



BSI Standards Publication

Railway applications — Rolling stock — Electronic equipment

National foreword

This British Standard is the UK implementation of EN 50155:2021. It supersedes BS EN 50155:2017, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee GEL/9/2, Railway Electrotechnical Applications - Rolling stock.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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utilisés sur le matériel roulant

Bahnanwendungen - Fahrzeuge - Elektronische
Betriebsmittel

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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- latest date by which the national standards conflicting with this document have to be withdrawn (dow) 2024-06-28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.

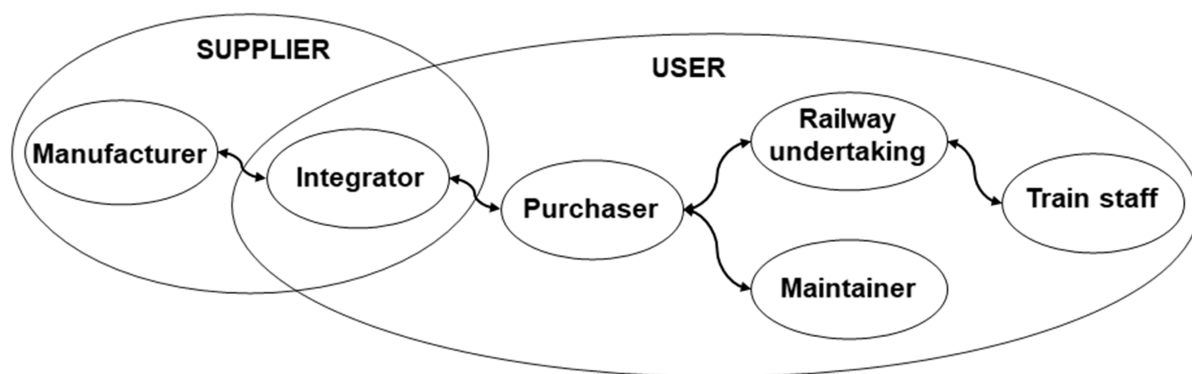


Figure 1 — Roles and relationship of user and/or supplier

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: IEC 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: IEC 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

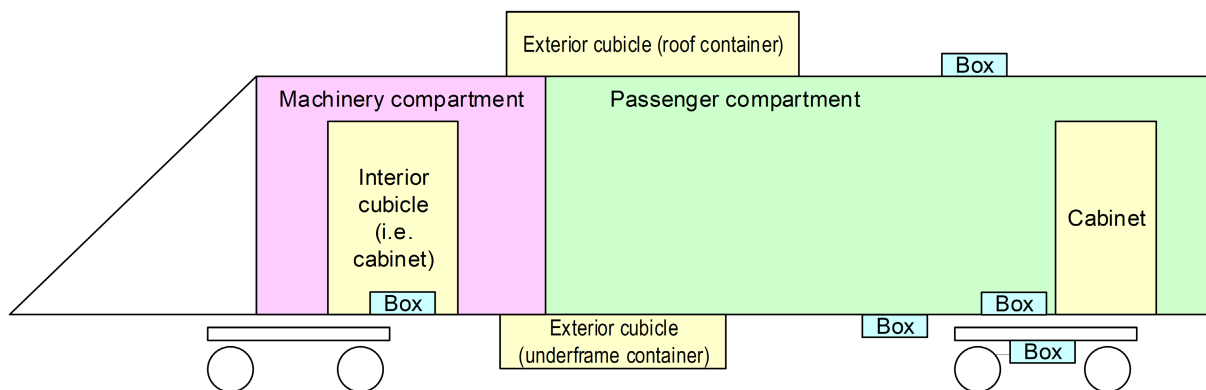


Figure 2 — Types of enclosures

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: IEC 60050-101, 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: IEC 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 (IEC 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: IEC 192-04-01]

3.1.23

performance

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

[SOURCE: IEC 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: IEC 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: IEC 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: IEC 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: IEC 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: IEC 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: IEC 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: IEC 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: IEC 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: IEC 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, Note 1 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:

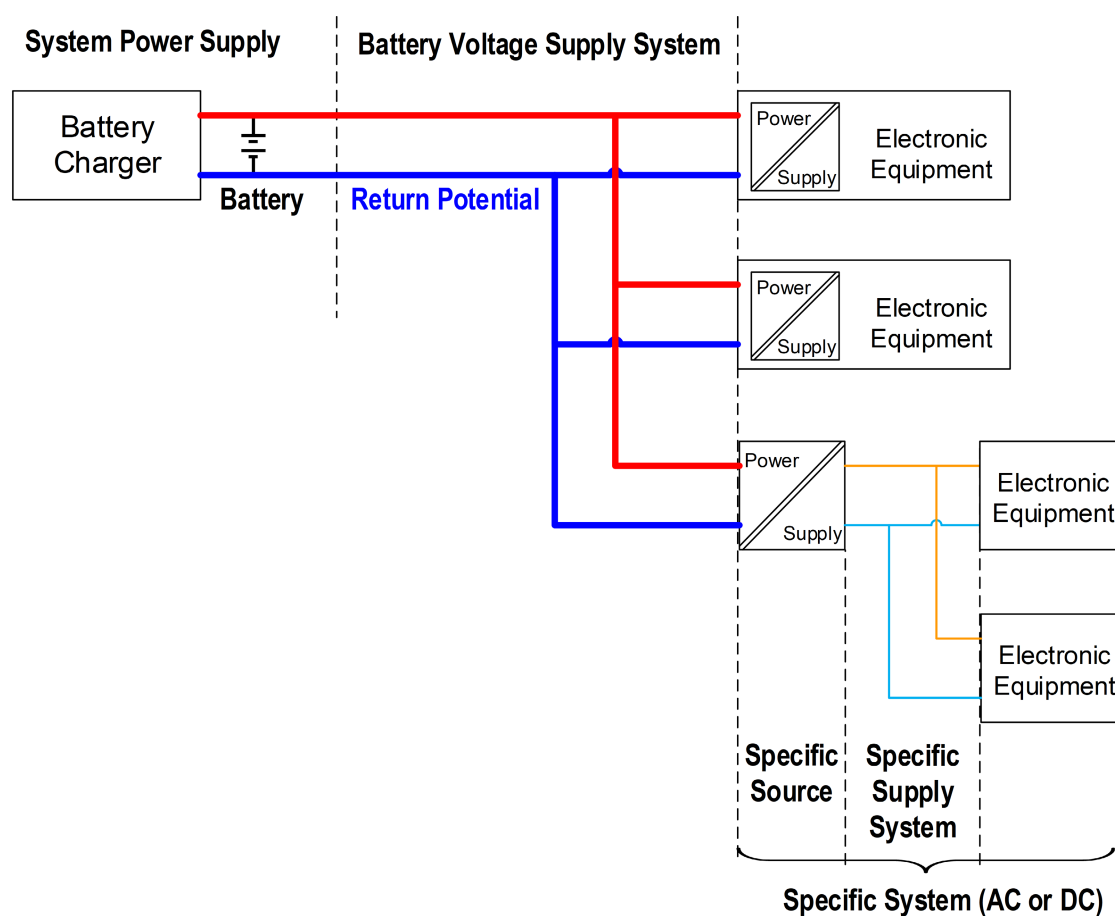


Figure 3 — Topology of on-board DC supply system

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:

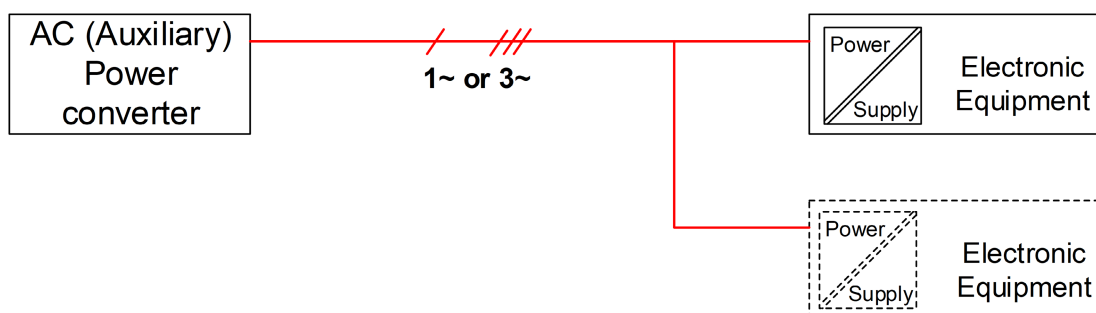


Figure 4 — Topology of on-board AC supply system (1~ or 3~)

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	$0,6 U_n$	$\leq 0,1 \text{ s}$	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	$1,4 U_n$	$\leq 0,1 \text{ s}$	A
Maximum temporary supply overvoltage	$1,4 U_n$	$\leq 1,0 \text{ s}$	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 $0,1 \text{ s}$ 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 $0,1 \text{ s}$ 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 $0,7 \times 24$ V and the maximum continuous voltage is $1,25 \times 110$ 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 $0,6 \times 24$ V and the maximum temporary supply voltage to consider is $1,4 \times 110$ 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 $2 \text{ V} / 101 \text{ V} \approx 1,98 \%$.

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 $0,6 U_n$ or rise above $1,4 U_n$.

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.