ON under nominal voltage and continuous operational checks shall be carried out for a minimum time of 5 min.

At the beginning of the second cycle, if condensation has not occurred (low thermal inertia of equipment) or is not visible, the speed of temperature variation should be increased, but not exceed 1 K/min, at a constant relative humidity level.

Return to room temperature is carried out under controlled recovery conditions.

Check and final measurements:

— continuous operational checks shall be performed at the end of the recovery period, the equipment is switched on and maintained under nominal voltage for the subsequent measurements;

— insulation test shall be performed when equipment is dry (absence of liquid water at the surface of the equipment and associated PBAs), which may take more than 30 min;

— performance test.

Test acceptance requirements:

The results of the insulation test, the performance tests and operational checks obtained after the first and second cycles shall be within the specified tolerances and the specified operation performance, respectively.

During all ON-phases and after the complete test, the equipment shall work as intended and within its specified limits **(performance criterion A)**.

Equipment start-up condition shall be at its nominal voltage.

Equipment specified for a wide input voltage range shall be tested at the highest nominal input voltage specified for this equipment.

EXAMPLE 1 Equipment specified for a wide input voltage range DC 72 V – DC 110 V: the cyclic damp heat operational check and performance tests are carried out at DC 110 V.

EXAMPLE 2 Equipment specified for a wide input voltage range DC 24 V – DC 72 V: the cyclic damp heat operational check and performance tests are carried out at DC 72 V.

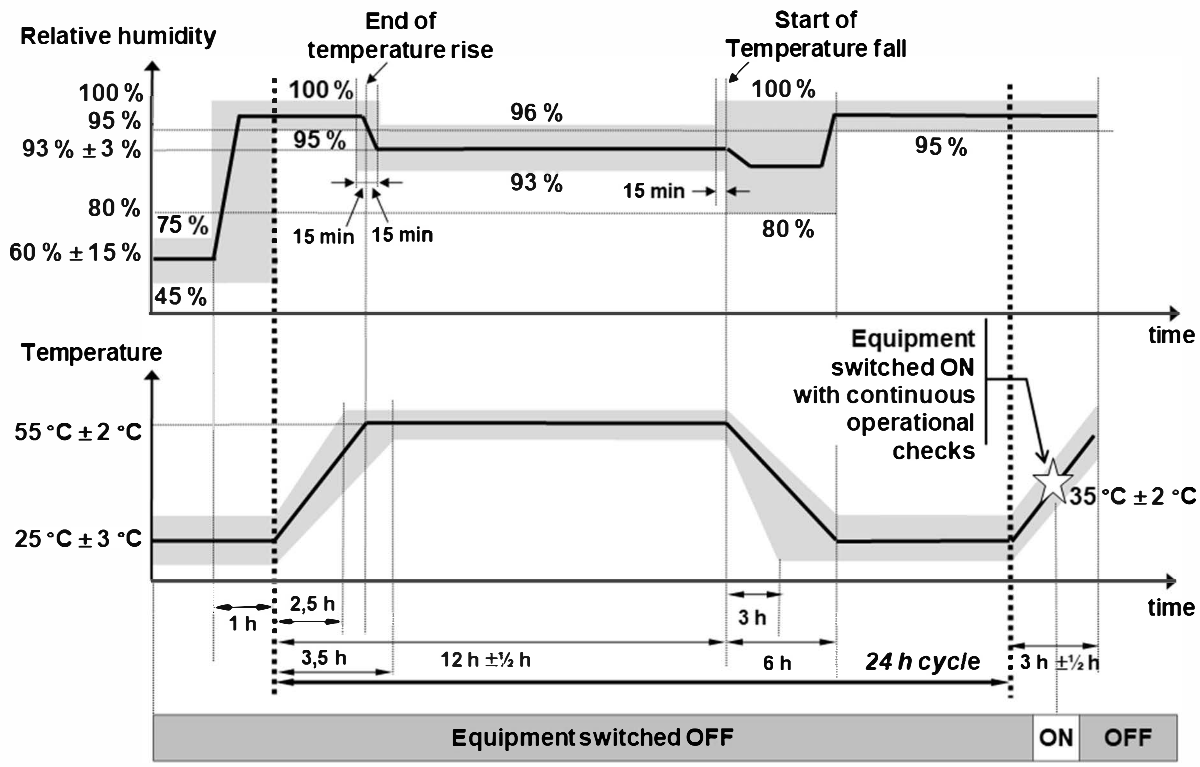


Figure 17 — Cyclic damp heat test: 1st and begin of 2nd 24-h cycle

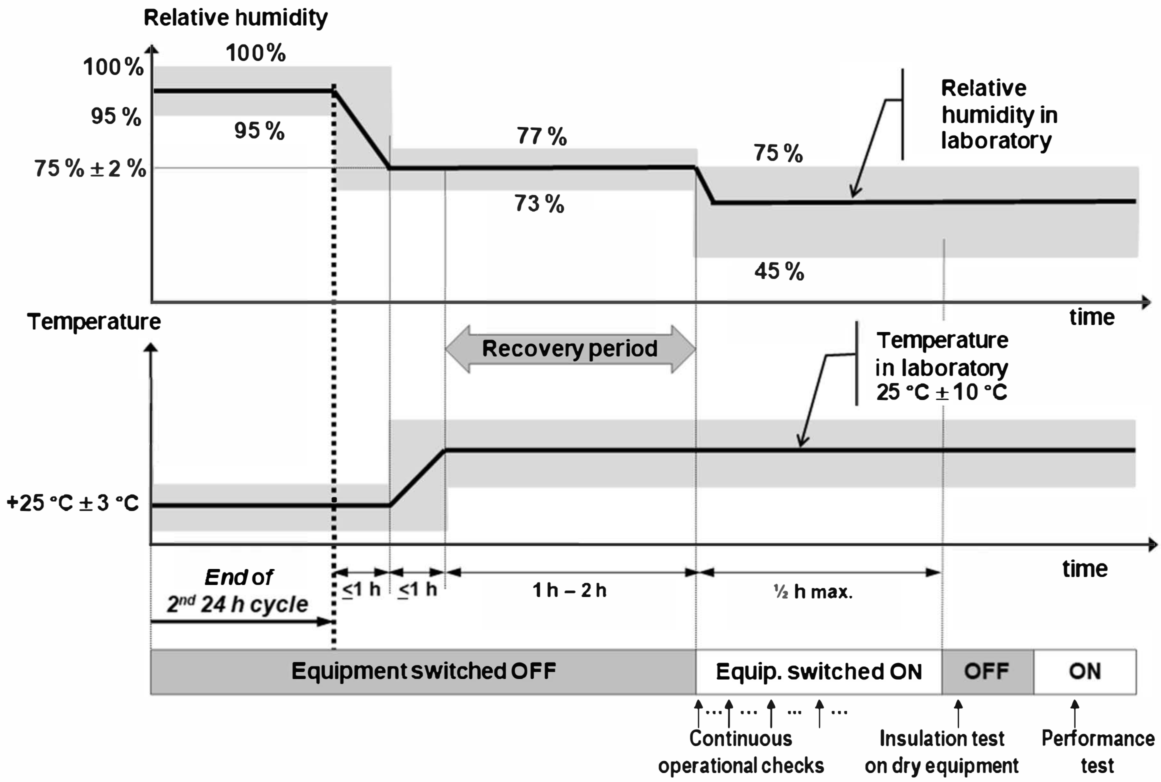


Figure 18 — Cyclic damp heat test: End of 2nd cycle and recovery period

NOTE Figure 17 and Figure 18 are taken from EN 60068-2-30:2005, Test Db, Variant 2, added by “Equipment switched ON/OFF” and the different types of tests to be established.

13.4.9 Electromagnetic compatibility test

All EMC tests of the electronic equipment shall be carried out according EN 50121-3-2:2016.

13.4.10 Shock and vibration test

13.4.10.1 General

This test shall be carried out in accordance with EN 61373:2010.

For the test the equipment shall be placed in conditions representative of its use and with the orientation and associated equipment parts recommended by the supplier for its operation (e.g. cabinet and / or complete chassis, auxiliary and mounting accessories, including its damping devices, if any, and with mated connectors as used in normal operation).

During testing (with the exception of simulated endurance tests), the equipment shall be functional, and its performance monitored.

13.4.10.2 Simulated long life testing

During the simulated long life testing the equipment shall not be powered.

Test shall be carried out according to EN 61373:2010, Clause 9.

Test acceptance requirements:

— no damage shall be visible after the test;

— after the test, the equipment shall work as intended and within its specified limits.

13.4.10.3 Shock testing

Test shall be carried out according to EN 61373:2010, Clause 10.

Half-sinusoidal shocks test shall be carried out on a powered functional equipment.

Test acceptance requirements:

— no damage shall occur during the test;

— during the test, the equipment is monitored and shall work as intended within its specified limits. (**performance criterion A**).

13.4.10.4 Functional random vibration test

Test shall be carried out according to EN 61373:2010, Clause 8 on a powered functional equipment.

Test acceptance requirements:

— no damage shall be visible after the test;

— during the test, operational checks shall be carried out and the equipment shall work as intended within its specified limits (**performance criterion A**).

Equipment specified for a wide input voltage range may be tested at only one of the nominal input voltages which shall be specified in the test specification.

13.4.10.5 Enclosure protection test (IP code)

As electronic equipment is generally mounted either inside the body of the vehicle or in enclosures outside (e.g. location 1, 2 and 3 according to Table C.1), there is no need to carry out enclosure protection tests. Exceptional cases shall be agreed between the involved parties (EN 60529 may be used as a guide).

13.4.11 Stress screening test

The user may require an equipment stress screening test procedure to be applied to the completed equipment or a part of it, for the purpose of eliminating dormant manufacturing or component defects.

The test specification may include:

— operation at elevated temperature;

— thermal cycling;

— vibration.

The process and the tests to be applied to the equipment under consideration shall be agreed between the involved parties at tender stage.

To carry out this stress screening test, EN 61163-1 may be used as a guide.

13.4.12 Rapid temperature variation test

This optional test is intended for electronic equipment mounted outside the vehicle (e.g. location 4, 5, 6 and 7 according to Table C.1). In this case, the rapid temperature variation test should be carried out according to the requirements of class H2 of Table 3. The equipment shall be tested in representative condition (e.g. mounted in its enclosure). This test is not applicable for equipment inside closed containers or housings where this rapid temperature changes cannot happen.

The test specification and the test procedure shall be agreed between the involved parties, EN 60068-2-14 may be used as a guide.

13.4.13 Salt mist test

This test shall be carried out in accordance with EN IEC 60068-2-11:2021, test Ka.

Equipment is placed, without any voltage applied, in a test chamber.

The equipment should be tested in the manner in which it is expected to be used, i.e. with protective covers and enclosure. The equipment should be mounted, as nearly as possible, in the position it will occupy in its normal operating conditions.

The test chamber shall be kept closed and spraying of the salt solution shall continue without interruption during the whole conditioning period of 48 h. After the recovery period, a performance test is carried out.

Test acceptance requirements:

— visual inspection with criteria specified in the type test specification;

— after the test a performance test shall not show any failure or damage. The equipment shall work as intended and within its specified limits.

Annex A
(informative)

List of default requirements of EN 50155 and related subclauses

The following list summarizes the default requirements given in the main body of the standard:

NOTE The default requirements of this standard regarding environmental conditions (e.g. temperature, shock and vibration) are selected taking into account the locations 1 and 2 of Figure C.1.

Table A.1 — Default requirements

Subclause	Title	Default requirements
4.4.1	Altitude	Unless otherwise specified, the requirements of EN 50125-1:2014, Table 1, class A1 apply.
4.4.2	Operating Temperature	Unless otherwise specified, the requirements of class OT3 apply.
4.4.3	Increased operating temperature at switch-on	Unless otherwise specified, the requirements of class ST1 apply.
4.4.4	Rapid temperature variations	Unless otherwise specified, the requirements of class H1 apply.
4.4.5	Shock and vibration	Unless otherwise specified, the requirements of category 1 class B of EN 61373:2010 apply.
5.2.4	Interruption of supply voltage	• Unless otherwise specified, the requirements of class S2 apply. • Unless otherwise specified, the requirements for interruption of supply voltage apply to the power supply input ports only.
5.2.5	Supply change-over	• Unless otherwise specified, the requirements of class C1 apply. • Unless otherwise specified, the requirements for interruption of supply voltage apply to the power supply input ports only.
6.2	Useful life	Unless otherwise specified, the life class L4 applies.
7.2.1	Insulation coordination	• Unless otherwise specified, the pollution degree PD2 of the EN 50124-1:2017 applies. • Unless otherwise specified, only the insulation tests (13.4.7) of this standard shall be applied.
10.2.5	Integrated circuit sockets and edge connectors	Unless otherwise specified, class K2 applies.
10.7	Protective coatings for printed board assemblies	Unless otherwise specified, the requirements of class PC2 apply.
12.7.8.3	User Programmable Integrated Circuits (UPIC, e.g. FPGA, PLD, ASIC)	Unless otherwise specified, the requirements of class M0 apply.

Annex B
(informative)

System testing approach

B.1 General

This annex describes the structure and methodology for the verification of equipment by the system integrator at system level.

The design, documentation and tests requirements are detailed in Clauses 7, 12 and 13 of this document. The types of proof are undertaken in the equipment life cycle as follows, see Table B.1 .

Table B.1 — Types of proof

No.	Type of proof
1	Item level
2	Equipment level
3	Vehicle level
4	Equipment re-verification and item / ancillary component replacement.

No. 1 is performed on newly manufactured items.

No. 2 and 3 are performed on all equipment in accordance with the scope of this document. The types of proof to be carried out primarily deal with system level requirements and are not a repetition of the details at item level.

No. 4 might become necessary e.g. after a long production stop or redevelopment of functionally similar device in case of obsolescence of components.

B.2 Situation of applicability

The testing stages described in this document apply in case of:

— Item integration into equipment;

— Equipment installation into vehicle;

— Equipment periodic re-verification;

— Item / ancillary component replacement.

B.3 General methodology

B.3.1 General

The demonstration that the requirements are fulfilled can be done by the following procedures, see Table B.2 and Table B.3.

Table B.2 — Procedures for integration / installation

Procedure	Type of proof		Remark
A		design review	
B	Item	type test	
C		routine test	
D		design review	
E	*Item integration into equipment*	type test	= Equipment type test
F		routine test	
G		design review	
H	Equipment installation into vehicle	type test	
I		routine test	
NOTE	For the equipment intended for type test, the routine test is performed before the type test.		

Table B.3 — Procedures for re-verification and replacement

Procedure	Type of proof
J	Equipment periodical re-verification
K	System items / ancillary component replacement

Table B.2 illustrates as an example the possible procedures of integration.

Table B.3 illustrates as an example the possible procedures of re-verification and replacement

B.3.2 Item specific procedures

Procedures from A) to C) are listed in logical order and are used at item level.

At the stage of delivery, the manufacturer of an item should have demonstrated that all requirements are addressed:

— the results of the item type test report that the item is operating according to the specified functional requirements;

— the results of the item routine test report that the item is ready to be brought into use.

A test specification for the item (see Table 11) should list all the tests. The test procedures should be written by the supplier. During the type tests and routine tests, the item should operate as specified.

B.3.3 Equipment specific steps

Procedures from D) to I) are listed in logical order and apply at system level. They may be carried out in the same testing environment.

After completing the steps E and F, the equipment can be installed into rolling stock, taking into account the installation requirements. If the equipment is not a customized solution intended for a special rolling stock environment, it can be used for the installation on different vehicle types.

The procedures J) and K) address re-verification and an item/component replacement.

All items forming a specific equipment type should have passed the appropriate type tests.

The system integrator at equipment level (integration) or vehicle level (installation) should demonstrate that he has addressed all requirements and he should provide the following:

a) at integration stage of the items into the equipment:

(an) item type test report(s) or/and an item integration test report according to the type test procedure to demonstrate that all the items forming a specific equipment when integrated together are operating in accordance with the specified functional requirements, see 4.1;

b) at installation stage of the equipment into a vehicle:

an equipment type test report or/and an equipment installation test report according to the installation test procedure to confirm that the installed equipment is operating in accordance with the specified functional requirements.

The test specification listing all the tests to be performed on the electronic equipment and their procedures should be written by the integrator.

During the type tests and routine tests, the item should not malfunction or produce a performance which is outside its specification.

B.4 Equipment integration design review

The integration design review demonstrates that all the items of a specific equipment type used to form an equipment are able to be brought together correctly in accordance with an equipment design, and when integrated together provide the intended functionality in accordance with this standard and the equipment specification.

B.5 Equipment integration type test

The integration type test demonstrates that all the items of a specific equipment type when integrated together are functioning as intended in accordance with this standard and the equipment specification.

B.6 Equipment installation design review

The installation design review assesses the compatibility between a specific equipment type and a vehicle type, so that its functionality is maintained when installed on-board.

B.7 Equipment installation type test

The installation type test demonstrates that the equipment type, when installed on-board on the vehicle type, is functioning as intended in accordance with this standard and the equipment specification.

B.8 Equipment installation routine test

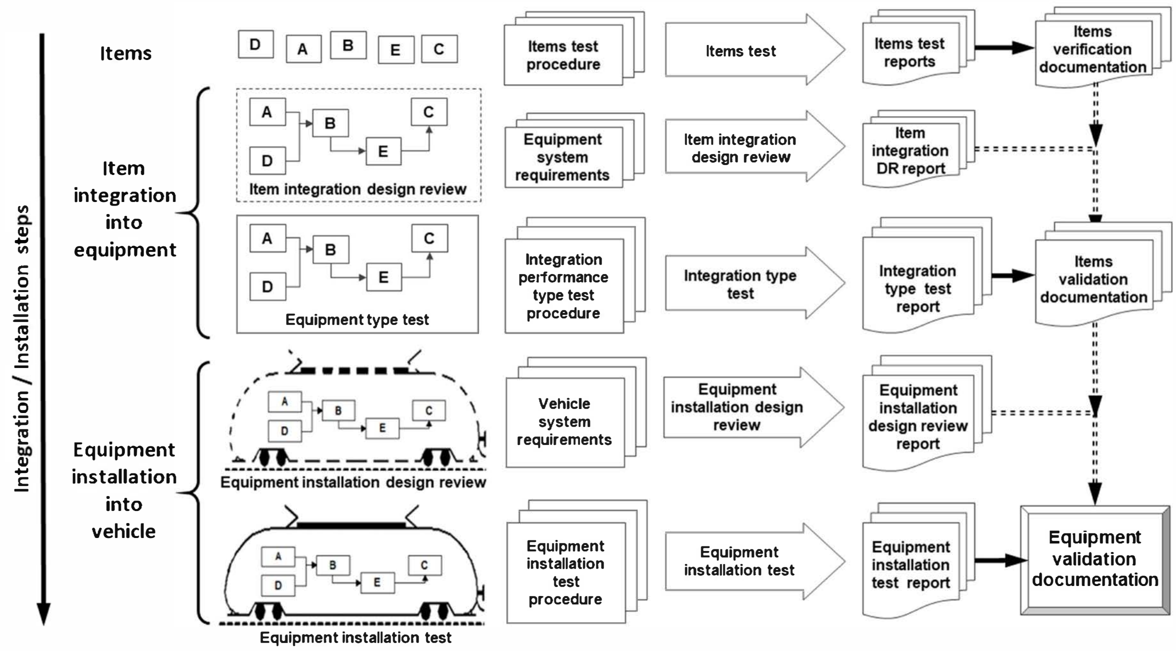
The installation routine test demonstrates that the properties of the equipment are ensured for each installation on vehicles of the same type.

B.9 Equipment periodic re-verification

The equipment periodic re-verification activities are used to demonstrate that the equipment in-service still fulfils the functional requirements. To verify this, not only functional tests, but also measurements might be necessary.

B.10 Replacement of items and ancillary components

If an item / ancillary component of an in-service equipment is replaced, the substitution procedure ensures that the equipment conformity assessment remains valid and the equipment can continue to be used.



NOTE The capital letters A, B, C, D and E identify functional items only.

Figure B.1 — Integration / Installation steps

Annex C
(informative)

Severity level of service conditions in different vehicle locations

C.1 General

This annex provides guidance to select the requirements for equipment installed in different location on-board of rolling stock.

C.2 Severity of service conditions in different rolling stock types

Different rolling stock types (e.g. mass transit underground, mass transit and high speed for passenger trains, freight trains) can lead to specific service conditions.

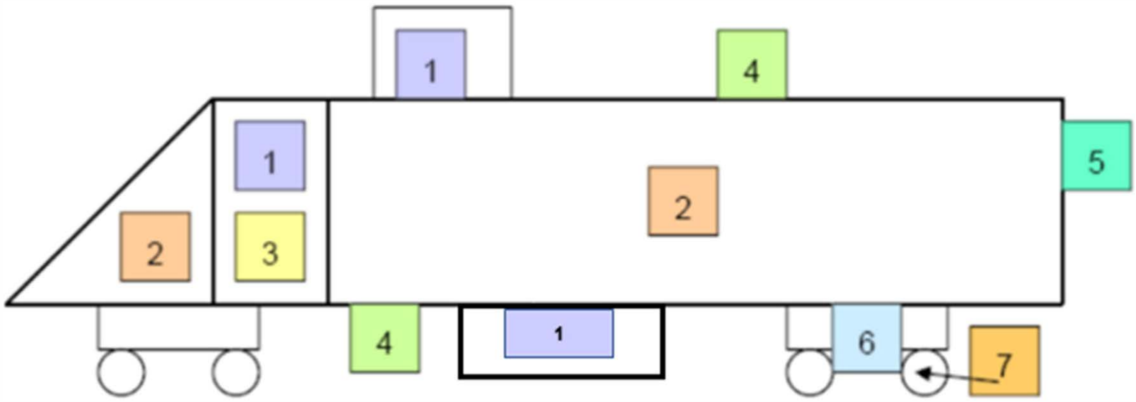
C.3 Intended use of rolling stock

The intended use of rolling stock depends on its geographical destination and whether it is operated underground or above ground. The specific conditions for the equipment can differ as a result of the intended use (e.g. rapid temperature variations at exit of/entrance into long tunnels, bogie mounted).

C.4 Location of equipment on-board rolling stock

The typical location of equipment and examples of consequences on requirements is shown in Figure C.1 and Table C.1 .

Design and testing constraints for equipment are directly related to the location on-board rolling stock.



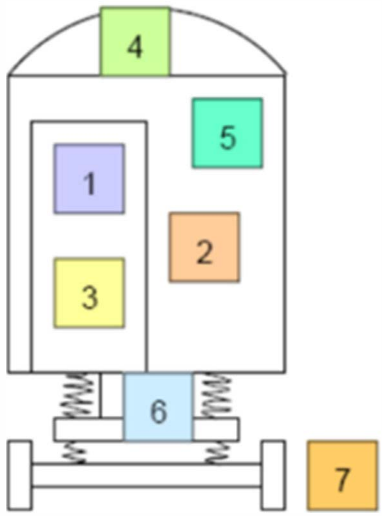


Figure C.1 — Typical equipment locations on-board rolling stock

Table C.1 — Example of typical equipment locations on-board rolling stock

Location according to Figure C.1	Definition	Examples	Examples of consequences on requirements
1	closed electrical operating area	interior vehicle cubicle (weather-protected) exterior vehicle cubicle (weather-protected) either under-frame or upper-roof	Operating temperatures and/or shock levels depending on the location of the installation.
2	cabin and interiors	passenger vehicle compartment and driver cabin	Air with low dust and chemical contamination

Location according to Figure C.1	Definition	Examples	Examples of consequences on requirements
3	closed electrical operating area; forced filtered ventilation with outside air	machinery compartment	- higher operating temperature in case of engine/power converter compartment; - resistance to fuels and fluids
4	outdoor static applications	under carbody, roof (non-weather-protected locations)	non weather-protected location higher IP code - resistance to light (UV) - resistance to ozone also for rubber and plastic parts
5	outdoor dynamic applications	inter-vehicle	non weather-protected location higher IP code - resistance to light (UV) - resistance to ozone also for rubber and plastic parts - higher mechanical resistance
6	outdoor highly dynamic applications	bogie	non weather-protected location higher IP code - resistance to light (UV) - resistance to ozone also for rubber and plastic parts - higher mechanical resistance - high shock and vibration constraints - resistance to fuel and fluids
7	outdoor highly dynamic applications	axles	non weather-protected location higher IP code - resistance to light (UV) - resistance to ozone also for rubber and plastic parts - higher mechanical resistance - very high shock and vibration constraints - resistance to fuels and fluids

C.5 Severity of the service conditions in different rolling stock locations

The severity of the service conditions in different rolling stock locations may lead to different environmental requirements (e.g. temperature, shock and vibration, pollution degree).

Example for vibration and pollution degree. In the case of electronic equipment incorporating a PBA to be installed on location 7 of Figure C.1, the shock and vibration to be considered could be category 3 according EN 61373:2010 and the pollution degree could be PD4 according EN 50124-1:2017.

Example for temperature: In the case of electronic equipment incorporating a PBA (see the top of Figure C.2), the temperature class OT3 (Table 1) is specified for the integration of the equipment (with PBA inside its enclosure) into a vehicle cabinet (Location 1, Figure C.1). The temperature class OT5 (Table 1) is specified for the single PBA inside the electronic enclosure (taking into account a temperature rise of 15 °C inside its enclosure).

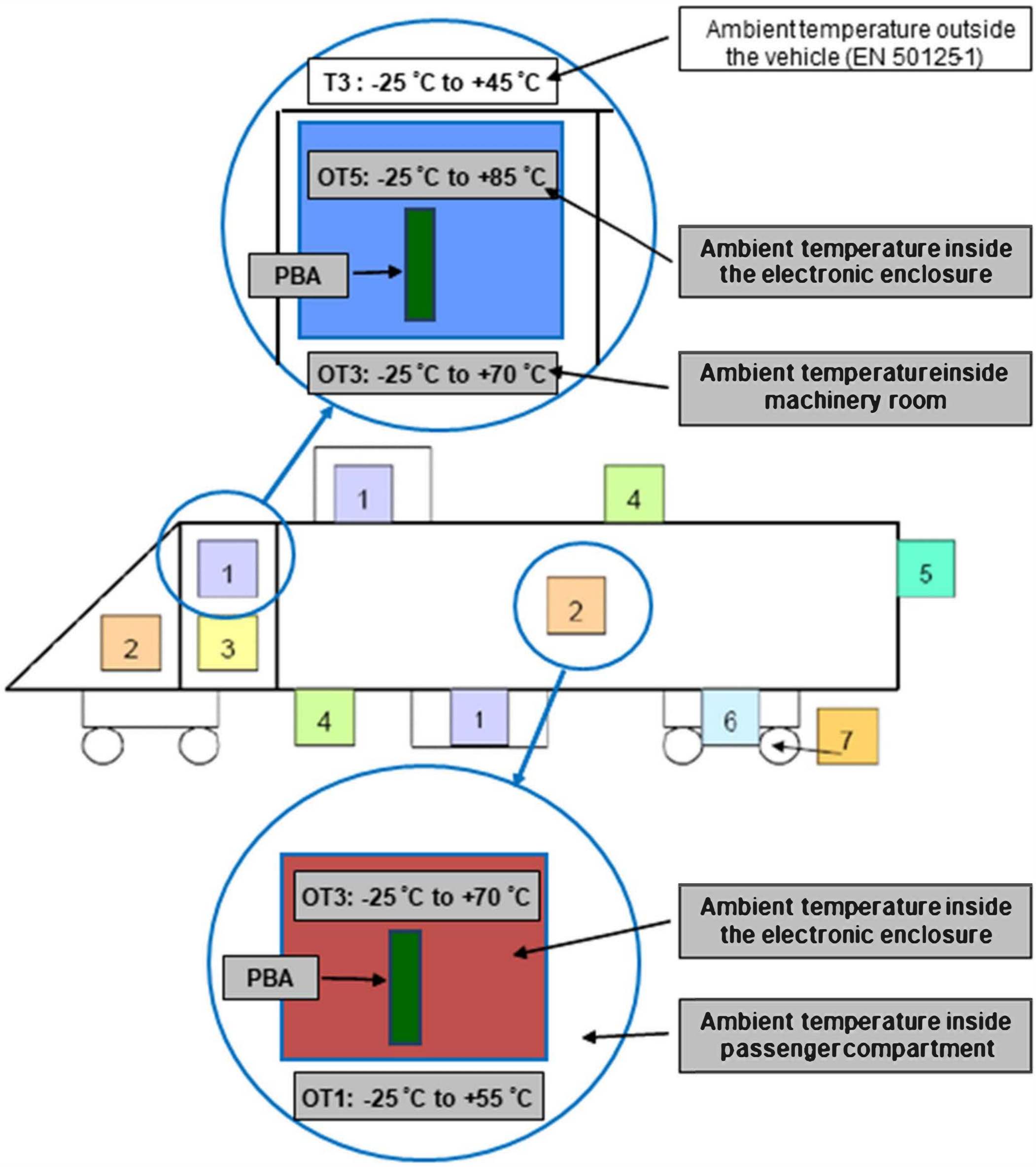


Figure C.2 — Integration of the equipment into the vehicle

In Figure C.2 , the indicated temperatures inside vehicle and cubicle are values measured in free air away from the heat emitting elements.

If the equipment is to be installed in a controlled climatic environment, a narrow temperature range may be sufficient, provided that the unit does not need to be operated outside these conditions.

Electronic equipment should be thermally designed in such a way to ensure reliable functionalities within its entire operating temperature range. The reliability of the components is very sensitive to their ambient temperature.

For peripheral units (e.g. measuring transducers), or if the equipment is in a decentralized configuration, each unit/item might have different ambient temperature requirements to be respected.

Annex D
(informative)

Example for a summary of equipment type test compliance

The Table D.1 below is only an example for fictive equipment, not a template. The content of this table (particularly the columns "Type" and "Routine") should be adapted for each real equipment.

Table D.1 — Summary of equipment type test compliance (example)

Performed test	**Type**	**Routine**	**Subclause**	**Referenced standard (to be completed with date) or specification with applied class and acceptance criteria**
Visual inspection	Yes	Yes	13.4.1	According to the routine and type test specification
Performance test	Yes	Yes	13.4.2	According to the performance test specification and performance test procedure.
DC Power supply test	Yes	No	13.4.3	Test is performed in accordance with EN 50155 — Supply Voltage: 0,7 U_n to 1,25 U_n continuous, Criterion A; — Supply voltage: 0,6 U_n to 1,40 U_n 100 ms, Criterion A; — Supply voltage: 1,25 U_n to 1,40 U_n 1 sec, Criterion B; — Interruption test 10 ms (Class S2). Low supply impedance, Criterion A.
Low temperature test	Yes	No	13.4.4	Test is performed in accordance with EN 60068-2-1:2007 (test Ad), using natural ventilation — Class OT4 -40 °C, Criterion A.
Dry heat test	Yes	No	13.4.5	Test is performed in accordance with EN 50155 and EN 60068-2-2:2007 (Test Bd) — Cycle C - Class OT4 - ST2 +85 °C (10 min) +70 °C (6 h) Criterion A.
Low temperature storage test	Yes	No	13.4.6	Test is performed in accordance with EN 60068-2-1:2007 — Test Ab at -40 °C Criterion A.

Performed test	Type	Routine	Subclause	Referenced standard (to be completed with date) or specification with applied class and acceptance criteria
Insulation test	Yes	Yes	13.4.7	Test is performed in accordance with EN 50155 — Insulation resistance measurement between equipotential areas is carried out at 500 V DC, Criterion: Resistance ≥ 20 MΩ; — Voltage withstand test is carried out at DC 750 V for signal working voltage < 72 V and DC 1 500 V for signal working voltage ≥ DC 72V and < DC 125 V, (during 1 min in type test or 10 sec in Routine test) Criterion: No disruptive discharge. — Second Insulation resistance measurement between equipotential areas is carried out at 500 V DC, Criterion: Resistance ≥ 20 MΩ.
Cyclic damp heat test	Yes	No	13.4.8	Test is performed in accordance with EN 60068-2-30:2005 — Test Db - 2 cycles, each 24 h, — Criterion A.
EMC test	Yes	No	13.4.9	Test is performed in accordance with EN 50121-3-2:2016 The manufacturer should provide a type test summary which lists all tests performed to the equipment with: — Name of the tests performed, — Test conditions, — Acceptance criteria.
Shock and vibration test	Yes	No	13.4.10	Test is performed in accordance with EN 61373: 2010 for category 1 Class B
Enclosure protection test (IP code)	No	No	13.4.10.5	Not applicable
Stress screening test	No	Yes	13.4.11	Thermal cycles are applied with: — Duration: 8 h, — 2 cycles -25 °C to 70 °C, — Powered equipment, — Criterion A.

Performed test	Type	Routine	Subclause	Referenced standard (to be completed with date) or specification with applied class and acceptance criteria
Salt mist test	Yes	No	13.4.13	Test is performed in accordance with EN IEC 60068-2-11:2021 — Test Ka, — 48 h. — Criterion: visual inspection and performance test.

Annex E
(informative)

User programmable integrated circuit life cycle example

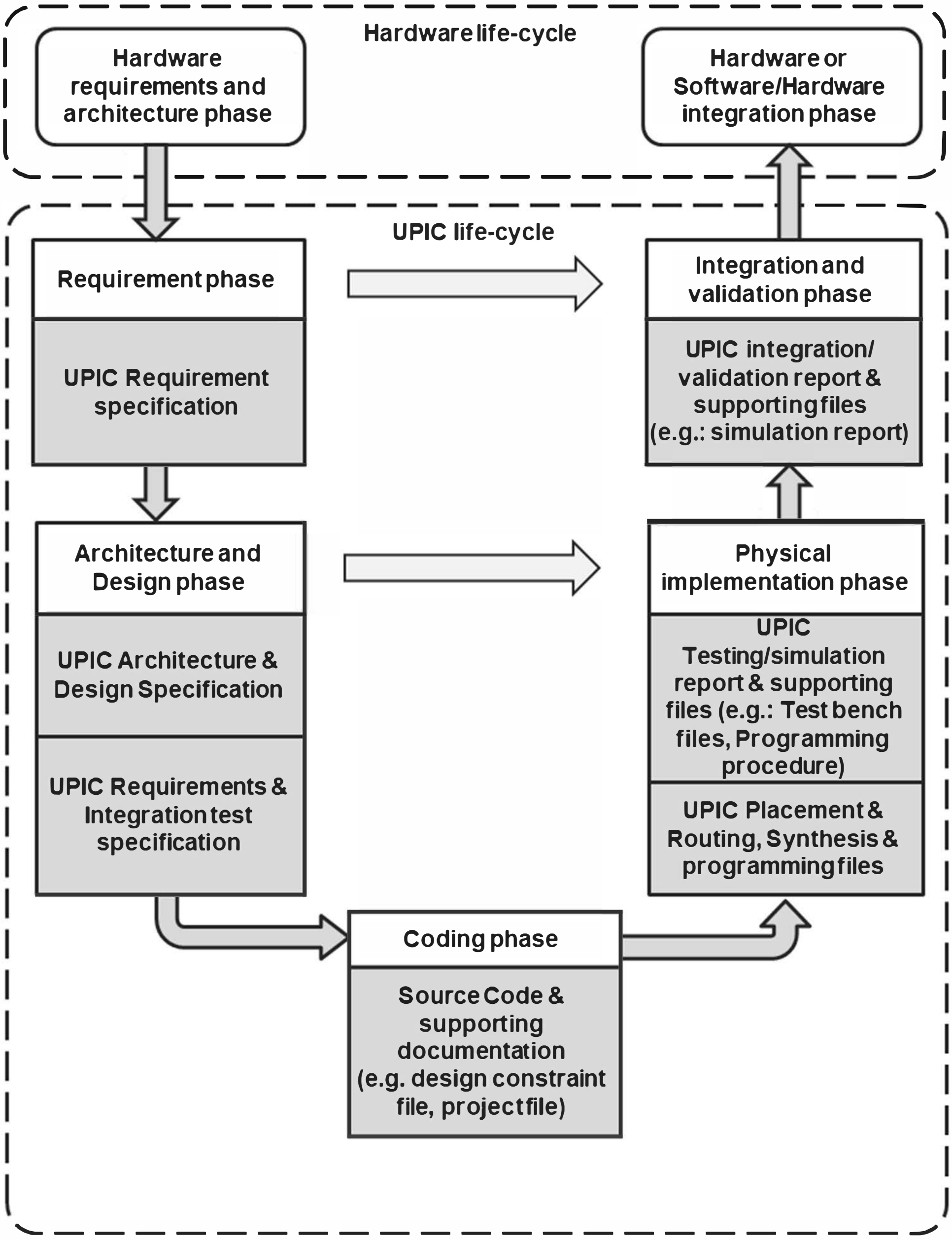


Figure E.1 — User programmable integrated circuit life cycle example

Annex F
(informative)

Design suggestions for electronic hardware used on rolling stock

F.1 Purpose of this annex

These design suggestions are intended to support the designer of electronic hardware by the development of durable and robust electronic equipment to be used on-board of rolling stock.

This annex considers neither newer component technology nor newer assembly technology. It focusses on simple components.

This annex is not intended to be used as requirement specification.

F.2 Design topics

F.2.1 Pollutants

The needs arising from the presence of contaminants should be kept in mind in the design of the devices and/or equipment.

The type and concentration of pollutants (atmospheric and non-atmospheric) are shown in Table F.1 below in accordance with to EN 50125–1:2014.

Table F.1 — Type and concentration of pollutants

Pollutants	CLASS according EN 60721-3-5:1997
Chemically active substances	5C2
Fluids	5F2 - 5F3 in accordance with applicability
Biologically active substances (including leaves, grass, pollen, insects, fibres, etc.)	5B2
Dust	5S2 Dust granulometry: from 80 µm to 200 µm = 10 % by weight; from 0 µm to 80 µm = 90 % by weight. NB: in case of moisture, dust can become conductive due to the presence of metal particles and carbon.
Stones from the ballast	max 15 mm diameter

This table does not take into account the reduction of pollutions in internal installation of cubicles or enclosures surrounding PBAs. Also, special conditions (e.g. presence of sand, saline atmospheres) are not covered.

F.2.2 Methods against ageing regarding energetic transient pulses

Transient pulses can occur which might cause ageing of the equipment over time. Ageing is not covered by the EMC tests given in EN 50121-3-2.

To ensure sufficient lifetime for battery referenced ports against ageing effects of energetic transient pulses the following design rules are given:

Ports with small current and power dissipation (e.g. signal- and control inputs): If a voltage limiting device is used (like clamping diode or transient voltage suppressor diode), use series resistor(s) in front of the voltage limiting device. This resistor will limit the current in the case of transient pulses. It should be suitable for 2 kV maximum pulse voltage. This can be achieved alternatively by a series circuit of more resistors each with rated voltage less than 2 kV.

Ports not suited for series resistor(s) (e.g. power supply ports, ports with high current or ports not suited for a voltage drop by a series resistor): use voltage suppressor elements with high energy absorption capability.

Transient voltage suppressors can only be used between the poles of the power supply referenced ports in differential mode on battery referenced ports (I/O or supply voltage). Transient voltage suppressors cannot be recommended in common mode between battery referenced signals and earth in order to ensure the correct high dielectric insulation between those potentials. The rated voltage of the input components should be chosen to withstand the maximum clamping voltage of the transient voltage suppressor.

The general problem with the dimensioning of suppressor elements is that real pulse shapes, energy and frequency of occurrence are not known exactly in the development state of a product. Thus, careful design with sufficient margin to low impedance energetic transient pulses is strongly recommended. Furthermore, suppressor elements with sufficient energy absorption capability are necessary, especially, if a series limiting current component (like a resistor) cannot be used.

In this context, ageing of varistors is a common problem of inadequate circuit design, which consequently leads to a failure of the equipment. Careful design with sufficient severity level to the varistors maximum limits is necessary. Another disadvantage is that the maximum clamping voltage is significantly higher than the nominal voltage of varistors. Thus, the voltage level of the components should be designed in such a way that it withstands the maximum clamping voltage of a varistor.

Therefore, instead of varistors the use of transient voltage suppressor diodes is suggested. Their clamping voltage is much lower, and there is no ageing. For some time, also transient voltage suppressor diodes with high energy absorption rates have been available (for example 30kW), which do not need a current limiting component (like a resistor).

Voltage limiting components connected to the vehicle earth should be avoided because they can cause the following problems:

— uncontrolled capacitance to earth;

— earth fault detection systems of floating battery voltage supply system can fail.

In case of extended vehicle cabling of the battery voltage supply system high transient voltages can occur against earth.

F.2.3 Capacitors to earth

It is common to indicate earth faults on floating battery voltage supply systems by electronic detection systems. Many capacitors to earth lead to high capacitance between floating battery voltage supply systems and earth (carbody).

Such high capacitance can cause the failure of the earth fault detection systems. The use of Y – capacitors at digital I/O ports should be avoided. If this is not possible, they should be designed in accordance with EN 60384-14 (recommended class Y1 or Y2) and their capacitance value should not exceed 10 nF. Higher capacitance values are subject to agreement between manufacturer and system integrator.

F.2.4 Inside cabling for equipment

The feed and the return cables of a circuit should be laid as close together as practicable, in particular in the case of power cables emitting disturbances, and sensitive signal cables. Twisted cables or cores should be used for this purpose, where available and practicable, see also EN 50343.

For EMC measures for cabling see EN 50343.

F.2.5 Earth configuration

The equipment should operate correctly in systems with one of the battery poles earthed or with the battery isolated from earth.

F.2.6 Prototype testing

“Prototype testing”, performed according to the type test specification, are recommended on a prototype equipment for new design verification purposes or can be performed on a modified serial equipment in case of design modification of an equipment.

Those tests are valid as design qualification tests or as investigation tests, however they cannot be used to produce a “type test report”, because the “prototype equipment” is not representative of a serial equipment manufactured according to a given manufacturing procedure.

F.2.7 Interfacing

Analogue and digital interfaces of electronic equipment should be galvanically isolated from their internal earth reference. If the interfaces are not galvanically isolated, they should be of differential type in order to ensure adequate common-mode noise rejection.

The internal 0V reference of the electronic equipment should itself be galvanically isolated from the battery voltage supply of the equipment.

F.2.8 Solder joint on PBA

Except for admitted tolerances for certain components in railway applications (see derating factor “R" in the following Table F.2 to Table F.19), the following recommendation should be applied:

PCB surface temperature at solder joints, which can be caused by thermal power dissipation of components, should not exceed 110°C. Otherwise grain coarsening and mechanical stress can damage the solder joints.

F.2.9 Derating

The derating of a component is the limitation of the thermal shocks and electrical stresses at levels below the maximum level specified by the supplier. Its purpose is to reduce the rate of degradation and herewith prolong the operational life of the component.

Derating increases the margin of safety between the level of operating stress and that envisaged by the supplier, reducing the failure rate of the component and providing additional protection from system anomalies not foreseen by the designer. Derating also reduces the changes in the values and parameters of components that might occur during the operational life cycle due to ageing. The circuits should be specified so that such changes do not affect the declared performance and proper operation of the equipment.

Combined effects of all the tolerances, initial and those caused by ageing, inside a single component and between the various components should be taken into account during the design process. All worst-case combinations, caused by the environmental and operating conditions as well as by the dispersion of component properties, should be considered.

Statistical hypotheses based on the fact that only certain combinations of tolerances might take place unless the parameters considered are invariably interdependent are not allowed.

The WORST-CASE design is to be applied both as regards the level of stress to which the components can be subjected and as regards the correct operation of the equipment.

Derating should be applied to all components of an equipment in accordance with values given in Table F.2 to Table F.19 . The loading rates listed below represent the maximum stress values recommended and do not preclude performing a further derating.

If the supplier uses derating factors (R) higher than the maximum ones specified below, he should verify that the equipment meets all its requirements, particularly with regard to the reliability and life of the components.

The designer of the equipment should size the components, in consideration of the worst operating conditions under which the component might be used in the railway environment.

The most important stress factors to be considered are temperature, voltage, current, power, vibrations, etc.

Temperature stress should be reduced as much as possible while ensuring good thermal conduction to the heat sinks and placing the temperature-sensitive components away from heat sources. The designer should carefully evaluate and document the thermal resistances and the consequent performance downgrading. This should be done in respect to the nominal ratings of the components on the basis of the ventilation and dissipation conditions of any heatsinks.

The electrical stresses, such as voltage, should be calculated including the highest transients expected during operation.

Derating factors have to be defined (and justified) by the designer by taking into account for each component its special conditions of use. (e.g. component technology, environmental conditions, mounting location).

This annex considers neither newer component technology nor newer assembly technology. It focusses on simple components.

The values in the tables are examples of typical use and can vary (significantly) from design to design.

This annex is not intended to be used as requirement specification.

Table F.2 — Suggested derating factor (R) for wire-wound resistors

WIRE-WOUND RESISTORS	R
$R = \dfrac{\text{ACTUAL POWER DISSIPATION}}{\text{RATED POWER DISSIPATION AT } 25\,°\text{C}}$	≤ 0,22
$R = \dfrac{\text{ACTUAL WORKING VOLTAGE}}{\text{RATED WORKING VOLTAGE}}$	≤ 0,75
HOT SPOT TEMPERATURE AT HIGHEST AMBIENT TEMPERATURE	< 120 °C

Table F.3 — Suggested derating factor (R) for metal film and thin film resistors and networks

METAL FILM RESISTORS AND THIN FILM RESISTORS AND NETWORKS	R
$R = \dfrac{\text{ACTUAL POWER DISSIPATION}}{\text{RATED POWER DISSIPATION AT } 70\,°\text{C}}$	< 0,8 according to mounting and cooling conditions
$R = \dfrac{\text{ACTUAL WORKING VOLTAGE}}{\text{RATED WORKING VOLTAGE}}$	≤ 0,75
SURFACE TEMPERATURE AT HIGHEST AMBIENT TEMPERATURE	< 120 °C

Table F.4 — Suggested derating factor (R) for carbon and thick film resistors and networks

CARBON RESISTORS / THICK FILM RESISTORS AND NETWORKS	R
$R = \frac{\text{ACTUAL POWER DISSIPATION}}{\text{RATED POWER DISSIPATION AT 70 °C}}$ REMARK: This depends on the mounting and the temperature of the solder joints and the surface temperature of the PCB	≤ 0,25 for SMD (small pads) ≤ 0,5 for THT
$R = \frac{\text{ACTUAL WORKING VOLTAGE}}{\text{RATED WORKING VOLTAGE}}$	≤ 0,75
SURFACE TEMPERATURE AT HIGHEST AMBIENT TEMPERATURE	< 100 °C

Table F.5 — Suggested derating factor (R) for capacitors with liquid electrolyte

ALUMINIUM CAPACITORS WITH LIQUID ELECTROLYTE	R
$R = \frac{\text{ACTUAL WORKING VOLTAGE}}{\text{RATED WORKING VOLTAGE}}$	Rmax = 0,8 Rmin = 0,3
$R = \frac{\text{ACTUAL WORKING CURRENT}}{\text{SPECIFIED WORKING CURRENT AT 100 °C}}$	≤ 0,7
USE DEVICES WITH AN OPERATING LIFE AT 105 °C OF AT LEAST	5 000 h

Table F.6 — Suggested derating factor (R) for tantalum electrolytic capacitors

SOLID TANTALUM ELECTROLYTIC CAPACITORS	R
$R = \frac{\text{ACTUAL WORKING VOLTAGE}}{\text{RATED WORKING VOLTAGE AT 85 °C}}$	≤ 0,5
$R = \frac{\text{ACTUAL WORKING CURRENT}}{\text{RATED WORKING CURRENT AT 85 °C}}$	≤ 0,7
MINIMUM TEMPERATURE DIFFERENTIAL BETWEEN MAXIMUM RATED TEMPERATURE AND ACTUAL HOT SPOT TEMPERATURE AT HIGHEST AMBIENT TEMPERATURE	30 °C
MAXIMUM TEMPERATURE RISE	5 K
REMARKS: This kind of capacitor should be used with a series resistance of at least 1 Ω/V. Do not use more than two capacitors in parallel of the same capacity without series resistor. Do not use one tantalum and one electrolytic capacitor in parallel without series resistor. Avoid the use of tantalum capacitors as far as possible.	

Table F.7 — Suggested derating factor (R) for film capacitors

FILM CAPACITORS	R
$R = \frac{\text{ACTUAL WORKING VOLTAGE}}{\text{RATED WORKING VOLTAGE AT} 105\,°\text{C}}$	≤ 0,5
$R = \frac{\text{ACTUAL WORKING CURRENT}}{\text{RATED WORKING CURRENT AT} 105\,°\text{C}}$	≤ 0,7
MINIMUM TEMPERATURE DIFFERENTIAL BETWEEN MAXIMUM RATED TEMPERATURE AND ACTUAL HOT SPOT TEMPERATURE AT HIGHEST AMBIENT TEMPERATURE	10 K
MAXIMUM TEMPERATURE RISE for high temperature capacitors in resonant converters	5 K 20 K
REMARKS: Excessive voltage derating is not recommended for metallized film capacitors. Applied voltage should be sufficiently high (0,1 V or greater) and circuit series resistance sufficiently low (1 kΩ or less) to support self-healing phenomenon. There are also types of film capacitors with advanced temperature range (like PPS capacitors), which allow higher temperature rises	

Table F.8 — Suggested derating factor (R) for ceramic capacitors

CERAMIC CAPACITORS	R
$R = \frac{\text{ACTUAL WORKING VOLTAGE}}{\text{RATED WORKING VOLTAGE}}$	≤ 0,7
$R = \frac{\text{ACTUAL WORKING CURRENT}}{\text{SPECIFIED WORKING CURRENT AT} 105\,°\text{C}}$	≤ 0,7
MAXIMUM TEMPERATURE RISE	10 K

Table F.9 — Suggested derating factor (R) for mica and glass capacitors

MICA AND GLASS CAPACITORS	R
$R = \frac{\text{ACTUAL WORKING VOLTAGE}}{\text{RATED WORKING VOLTAGE}}$	≤ 0,25
$R = \frac{\text{ACTUAL WORKING CURRENT}}{\text{SPECIFIED WORKING CURRENT AT} 100\,°\text{C}}$	≤ 0,7
MAXIMUM TEMPERATURE RISE	5 K
REMARK: Components with glass bodies are problematic because of mismatch of their thermal coefficient of expansion with that of the PCB ➔ danger of cracks.	

Table F.10 — Suggested derating factor (R) for rectifying, switching and signal diodes

CTIFYING, SWITCHING AND SIGNAL DIODES	**R**
$R = \dfrac{\text{ACTUAL MEAN OPERATING CURRENT}}{\text{RATED MEAN OPERATING CURRENT AT } 25\,^\circ\text{C}}$. For power diode	≤ 0,35 ≤ 0,5
$R = \dfrac{\text{ACTUAL PEAK INVERSE VOLTAGE}}{\text{RATED PEAK INVERSE VOLTAGE}}$	≤ 0,75
MINIMUM TEMPERATURE DIFFERENTIAL BETWEEN MAXIMUM RATED JUNCTION TEMPERATURE AND ACTUAL JUNCTION TEMPERATURE	25 K

Table F.11 — Suggested derating factor (R) for Zener / transient suppressor diodes

ZENER / TRANSIENT SUPPRESSOR DIODE	**R**
$R = \dfrac{\text{ACTUAL MEAN OPERATING POWER}}{\text{RATED MEAN OPERATING POWER AT } 25\,^\circ\text{C}}$ For power Zener:	≤ 0,35 ≤ 0,5
MINIMUM TEMPERATURE DIFFERENTIAL BETWEEN MAXIMUM RATED JUNCTION TEMPERATURE AND ACTUAL JUNCTION TEMPERATURE AT HIGHEST AMBIENT TEMPERATURE	25 K

Table F.12 — Suggested derating factor (R) for thyristor / IGBT

THYRISTORS / IGBT	**R**
$R = \dfrac{\text{ACTUAL MEAN OPERATING CURRENT}}{\text{RATED MEAN OPERATING CURRENT AT } 25\,^\circ\text{C}}$	≤ 0,15
$R = \dfrac{\text{ACTUAL PEAK INVERSE VOLTAGE}}{\text{RATED PEAK INVERSE VOLTAGE}}$	≤ 0,75
$R = \dfrac{\text{ACTUAL dI / dt}}{\text{RATED dI / dt}}$	≤ 0,5
$R = \dfrac{\text{ACTUAL dV / dt}}{\text{RATED dV / dt}}$	≤ 0,5
MINIMUM TEMPERATURE DIFFERENTIAL BETWEEN MAXIMUM RATED JUNCTION TEMPERATURE AND ACTUAL JUNCTION TEMPERATURE AT HIGHEST AMBIENT TEMPERATURE	25 K

Table F.13 — Suggested derating factor (R) for light emitting diodes

LIGHT EMITTING DIODES	R
$R = \dfrac{\text{ACTUAL MEAN OPERATING CURRENT}}{\text{RATED MEAN OPERATING CURRENT AT } 25\,°\text{C}}$	≤ 0,33
If a failure of the LED causes only loss of visual information	≤ 0,5
MINIMUM TEMPERATURE DIFFERENTIAL BETWEEN MAXIMUM RATED JUNCTION TEMPERATURE AND ACTUAL JUNCTION TEMPERATURE	25 K
If a failure of the LED causes only loss of visual information REMARK: Power LED application (e.g. for illumination) might be subjected to other dimensioning.	≤ 10 K

Table F.14 — Suggested derating factor (R) for transistors and MOSFET

TRANSISTORS and MOSFET	R
$R = \dfrac{\text{ACTUAL MEAN OPERATING POWER}}{\text{RATED MEAN OPERATING POWER AT } 25\,°\text{C}}$ For power transistor	≤ 0,15 ≤ 0,2
$R = \dfrac{\text{ACTUAL PEAK OPERATING CURRENT}}{\text{RATED PEAK OPERATING CURRENT AT } 25\,°\text{C}}$	≤ 0,5
$R = \dfrac{\text{ACTUAL PEAK OPERATING VOLTAGE}}{\text{RATED PEAK OPERATING VOLTAGE}}$	≤ 0,75
MINIMUM TEMPERATURE DIFFERENTIAL BETWEEN MAXIMUM RATED JUNCTION TEMPERATURE AND ACTUAL JUNCTION TEMPERATURE	25 K
REMARKS: The above given values are derived from classic through-feed technology. Surface Mounted Device technology, depending on the cooling situation (e.g. ground planes or high density of heat dissipating components in the vicinity), might lead to other dimensioning. To verify this situation, an infrared camera is useful. The operating point should fall within the safe operating area (including second breakdown) calculated at actual junction temperature with a safety margin not less than 20 % for worst-case circuit operating conditions.	

Table F.15 — Suggested derating factor (R) for linear integrated circuits

LINEAR INTEGRATED CIRCUITS	R
$R = \dfrac{\text{ACTUAL MAX OUTPUT CURRENT}}{\text{RATED OUTPUT CURRENT AT}85°\text{C}}$	≤ 0,8
$R = \dfrac{\text{ACTUAL MEAN POWER DISSIPATION}}{\text{RATED MEAN POWER DISSIPATION AT}85°\text{C}}$	≤ 0,8
$R = \dfrac{\text{GAIN, GBWP, CMRR, ETC. TO BE USED IN DESIGN CALCULATION}}{\text{RATED VALUES OVER TEMPERATURE RANGE}}$	= 0,85
$R = \dfrac{\text{LEAKAGE CURRENTS, OFFSET, ETC. TO BE USED IN DESIGN CALCULATION}}{\text{RATED VALUES OVER TEMPERATURE RANGE}}$	= 1,25
MINIMUM TEMPERATURE DIFFERENTIAL BETWEEN MAXIMUM RATED JUNCTION TEMPERATURE AND ACTUAL JUNCTION TEMPERATURE AT HIGHEST AMBIENT TEMPERATURE	25 K

Table F.16 — Suggested derating factor (R) for optocouplers

OPTOCOUPLERS	R
$R = \dfrac{\text{ACTUAL MAXIMUM SUPPLY VOLTAGE}}{\text{RATED MAXIMUM SUPPLY VOLTAGE}}$ Except for devices with a fixed supply voltage (e.g. 5V ± 5 %)	≤ 0,8
$R = \dfrac{\text{ACTUAL MAX OUTPUT CURRENT}}{\text{RATED OUTPUT CURRENT AT}85°\text{C}}$	≤ 0,5
$R = \dfrac{\text{ACTUAL MAX INPUT CURRENT}}{\text{RATED INPUT CURRENT AT}85°\text{C}}$	≤ 0,5
$R = \dfrac{\text{ACTUAL MEAN POWER DISSIPATION}}{\text{RATED MEAN POWER DISSIPATION AT}85°\text{C}}$	≤ 0,5
$R = \dfrac{\text{CTR TO BE USED IN DESIGN CALCULATION}}{\text{RATED VALUE OVER TEMPERATURE RANGE}}$ $R = \dfrac{\text{LEAKAGE CURRENTS TO BE USED IN DESIGN CALCULATION}}{\text{RATED VALUE OVER TEMPERATURE RANGE}}$	= 0,8 = 1,25
MINIMUM TEMPERATURE DIFFERENTIAL BETWEEN MAXIMUM RATED OPERATING TEMPERATURE AND ACTUAL OPERATING TEMPERATURE (ambient and package) REMARK: In datasheets the word “case” instead of “package” is often used.	15 K
MINIMUM TEMPERATURE DIFFERENTIAL BETWEEN MAXIMUM RATED JUNCTION TEMPERATURE AND ACTUAL JUNCTION TEMPERATURE AT HIGHEST AMBIENT TEMPERATURE	25 K
The ageing of the optocouplers component should be taken into account.	

Table F.17 — Suggested derating factor (R) for isolation devices

ISOLATION DEVICES (e.g. OPTOISOLATORS, TRANSFORMERS, ETC.)	R
$R = \frac{\text{ACTUAL PEAK OPERATING VOLTAGE}}{\text{RATED PEAK INSULATION VOLTAGE}}$	≤ 0,5

Table F.18 — Suggested derating factor (R) for relays and switches (current rating < 25 A)

RELAYS AND SWITCHES (CURRENT RATING OF LESS THAN 25 A)	R
$R = \frac{\text{ACTUAL WORKING CURRENT}}{\text{RATED DC CONTACT CURRENT AT} 100\,°\text{C}}$ RESISTIVE LOAD INDUCTIVE LOAD MOTOR FILAMENT	≤ 0,75 ≤ 0,4 ≤ 0,2 ≤ 0,1
$R = \frac{\text{ACTUAL CONTACT POWER}}{\text{RATED CONTACT POWER}}$	≤ 0,5
$R = \frac{\text{MAX NUMBER OF SWITCHING CYCLES TO BE USED IN DESIGN CALCULATION}}{\text{RATED NUMBER OF SWITCHING CYCLES}}$	= 0,5
$R = \frac{\text{MAX CONTACT RESISTANCE TO BE USED IN DESIGN CALCULATION}}{\text{RATED CONTACT RESISTANCE}}$	= 2
MINIMUM TEMPERATURE DIFFERENTIAL BETWEEN MAXIMUM RATED TEMPERATURE AND ACTUAL TEMPERATURE REMARK: The use of relays should be avoided on PCBs through a couple of disadvantages: Stress of the PCB and its soldering points by shock / vibration through switching, limited number of switching cycles, high energy consumption and heat dissipation.	15 K

Table F.19 — Suggested derating factor (R) for connectors

CONNECTORS	R
$R = \frac{\text{ACTUAL WORKING CURRENT}}{\text{RATED DC CONTACT CURRENT AT} 100\,°\text{C}}$	≤ 0,5
$R = \frac{\text{ACTUAL WORKING VOLTAGE}\left(\text{PEAK}\right)}{\text{RATED WORKING VOLTAGE}\left(\text{AC RMS}\right)}$	≤ 0,65
$R = \frac{\text{MAX NUMBER OF MATE / DEMATE CYCLESTO BE USED IN DESIGN CALCULATION}}{\text{RATED NUMBER OF MATE / DEMATE CYCLES}}$	= 0,5
$R = \frac{\text{MAX CONTACT RESISTANCE TO BE USED IN DESIGN CALCULATION}}{\text{RATED CONTACT RESISTANCE}}$ MINIMUM TEMPERATURE DIFFERENTIAL BETWEEN MAXIMUM RATED HOT SPOT TEMPERATURE AND ACTUAL HOT SPOT TEMPERATURE	= 2 30 K

Annex G
(informative)

Electronic equipment not designed for use on rolling stock

For the use of electronic equipment not designed for use on rolling stock (see Clause 8), this annex provides a list of some relevant applicability conditions and a guideline regarding permissions and possible mitigation provisions to be evaluated and agreed between the involved parties.

Recommended list of applicability conditions and deliverables for the suitability evaluation:

— equipment is not essential for train operation and that requested functionalities are not achievable with existing electronic equipment designed for use on rolling stock;

— type test reports or test certificates, showing that the equipment has successfully passed the following tests (Type test as specified by Table 11);

  o power supply test;

  o low temperature test and dry heat test;

  o EMC test;

  o fire behaviour requirements;

  o personnel safety requirements;

  o shock and vibration test;

— an interface specification, carrying the necessary information to permit replacement of the equipment with another one from a different supplier;

— a measured or calculated predictive reliability level (according to 6.1.1 or 6.1.2) or an accelerated life test report, allowing evaluation of the target level for field reliability.

List of possible applicable permissions or mitigation provisions to be implemented for the suitability evaluation:

— mitigation provisions if the operating temperature of the equipment does not fulfil the range of the operating temperature classes listed in Table 1 (Low temperature and dry heat test);

— type test report, or test certificate, attesting that insulation coordination of the equipment meets a different standard than EN 50124-1 (e.g. EN 62368 series);

— mitigation provisions if the useful life class of the equipment or of a component used inside an equipment is less than the required useful life (e.g. obsolescence management);

— the design process may not be visible and auditable;

— the design documentation (e.g. circuit diagram, component list, software documentation, programmable component documentation) may not be available;

— reverse polarity of the power supply input voltage may lead to failure of the equipment;

— the equipment may be considered to be non-repairable;

- some of the requirements specified in Clause 9 (Components) may not be applicable;
- some of the requirements specified in Clause 10 (Construction) may not be applicable;
- cyclic damp heat test may not be performed if the equipment is not exposed to high level of relative humidity or exposed to rapid temperature variations with likely risk of condensation;
- moisture condensation may lead to malfunction or failure;
- salt mist test needs not to be performed if the equipment is not exposed to salty atmosphere or to polluted environment.

Both lists are not intended to be exhaustive and the evaluation of the suitability of such electronic equipment for use on rolling stock may depend on additional criteria or on other environmental mitigation measures to put in place for the integration into rolling stock.

Annex H
(informative)

Paragraphs with Agreements between the involved Parties

The following table provides the places inside the standard were agreements between the involved parties are mentioned. In some cases, for understanding the particular themes, the relevant paragraphs are complemented in the subsequent table with surrounding paragraphs and / or higher-ranking heading(s) of the standard.

The table is given without demand on completeness.

Table H.1 — Clauses/Subclauses relating to agreements between the involved parties

No.	Clause / Subclause	Text paragraph
1.	4.3 Performance criteria 4.3.1 General	If agreed between the involved parties, the normal performance level of the equipment under test can be replaced by a defined deviation of the specified performance.
2.	4.3.4 Performance criterion C	shall be manually restarted or process-controlled restarted. In this case the restart process shall be clearly defined in the user manual and agreed between user and supplier at tender stage.
3.	4.4.1 Altitude	If the required altitude exceeds the one specified in EN 50125-1:2014, Table 1 class A1, compliance with the requirements shall be agreed between the involved parties.
4.	4.5 Special service conditions 4.5.1 General	Special arrangements shall be agreed between the involved parties when service conditions can be proved different from those mentioned in 4.3 (e.g. bogie mounted equipment or integrated into a power converter). For checking the functionality and the performance level of such arrangements, optional type tests can be carried out on the vehicle itself in accordance with methods to be agreed between the involved parties.
5	5.2.8 Behaviour of system power supply during start of combustion engine	The behaviour of essential electronic equipment, if relevant, shall be agreed between user and supplier.
6.	5.3.1 Supply by a specific source	Characteristics (e.g. range, variation, ripple factor) of the output voltage of the supply and input voltage of the equipment shall fit together and be agreed between the involved parties.
7.	6.1.1 Predicted reliability	The method of calculation shall be agreed between the manufacturer and the user at tender stage and shall be in accordance with a recognized standard.

8.	6.1.2 Proof of reliability	If the proof of reliability is required, it shall be agreed between the involved parties at tender stage. The proof of reliability can be a costly process. Thus, the reliability evaluation plan and the associated procedure should be clarified in an early stage between the involved parties. The reliability evaluation plan and associated procedure shall be agreed between the involved parties. The manufacturer and the user shall agree how to monitor and to record all actions carried out on the equipment. To demonstrate the reliability level of the equipment a reliability report will be presented at the end of a mutually agreed period (km or hours) identifying at least the components replaced (circuit reference number, type, manufacturer, number of manufacturing lot, kilometres and/or hours etc.), the definition and cause of faults (design weakness, software, component problems etc.).
9.	6.2 Useful life Examples of standards providing guidance on this topic: - For collection of dependability data from the field: EN 60300-3-2; - For reliability growth programs: EN 61014; - For performing accelerated ageing tests: EN 62506. Useful life Table 7	LX As agreed by the involved parties
10.	6.3.3.1 On-vehicle diagnosis and repair	The user and the supplier shall agree on the type of LRU, if appropriate. These units shall be designed to be easily exchanged.
11.	7.2.5 Interchangeability	Unless otherwise agreed, all individual PBAs or LRUs forming part of a system shall be functionally complete and fully interchangeable with any other unit of the same functional type without the need for any recalibration of the hardware after the PBA or LRU has been inserted in the system.
12.	8 Electronic equipment not designed for use on rolling stock	In such cases, an agreement is necessary between the involved parties. Annex G provides a guideline for the applicable requirements.

13.	9 Components 9.1 Procurement	The specialized component documentation is delivered only under specific request of the user and is subject to a contract agreement between supplier and user regarding the confidentiality and the rights of use of those documents.
14.	10.7 Protective coatings for printed board assemblies Table 9	PCX As agreed between user and supplier
15.	10.10 Cooling and ventilation	Cooling shall not be achieved by the forced induction of air into the equipment enclosure, unless precautions agreed between involved parties are taken to ensure that the life of the equipment is not thereby adversely affected by the introduction of contaminants.
16.	12.2 Supply and storage of documentation	The following documentation requirements, shall be agreed between the involved parties at tender stage: - the quantity, scope, content, language, presentation, medium and updating process of documentation required by the user; - the scope, conditions and duration applying to the storage of documentation by the supplier.
17.	12.7 Design documentation 12.7.1 General	The design documentation is delivered only as a specific request of the user and is subject to a contractual agreement between the involved parties.
18.	12.7.8.2 Manufacturing data	The manufacturing data are delivered only under specific request of the user and are subject to a contractual agreement between supplier and user regarding the confidentiality and the rights of use of those documents.
19.	12.7.8.3 User Programmable Integrated Circuits (UPIC, e.g. FPGA, PLD, ASIC)	Class M0: The documents listed in the column “Class M0” of Table 10 shall be available according to the contractual agreement between the involved parties. These documents shall be sufficiently precise to allow subsequent redesign of a ‘functionally equivalent component at interface level’. Class M1: The documents listed in the column “Class M1” of Table 10 shall be available according to the contractual agreement between the involved parties. These documents shall be sufficiently precise to allow a modification of the design.
20.	12.7.10 Repair documentation 12.7.10.1 General	The repair documentation is delivered only under specific request of the user and is subject to a contractual agreement between supplier and user regarding the confidentiality and the rights of use of this documentation.
21.	12.7.11 Documentation – Software	The design software documentation is delivered only under specific request of the user and is subject to a contractual agreement between supplier and user regarding the confidentiality and the rights of use of this documentation.

22.	13 Testing 13.1 General	The access and delivery of type test and routine test reports shall be agreed between the involved parties at tender stage. The requirements not associated with a test procedure shall be verified at the design review level. Additional requirements, acceptance criteria and the related verification/test shall be agreed between the involved parties at tender stage. Since some of the tests subject to agreement may be costly, it is advisable to carry out only necessary tests. The user may require to observe and check the results of any tests. This shall be agreed between the involved parties.
23.	13.2 Categories of tests 13.2.1 General	At tender stage, the user shall identify any tests subject to agreement (see Table 11 - List of tests).
24.	13.2.2 Type tests	According to an agreement between the user and the supplier, some or all tests may be repeated from time to time on samples drawn from current production or deliveries, to confirm that the quality of the product still meets the specified requirements.
25.	13.2.4 Investigation tests	If investigation tests are requested by the user, they shall be agreed between the involved parties.
26.	13.3.1 List of tests Table 11	Tests marked “O” are optional and subject to contract agreement between the user and the supplier.
27.	13.4.7.2 Insulation resistance test	For assembled equipment (e.g. control electronics in traction converter), the minimum value of the insulation resistance of equipotential areas depends on the extent of the complete circuit. The insulation resistance at the interfaces to the vehicle shall be agreed between the involved parties.
28.	13.4.10.5 Enclosure protection test (IP code)	As electronic equipment is generally mounted either inside the body of the vehicle or in enclosures outside (e.g. location 1, 2 and 3 according to Table C.1), there is no need to carry out enclosure protection tests. Exceptional cases shall be agreed between the involved parties (EN 60529 may be used as a guide).
29.	13.4.11 Stress screening test	The process and the tests to be applied to the equipment under consideration shall be agreed between the involved parties at tender stage.
30.	13.4.12 Rapid temperature variation test	The test specification and the test procedure shall be agreed between the involved parties, EN 60068-2-14 may be used as a guide.
31.	Annex F, F.2.3 Capacitors to earth	The use of Y – capacitors at digital I/O ports should be avoided. If this is not possible, they should be designed in accordance with EN 60384-14 (recommended class Y1 or Y2) and their capacitance value should not exceed 10 nF. Higher capacitance values are subject to agreement between manufacturer and system integrator.

32	Annex I (informative) Electronic equipment supplied from AC supply system I.1 General	The requirements and the list of tests for electronic equipment not (fully) described in this annex, should be agreed between the involved parties (in particular: 5.2 and 13.4.3 that are not applicable to AC supply system).

Annex I
(informative)

Electronic equipment supplied from AC supply system

I.1 General

This annex describes the electric requirements for electronic equipment supplied from AC voltage, e.g. derived from auxiliary inverters or electric generators.

The requirements and the list of tests for electronic equipment not (fully) described in this annex, should be agreed between the involved parties (in particular: 5.2 and 13.4.3 that are not applicable to AC supply system).

All other requirements (e.g. temperature, shock, vibration, EMC) are applicable.

I.2 Electric requirements

The electronic equipment powered by AC voltage should comply with all the requirements of the preceding paragraphs of this standard except those listed in the table below.

Table I.1 — Test requirements for electronic equipment powered by AC voltage

Subclause	Applicability Yes / No	Note
5.2 Battery voltage supply system and subclauses	No	
7.2.7 Reverse polarity protection	No	
13.3 Table 11 – List of tests	Yes (partially)	Table 11 is applicable except DC Power supply test.
13.4.3 DC Power supply test and subclauses	No	For equipment designed for one phase train line, EN 50160 for static voltage tolerances and EN 61000-6-2 for short dips/interruptions should be used as a guide. For equipment designed for three phase train line according EN 50533, this standard should be used
13.4.7.3 Voltage withstand test	Yes (partially)	Test voltages can be derived from EN 50124-1 or EN 60077-1

Annex J
(informative)

Typical content of datasheets

A datasheet should contain the following content (In the following list the term “if any” means that this item is optional):

a) equipment identification:

   1) manufacturer's name or trademark;

   2) equipment name and type;

   3) equipment version (if any);

b) table of contents;

c) definitions or acronyms used in the document (If any);

d) general description:

   1) pictures (If any);

   2) hardware architecture;

   3) functional purpose and principle of operation of the equipment;

   4) optional parts available, with their description and functionalities (if any);

e) electrical features:

   1) nominal supply voltage(s): U_n = Volts DC (see 5.2.2 or 5.3.1 if AC supply system);

   2) nominal power consumption: [Watts] (Min., Max., power consumption if appropriate);

   3) inrush current characteristics: [I^2t] (see 7.2.8);

   4) class of supply voltage interruptions (see 5.2.4);

   5) supply change-over class (if appropriate): (see 5.2.5);

   6) functional / protection earth;

f) mechanical features:

   1) overall dimensions [mm, or – if applicable – “U” / TE for EN 60297 (all parts) racks];

   2) mechanical drawings with positions / diameters / screw threads (if any) of the fixing points;

   3) weight [g, or kg];

   4) IP code [see EN 60529];

g) environmental features:

1) operating temperature range: [see Table 1 - Operating temperature classes (°C)];

2) class of increased operating temperature at switch-on: see Table 2 – Classes of increased operating temperature at switch-on;

3) natural cooling or forced ventilation constraints for the equipment;

4) storage temperature range: [min. max. °C];

5) relative humidity compliance: [% max];

6) altitude class: [1000, 1200, 1400, etc., metres max.];

7) pollution degree conformance: [PD1, PD2, etc.];

8) shock and vibration “categories & classes” [as specified by EN 61373];

9) rapid temperature variation class (if any): [see Table 3];

10) conformal coating type;

11) information relating to any hazardous materials that are present in the equipment (if any);

h) RAMS features:

1) useful life class: [Years] [see Table 7- Useful life classes];

2) [repairable, not repairable], equipment or parts of the equipment (if any);

3) identification of the LRU parts of the electronic equipment;

4) list of limited life components to be replaced by preventive maintenance (if any);

5) storage precautions (if any);

6) identification of commercial off-the-shelf equipment/components inside the electronic equipment (if any);

7) periodic maintenance instructions (if any);

8) reliability [MTBF Hours] [Predicted or Measured from the field with all information about applied methodology, applied mission profile, Reliability handbook or standard used];

9) functional safety reference (if any);

10) operator safety instruction (if any);

i) functional description and interfaces:

1) functional block diagram, including hardware and software;

2) central processing unit and peripherals (if relevant);

3) memory (if relevant);

4) input-output ports description (at equipment interface level – connectors level);

5) signal name, pin-out, function, electrical features, with description of circuit operation, including DC or AC voltage, current, impedance, frequency, isolated signal, overcurrent/overvoltage protections, min. max loads characteristics, etc. where appropriate;

6) communication ports (e.g. CAN; MVB; Ethernet) and protocols descriptions (if any at equipment interface level);

7) cabling recommendations;

8) visual interfaces description (e.g. displays, lamps, LEDs) (if any);

j) equipment labelling description:

1) Product (LRU) Part number identification;

2) Product (LRU) Serial number identification;

3) Product (LRU) Revision index identification;

4) connectors identification;

5) other labels (fuses, battery, etc.) (if any);

k) routine and type test compliance summary (see Annex D):

1) list of performed test (routine and type) on the equipment;

2) summary of the test methods, reference standard and criteria applied;

l) ordering or commercial references:

1) reference of Commissioning Manual (if any);

2) reference of User Manual (if any);

3) reference of Application Notes (if any);

4) reference of Installation manual of the equipment (if any);

5) reference of optional part for the electronic equipment. (if any);

6) reference of accessories associated to the electronic equipment. (if any);

7) reference of special tools for mounting, dismounting the equipment (if any);

8) reference (commercial) of replaceable components (Fuses, Battery, etc.) (if any);

9) reference of replaceable PBAs (if any);

10) reference of PTE (portable test equipment) associated to the electronic equipment (if any);

11) reference of ATE (automatic test equipment) associated to the electronic equipment (if any);

12) reference of programming tools to use for uploading software (if any);

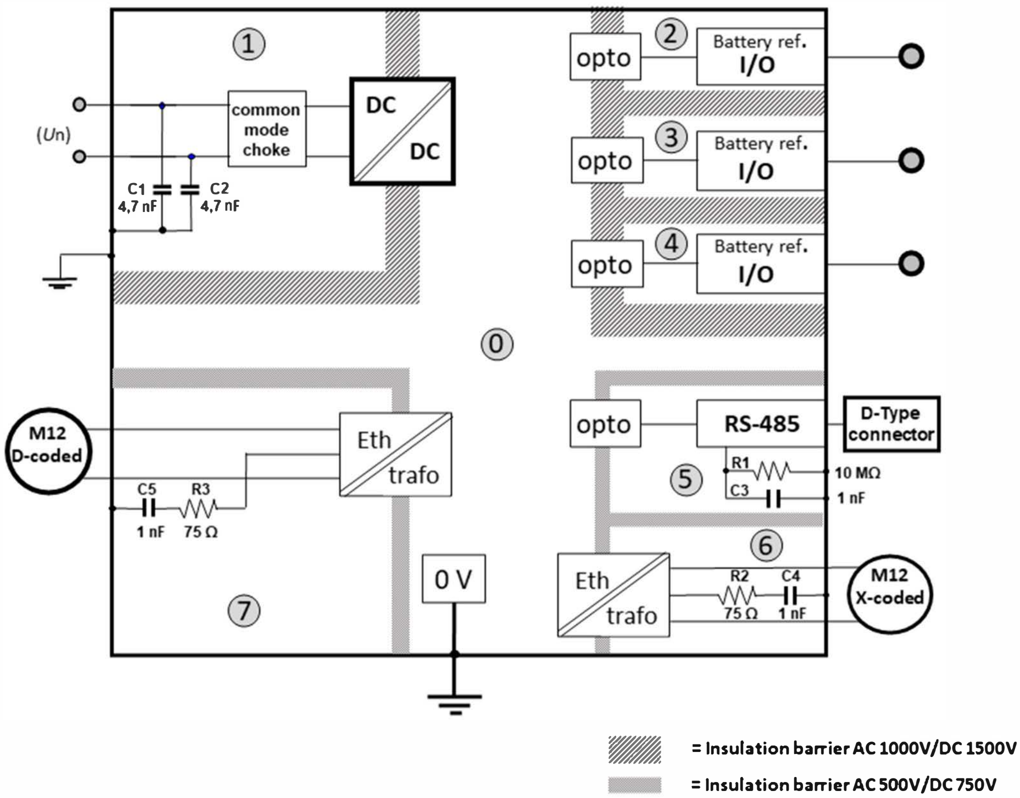
13) reference of standard software to upload on the electronic equipment (if any);

m) datasheet document history with revision index.

Annex K
(informative)

Insulation test and testing matrix example

The “insulation barriers” to be tested include the insulation on the PCB and/or the insulation of a module (e.g. DC/DC converter) or an electronic component (e.g. Ethernet transformer, optocoupler, digital isolator).



Key:

0 0 V electronic (connected to functional earth);

1 input from battery supply voltage system ($U_n \geq$ DC 72 V);

2 battery referenced I/O ports (e.g. “Binary inputs/outputs” as in Figure 5);

3 battery referenced I/O ports;

4 battery referenced I/O ports;

5 RS485 insulated communication port. (R1 and C3 are for EMC purposes; see 7.2.4);

6 1 Gbit/s Ethernet port;

7 100 Mbit/s Ethernet port.

NOTE Two phantom paths are present (through the functional earth connection) between port 1 and port 6 via C1//C2-functional earth-C4 and between port 1 and port 7 via C1//C2-functional earth-C5.

Figure K.1 — Example of electronic equipment with different types of I/O

According to the definition of adjacent circuit and from the Figure K.1, following equipotential areas are adjacent circuits:

Table K.1 — Equipotential areas and test voltages against adjacent circuits of Figure K.1

Equipotential area	0	1	2	3	4	5	6	7
0								
1	DC 1500 V							
2	AC 1000 V							
3	AC 1000 V		AC 1000 V					
4	AC 1000 V			AC 1000 V				
5	DC 750 V							
6	DC 750 V					DC 750 V		
7	DC 750 V							

NOTE 1 Table above is a diagonal symmetrical table; grey cells are not used. Only cells between adjacent areas are filled with test voltage values.

When the equipotential areas are not adjacent circuits (e.g. equipotential areas 2 and 4), the insulation between them needs not to be tested. Hence, in this case, it is allowed to tie equipotential areas 2, and 4 and to test them together against equipotential area 0 and 3, because the specified test voltages (see Table K.1) are the same.

In the case of high-impedance bleeder resistors between adjacent equipotential areas or between an equipotential area and functional earth (e.g. equipotential area 5), the effect of these resistors is to be deducted for the insulation measurement test.

If there are EMC capacitors to functional earth (e.g. equipotential areas 1, 7, 5, 6), AC test voltages are not applicable. In this case the corresponding DC test voltages should be applied.

NOTE 2 The RS485 signals are generally connected to a Sub-D type connector (e.g. 9-way female). This type of connector has a withstand voltage of AC 1000 V_{RMS}.

NOTE 3 For 1 Gbit/s Ethernet ports, the standard connector used for rolling stock application is a M12 X-coded (8-way female connector). According to EN 61076-2-109:2014 (Table 8) this connector type has a withstand voltage of AC 500 V_{RMS}.

NOTE 4 For 100 Mbit/s Ethernet ports, the standard connector used for rolling stock application is a M12 D-coded (4-way female connector). According to EN 61076-2-101:2012 (Table 8) this connector type has a withstand voltage of AC 1400 V_{RMS}.

However, insulation test of the equipotential area where those connectors are mounted, is performed at AC 500 V or DC 750 V according to the Table K.1.

Annex L
(informative)

Relationship between this European Standard and the Essential Requirements of EU Directive 2016/797/EU aimed to be covered

This European Standard has been prepared under a Commission's standardisation request "M/483 Mandate to CEN and CENELEC for Standardisation in the field of interoperability of the rail system" to provide one voluntary means of conforming to (parts of) essential requirements of Directive 2016/797/EU of the European Parliament and of the Council of 11 May 2016 on interoperability of the rail system (recast) as specified in the relevant technical specifications for interoperability (TSI).

Once this standard is cited in the Official Journal of the European Union under that Directive, compliance with the normative clauses of this standard given in Table ZZ.1 for "Locomotives and Passenger Rolling Stock", Table ZZ.2 for "Control-Command and Signalling" confers, within the limits of the scope of this standard, a presumption of conformity with the corresponding essential requirements of that Directive as specified in the technical specifications for interoperability (TSI), and associated EFTA regulations.

Table ZZ.1 — Correspondence between this European Standard, Commission Regulation (EU) N° 1302/2014 concerning the technical specification for interoperability relating to the 'rolling stock — locomotives and passenger rolling stock' subsystem of the rail system in the European Union* and Directive (EU) 2016/797

Essential Requirements of Directive (EU) 2016/797	Clauses of the Annex to the Technical Specification for Interoperability (TSI)	Clause/ subclauses of this European Standard	Comments
Section 3 of the Annex indicates the correspondence between the TSI clauses and the essential requirements of Directive (EU) 2016/797	4.2.1.3. (4); Safety aspects	5 Electrical service conditions 7 Design 11.3 Functional safety (1) 13 Testing	The standard sets out the general engineering requirements for interoperability namely environmental and electrical service conditions within the rolling stock boundaries, and installation
	4.2.6.1.1. Temperature	4.4 Environmental service conditions	
	4.2.12. Documentation for operation and maintenance	12 Documentation	

(*) As amended by:

Commission Regulation (EU) 2016/919, Commission Implementing Regulation (EU) 2018/868, Commission Implementing Regulation (EU) 2019/776 and Commission Implementing Regulation (EU) 2020/387

NOTE: The technical specification for interoperability (TSI) may refer to other clauses of this standard making the application of those clauses mandatory. Possible references to such clauses are found in the Appendix J to the TSI.

Table ZZ.2 — Correspondence between this European Standard, Commission Regulation 2016/919 concerning the technical specification for interoperability relating to the 'control-command and signalling' subsystems of the rail system in the European Union* and Directive (EU) 2016/797

Essential Requirements of Directive (EU) 2016/797	Clauses of the Annex to the Technical Specification for Interoperability (TSI)	Clause/ subclauses of this European Standard	Comments
Section 3 of the Annex to the TSI indicates the correspondence between the TSI clauses and the essential requirements of Directive (EU) 2016/797	3.2.5.1.1 Physical environmental conditions	4.4 Environmental service conditions 5 Electrical service conditions 7 Design 10 Construction 13 Testing	The standard sets out the general engineering requirements for interoperability namely environmental and electrical service conditions within the rolling stock boundaries, and installation
(*) As amended by: Commission Implementing Regulation (EU) 2019/776, Commission Implementing Regulation (EU) 2020/387 and Commission Implementing Regulation (EU) 2020/420. NOTE: The technical specification for interoperability (TSI) may refer to other clauses of this standard making the application of those clauses mandatory. Possible references to such clauses are found in the Tables A.3 and A.4 of Annex A to the TSI.			

WARNING 1 — Presumption of conformity stays valid only as long as a reference to this European Standard is maintained in the list published in the Official Journal of the European Union. Users of this standard should consult frequently the latest list published in the Official Journal of the European Union.

WARNING 2 — Other Union legislation may be applicable to the product(s) falling within the scope of this standard.

Bibliography

EN 50126-2:2017, Railway Applications — The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS) – Part 2: Systems Approach to Safety

EN 60077-1, Railway applications — Electric equipment for rolling stock — Part 1: General service conditions and general rules (IEC 60077-1)

EN 60068-2-14, *Environmental testing - Part 2-14: Tests - Test N: Change of temperature*

EN 60300-3-2, *Dependability management - Part 3-2: Application guide - Collection of dependability data from the field*

EN 60384-14, *Fixed capacitors for use in electronic equipment - Part 14: Sectional specification - Fixed capacitors for electromagnetic interference suppression and connection to the supply mains*

EN 60721-3-5:1997, *Classification of environmental conditions - Part 3: Classification of groups of environmental parameters and their severities - Section 5: Ground vehicle installations*

EN IEC 62368 (series), *Audio/video, information and communication technology equipment*

EN 61000-4-29, *Electromagnetic compatibility (EMC) - Part 4-29: Testing and measurement techniques - Voltage dips, short interruptions and voltage variations on d.c. input power port immunity tests*

EN 61014, *Programmes for reliability growth*

EN 61082-1, *Preparation of documents used in electrotechnology - Part 1: Rules*

EN 61124, *Reliability testing — Compliance tests for constant failure rate and constant failure intensity (IEC 61124)*

EN 61163-1, *Reliability stress screening - Part 1: Repairable assemblies manufactured in lots*

EN 61249 (series), *Materials for printed boards and other interconnecting structures*

EN 61287-1, *Railway applications - Power converters installed on board rolling stock - Part 1: Characteristics and test methods*

EN 62326-1, *Printed boards - Part 1: Generic specification*

EN 62326-4, *Printed boards - Part 4: Rigid multilayer printed boards with interlayer connections - Sectional specification*

EN 62326-4-1, *Printed boards - Part 4: Rigid multilayer printed boards with interlayer connections - Sectional specification - Section 1: Capability Detail Specification - Performance levels A, B and C*

EN 62506, *Methods for product accelerated testing*

EN ISO 9001, *Quality management systems - Requirements (ISO 9001:2015)*

IEC 60617, *Graphical symbols for diagrams*[Database]

EN 62402, *Obsolescence management - Application guide*

EN 50121-1:2017, *Railway applications - Electromagnetic compatibility - Part 1: General*

IEC 61709, *Electric components - Reliability - Reference conditions for failure rates and stress models for conversion*

IPC-2221, *Generic Standard on Printed Board Design*

IPC-2222, *Sectional Design Standard for Rigid Organic Printed Boards*

IPC-2223, *Sectional Design Standard for Flexible Printed Boards*

IPC-2226, *Sectional Design Standard for High Density Interconnect (HDI) Printed Boards*

IPC-2581, *Generic Requirements for Printed Board Assembly Products Manufacturing Description Data and Transfer Methodology*

IPC-4101, *Specification for Base Materials for Rigid and Multilayer Printed Boards*

IPC-6013, *Qualification and Performance Specification for Flexible Printed Boards*

ISO/TS 22163, *Railway applications — Quality management system — Business management system requirements for rail organizations: ISO 9001:2015 and particular requirements for application in the rail sector*

EN 61076-2-101:2012, *Connectors for electronic equipment - Product requirements - Part 2-101: Circular connectors - Detail specification for M12 connectors with screw-locking*

EN 61076-2-109:2014, *Connectors for electronic equipment - Product requirements - Part 2-109: Circular connectors - Detail specification for connectors with M 12 × 1 screw-locking, for data transmission frequencies up to 500 MHz*