INTERNATIONAL STANDARD

ISO 16750-1

Fourth edition
2023-07

Road vehicles — Environmental conditions and testing for electrical and electronic equipment —

Part 1: General

Véhicules routiers — Spécifications d'environnement et essais de l'équipement électrique et électronique —

Partie 1: Généralités

Reference number
ISO 16750-1:2023(E)

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 32, *Electrical and electronic components and general system aspects*.

This fourth edition cancels and replaces the third edition (ISO 16750-1:2018), which has been technically revised.

The main changes are as follows:

— integrating and harmonizing contents from ISO 19453-1:2018, (e.g. addition of 5.5);

— integrating terms from ISO 19453-1:2018 and addition of terms considering common terms in ISO 16750 series;

— modification to subdivide mounting locations matching with climate load tests of ISO 16750-4;

— addition of operating modes for 48 V DUT and voltage class B DUT (Clause 5);

— reorganization of operating mode tables for easy understanding (Clause 5);

— clarification of test procedure regarding parameter check and physical analysis (7.6, 7.7);

— update of coding system integrating voltage class A DUT and voltage class B DUT (Clause 8);

— definition of mass and volume classes related to mechanical and climatic loads (Annex C).

A list of all parts in the ISO 16750 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The purpose of the ISO 16750 series is to assist its user in systematically defining and/or applying a set of internationally accepted environmental conditions, tests and operating requirements based on the anticipated actual environment in which the equipment will be operated in and exposed to during its life cycle.

NOTE This edition of the ISO 16750 series (2023) does not contain electrical testing conditions or requirements in ISO 16750-2 for the voltage class B circuits of voltage class B components as well as 48 V circuits of 48 V components. For electrical testing conditions or requirements for voltage class B components and 48 V circuits of 48 V components, see instead the ISO 21498 series (voltage class B components) and ISO 21780 (48 V components).

The following environmental factors have been considered in the development of this document.

— World geography and climate

Road vehicles are operated in nearly all land regions of the earth. Significant variations in environmental conditions due to climatic environment, including diurnal and seasonal cycles, can therefore be expected. Consideration has been given to worldwide ranges in temperature, humidity, precipitation and atmospheric conditions including dust, pollution and altitude.

— Type of vehicle

Environmental conditions in and on road vehicles can depend on vehicle design attributes, such as whether to equip an internal combustion engine and/or an electric motor for vehicle propulsion, vehicle mass, vehicle size, electrical supply voltage and so on. Considerations have been given to typical series production vehicles, including passenger cars, light duty trucks and commercial (heavy) buses and trucks not only propelled by diesel or gasoline engines but also propelled by electric motors. These considerations include hybrid electric vehicles, battery electric vehicles, range extender hybrid electric vehicles and fuel cell vehicles, but does not include the equipment specific for fuel cell systems.

— Vehicle use conditions and operating modes

Environmental conditions in and on the vehicle vary significantly with road quality, types of road surface, road topography, vehicle use (e.g. commuting, towing, cargo transport, etc.) and driving habits. Operating modes such as storage, starting, driving, stopping and so on have been considered. Additionally, it has been taken into account that there is a difference of engine speed distributions between conventional vehicles and hybrid electric vehicles where driving modes with shut-off combustion engine exist.

— Equipment life cycle

Electrical and electronic equipment is intended to be resistant to environmental conditions experienced during manufacture, shipping, handling, storage, vehicle assembly and vehicle maintenance and repair. Such conditions and tests (e.g. handling drop to be tested by free-fall test) are within the scope of this document.

— Vehicle supply voltage

Supply voltage varies with vehicle use, operating mode, electrical distribution system design and even climatic conditions.

— Component mass and volume

The component mass and volume has a significant impact on the response of the device under test (DUT) to environmental loads, especially with respect to vibration and thermal load. For thermal loads the higher thermal capacity of the DUT is the major influence. For vibration loads the high dynamic system coupling (caused by high mass and moment of inertia as well as the centre of gravity) becomes relevant. Current components of the drive system of electrically propelled road vehicles, such as electric motors, inverters or DC-DC converters, tend to be much larger and heavier than small and lightweight E/E equipment, such as small sensors, ECUs or fuel injection equipment. Adding such equipment, the size and mass of components of the electric powertrain have been considered in this document, for example, by taking the inertia mass of those components into account as an effect on the measured excitation during vibration measurements. Also, the size and mass significantly influence the necessary exposure time at low and high temperatures when applying a thermal profile, such as in ISO 16750-4, as it takes much longer to reach the intended temperature in the core of the component (stabilisation time). For performing proper tests according to different component mass and volume, one of the typical solutions is to apply different test profiles based on a mass classification. This document shows an example of such mass classification (see Annex C).

— Mounting location in the vehicle

In current or future vehicle concepts, systems/components are mounted in almost any location of the vehicle. The environmental requirements for each specific application highly depend on its mounting location. Each location in a vehicle has its distinct set of environmental loads. As an example, the range of temperatures in the engine/electric motor compartment differs significantly from the range in the passenger compartment. This is also true for the vibration loads, except that in this case, not only are the vibration levels different, but the type of vibration load also varies. Body mounted components are typically exposed to random vibrations whereas for engine mounted systems/components the additional sine vibration from the engine is considered. Moreover, devices installed in doors are exposed to a high number of mechanical shocks from door slamming.

It is desirable for the vehicle manufacturer to group the different environmental load types and levels in a reasonable number of standard requirement sets. This strategy makes it possible to carry systems/components from one vehicle project to another. Furthermore, the exact requirement levels are often unknown when designing a component for a future vehicle concept. The expected environmental loads are usually compiled from other vehicle concepts with similar conditions. The grouping is normally done by mounting location, but it is difficult to define the right number of different mounting locations and respective load profiles, because there is a conflict of aims between having only few requirement classes and tailoring the requirement levels to each application. The reason is that the environmental loads are not only depending on the mounting location. There are other major factors that affect the stress levels for systems/components. For example, body styles, drive-train concepts or package densities can create absolutely different requirement levels for devices that are installed in different vehicles at almost the same location.

The purpose of the ISO 16750 series is to define requirement classes for separate load types. It distinguishes between electrical, mechanical, thermal, climatic and chemical loads. For each load type, several requirement classes are defined. Every requirement class is determined by a specific code letter. The complete environmental requirement set is created by defining the code letter combination. The code letters are defined in the respective clauses of this document. Additionally, tables in the annexes of each part show the usual mounting locations and give examples of their respective code letters. For normal applications, these code letters are used. If an application is very specific and therefore, the given code letter combinations cannot be used, it is possible to create new code letter combinations to serve this purpose. In case none of the given code letters are usable, new requirement levels can be created by using the code letter Z. In this case, the specific requirements are defined separately, but it is desirable not to change the test methods.

At a minimum, the following mounting locations referred to in Clause 4 should be considered for a DUT with respect to thermal, mechanical, climatic and chemical loads.

a) Applicability to manufacturer's responsibility

Due to technology limitations or variations in vehicle design, the vehicle manufacturer can be required to place a component in a location where it cannot withstand the environmental conditions described in the ISO 16750 series. Under these circumstances, it is the responsibility of the vehicle manufacturer to provide the necessary environmental protection.

b) Applicability to wiring harnesses, cables and electrical connectors

Although some environmental conditions and tests in the ISO 16750 series can be relevant to vehicle wiring harnesses, cables and connectors, its scope is not sufficient to be used as a complete standard. It is therefore not recommended that the ISO 16750 series is directly applied to such devices and equipment.

c) Applicability to parts or assemblies in or on equipment

The ISO 16750 series describes environmental conditions and tests to be applied to electrical and electronic equipment directly mounted in or on the vehicle. It is not intended for direct application to parts or assemblies that are part of the equipment. For example, the ISO 16750 series should not be directly applied to integrated circuits (ICs) and discrete components, electrical connectors, printed circuit boards (PCBs), gauges, etc. that are attached in or on the equipment. Electrical, mechanical, climatic and chemical loads for such parts and assemblies can be quite different from those described in the ISO 16750 series.

On the other hand, it is desirable to use the ISO 16750 series to help derive environmental conditions and test requirements for parts and assemblies that are intended for use in road vehicle equipment. For example, a temperature range from −40 °C to 90 °C may be specified for parts or assemblies contained inside a piece of equipment having a temperature range of −40 °C to 70 °C and an additional temperature rise of 20 K.

d) Applicability relative to system integration and validation

The user of the ISO 16750 series is cautioned that the scope of the ISO 16750 series is limited to conditions and testing at the equipment level, and therefore does not represent all conditions and testing necessary for complete verification and validation of the vehicle system. Environmental and reliability testing of equipment parts and vehicle systems can be required.

For example, the ISO 16750 series does not necessarily ensure that environmental and reliability requirements for solder joints, solderless connections, integrated circuits and so on are met. Such items are ensured at the part, material or assembly level. Additionally, vehicle and system level testing can be required to validate the equipment in the vehicle application.

e) Applicability to high voltage battery packs and systems or components inside

Although some environmental conditions and tests of mechanical loads in ISO 16750-3 and climatic loads in ISO 16750-4 can be relevant to high voltage battery packs (e.g. for traction) and systems or components inside, their scope is not sufficient to be used as a complete standard. It is therefore not recommended that the ISO 16750 series is directly applied to such devices and equipment. The dedicated International Standard, ISO 19453-6, is taken into account.

Road vehicles — Environmental conditions and testing for electrical and electronic equipment —

Part 1: General

1 Scope

This document applies to electric and electronic systems and components for vehicles including electric propulsion systems and components with maximum working voltages according to voltage class B. It describes the potential environmental stresses and specifies tests and requirements for the specific mounting location on/in the vehicle.

This document contains the terminology for the ISO 16750 series and general requirements.

This document is not intended to apply to environmental requirements or testing for systems and components of motorcycles and mopeds. Electromagnetic compatibility (EMC) is not covered by this document.

Systems and their components released for production, or systems and their components already under development prior to the publication date of this document, can be exempted from fulfilling the changes in this edition compared to the previous one.

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.

ISO 6469-3, *Electrically propelled road vehicles — Safety specifications — Part 3: Electrical safety*

ISO 16750-2, *Road vehicles — Environmental conditions and testing for electrical and electronic equipment — Part 2: Electrical loads*

ISO 16750-3, *Road vehicles — Environmental conditions and testing for electrical and electronic equipment — Part 3: Mechanical loads*

ISO 16750-4, *Road vehicles — Environmental conditions and testing for electrical and electronic equipment — Part 4: Climatic loads*

ISO 16750-5, *Road vehicles — Environmental conditions and testing for electrical and electronic equipment — Part 5: Chemical loads*

ISO 20653, *Road vehicles — Degrees of protection (IP code) — Protection of electrical equipment against foreign objects, water and access*

ISO 21498-1, *Electrically propelled road vehicles — Electrical specifications and tests for voltage class B systems and components — Part 1: Voltage sub-classes and characteristics*

ISO 21780, *Road vehicles — Supply voltage of 48 V — Electrical requirements and tests*

EN 13018, *Non-destructive testing — Visual testing — General principles*

3 Terms and definitions

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

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
active operating mode
operating mode with electric operation and control in some load

Note 1 to entry: This term is a substitute to avoid redundant repeats, used in requirements when describing operating modes aforementioned in test method.

EXAMPLE The term “active operating modes” described in requirements substitutes for “operating mode 3.2, 3.3 and/or 3.4” in test method.

3.2
customer
party that is using electrical and electronic equipment

3.3
DUT
device under test
single component or combination of components (system) as defined to be tested

3.4
dwell time
time when the systems/components have reached and stay within the specified conditions (e.g. temperature, voltage, engine speed)

3.5
electric propulsion system
combination of traction motor, power electronics and their associated controls for the conversion of electric to mechanical power and vice versa

[SOURCE: ISO 6469-1:2019, 3.8, modified — The term was originally "electric drive".]

3.6
electric propulsion vehicle
vehicle with one or more *electric propulsion system(s)* (3.5) for vehicle propulsion

[SOURCE: ISO 6469-1:2019, 3.9, modified — The term was originally "electrically propelled vehicle".]

3.7
exposure time
complete time that the systems/components are exposed to constant test conditions (e.g. temperature, humidity)

3.8
functional test
basic test to verify that the systems/components perform as designed specifically to satisfy the representative functions or characteristics such as output signals, output power and insulation performance, etc.

Note 1 to entry: Functional tests are performed in the shortest possible time to avoid temperature rise of the systems/components due to self-heating. Performed and checked functions or characteristics in the possible shortest time are determined by agreement between the *customer* (3.2) and the *supplier* (3.19).

3.9
hot-soak temperature
T_{maxHS}
maximum value of the ambient temperature which may temporarily occur in the engine/electric motor compartment after the vehicle has stopped and the engine is turned off

3.10
maximum operating temperature
T_{max}
maximum value of the ambient temperature at which the systems/components are designed to be operated in

3.11
maximum working voltage
highest value of AC voltage (RMS) or of DC voltage that can occur under any normal operating conditions according to the *customer's* (3.2) specifications, disregarding transients and ripple

3.12
minimum operating temperature
T_{min}
minimum value of the ambient temperature at which the systems/components are designed to be operated in

3.13
nominal voltage
U_N
voltage value used to describe the 12/24 V electrical system of a vehicle

3.14
paint repair temperature
T_{maxPR}
maximum temperature which occurs during vehicle paint repair

3.15
peak to peak voltage
U_{pp}
superimposed AC voltage

3.16
redundant supply
voltage supply source (e.g. DC-DC converter, battery, alternator, integrated starter generator, etc.) in the vehicle supply voltage network(s) that operates independently of other voltage supply source

EXAMPLE Two separate 12 V lead acid batteries, each supplying a separate, independent, 12 V grid in the vehicle.

3.17
redundantly supplied DUT
DUT (3.3) which has two or more power supply ports (can include both voltage lines as well as ground lines), allowing continued operation with full or reduced capacity, if the supply is interrupted or disturbed on one of the power supply ports

EXAMPLE A DUT with two duplicated internal circuits to achieve the same function, that are supplied by two independent (e.g. voltage Class A) power supplies for the purpose of increasing availability, allowing fault detection, or providing functional tolerance to single faults, most commonly used to ensure availability of safety critical applications.

3.18
stabilisation time
time needed for the systems/components to reach within the specified conditions (e.g. temperature, humidity)

3.19
supplier
party that provides electrical and electronic equipment

3.20
supply voltage
U_S
voltage of the electrical system of a vehicle that varies with the system load and the operating condition of the power supply (e.g. DC-DC converter, battery, alternator, integrated starter generator, etc.)

3.21
supply voltage maximum
U_{Smax}
highest *supply voltage* (3.20) in the specified supply *voltage range* (3.31) of the *DUT* (3.3) while performing in accordance with functional status class A

3.22
supply voltage minimum
U_{Smin}
lowest *supply voltage* (3.20) in the specified supply *voltage range* (3.31) of the *DUT* (3.3) while performing in accordance with functional status class A

3.23
supply voltage operating mode 2
U_B
supply voltage (3.20) from 12/24 V battery without applied charging

3.24
supply voltage for 48 V system operating mode 3 and 4
U_{48N}
supply voltage (3.20) from 48 V battery/DC-DC converter without applied charging

3.25
supply voltage operating mode 3 and 4
U_A
supply voltage (3.20) from 12/24 V battery with applied charging

3.26
test voltage
voltage(s) applied to the *DUT* (3.3) during a test

EXAMPLE U_A and U_B (see Table 4)

3.27
thermal equilibrium
state when the temperature of all parts in/on the systems/components are within 3 K of their final temperature, unless otherwise indicated by the systems'/components' specification

Note 1 to entry: The tolerance of 3 K is according to IEC 60068-1:2013, 3.11: thermal stability which provides technical information of testing devices with and without heat dissipation.

3.28
unlimited operating capability voltage
U_X
specified *supply voltage* (3.20) in the *voltage range* (3.31) of *voltage class B* (3.30) for which the *DUT* (3.3) performs in accordance with functional status class A

3.29
voltage class A
classification of an electric component or circuit with a *maximum working voltage* (3.11) of ≤ 30 V a.c. (RMS) or ≤ 60 V d.c. respectively

3.30
voltage class B
classification of an electric component or circuit with a *maximum working voltage* (3.11) of (> 30 and ≤ 1 000) V a.c. (RMS) or (> 60 and ≤ 1 500) V d.c. respectively

3.31
voltage range
general term covering voltage subclass, *working voltages* (3.32) and deviations from working voltages

3.32
working voltage
AC voltage (RMS) or DC voltage that can occur in an electric system under normal operating conditions according to the *customer's* (3.2) specifications, disregarding transients and ripple

4 Classification by mounting location

4.1 Engine/electric motor compartment

Device mounted:

a) to the body:

   1) front end, upper;

   2) front end, lower;

   3) higher than side member;

   4) lower than side member;

b) to the frame:

   1) front end, upper;

   2) front end, lower;

   3) higher than members;

   4) lower than members;

c) below the compartment cover (hood, cab floor);

d) on the flexible plenum chamber, not rigidly attached;

e) in the flexible plenum chamber, not rigidly attached;

f) on the engine/motor:

   1) top and middle part;

   2) bottom part;

g) in the engine/motor;

h) on the transmission /gearbox/retarder;

i) in the transmission /gearbox/retarder.

4.2 Passenger compartment

Device mounted in a position:

- without special requirements;
- exposed to direct solar radiation;
- exposed to radiated heat (e.g. ceiling).

4.3 Luggage compartment/load compartment

Device mounted inside.

4.4 Mounting on exterior/in cavities

Device mounted:

a) to the body (except under body):
   1) top part;
   2) side part;
   3) bottom part;

b) to the frame for commercial vehicle:
   1) space between frame members;
   2) outside space of frame members;

c) to underbody/wheel housing:
   1) unsprung masses;
   2) sprung masses:
      i) in the wheelbase;
      ii) floor tunnel;
      iii) rear overhang;

d) to the passenger compartment door:
   1) outside ;
   2) inside;

e) to the engine/electric motor compartment cover (outside);

f) in/on a luggage compartment lid/door:
   1) outside;
   2) inside;

g) in cavities:
   1) open towards interior;

2) open towards exterior;

h) in special compartments.

4.5 Other mounting location

For some locations with special environmental conditions (e.g. exhaust system), no standard specifications can be given. In these cases, the load shall be stated in the specification of the device.

The load data shall be taken from relevant measurements in vehicle, and with the guidelines specified in the related parts of this document, suitable test profiles may be developed.

NOTE For example, ISO 16750-3:2023, Annex A and ISO 16750-4:2023, Annex B can be used to make suitable test profiles.

5 Operating modes

5.1 General

An overview of the DUT operating modes according to this standard is given in Tables 1, 2 and 3.

The specific details of each load condition (e.g. typical mode, maximum load) are determined by agreement between the customer and the supplier.

Table 1 — Operating modes for 12/24 V DUT

Operating mode	Wire harness connected	12/24 V system supply voltage	Load condition	Auxiliary device (e.g. cooling system)
1.1	No	No applied voltage	Not applicable	Deactivated
1.2	Yes	No applied voltage	Not applicable	Deactivated
2.1	Yes	U_B [a]	Sleep mode	Deactivated
2.2	Yes	U_B [a]	Typical mode	Deactivated
2.3	Yes	U_B [a]	Minimum load	Deactivated
2.4	Yes	U_B [a]	Maximum load	Deactivated
3.1	Yes	U_A [a]	Stand-by mode [b]	Deactivated
3.2	Yes	U_A [a]	Typical mode	Deactivated
3.3	Yes	U_A [a]	Minimum load	Deactivated
3.4	Yes	U_A [a]	Maximum load	Deactivated
4.1	Yes	U_A [a]	Stand-by mode [b]	Activated
4.2	Yes	U_A [a]	Typical mode	Activated
4.3	Yes	U_A [a]	Minimum load	Activated
4.4	Yes	U_A [a]	Maximum load	Activated

[a] For electrical testing, other voltage levels and voltage profiles are specified in the individual test descriptions (see ISO 16750-2).

[b] ECUs with microprocessors such as audio, head up display, instrument cluster, etc. are activated and kept in stand-by mode with basic functions.

Table 2 — Operating modes for 48 V DUT (with 12/24 V circuits)

Operating mode	Wire harness connected	12/24 V system supply voltage	48 V System supply voltage	Load condition	Auxiliary device (e.g. cooling system)
1.1	No	No applied voltage	No applied voltage	Not applicable	Deactivated
1.2	Yes	No applied voltage	No applied voltage	Not applicable	Deactivated
2.1	Yes	U_B [a]	No applied voltage	Sleep mode	Deactivated
2.2	Yes	U_B [a]	No applied voltage	Typical mode	Deactivated
2.3	Yes	U_B [a]	No applied voltage	Minimum load	Deactivated
2.4	Yes	U_B [a]	No applied voltage	Maximum load	Deactivated
3.1	Yes	U_A [a]	U_{48N}	Stand-by mode [b]	Deactivated
3.2	Yes	U_A [a]	U_{48N}	Typical mode	Deactivated
3.3	Yes	U_A [a]	U_{48N}	Minimum load	Deactivated
3.4	Yes	U_A [a]	U_{48N}	Maximum load	Deactivated
4.1	Yes	U_A [a]	U_{48N}	Stand-by mode [b]	Activated
4.2	Yes	U_A [a]	U_{48N}	Typical mode	Activated
4.3	Yes	U_A [a]	U_{48N}	Minimum load	Activated
4.4	Yes	U_A [a]	U_{48N}	Maximum load	Activated

[a] For electrical testing, other voltage levels and voltage profiles are specified in the individual test descriptions (see ISO 16750-2).

[b] ECUs with microprocessors such as audio, head up display, instrument cluster, etc. are activated and kept in stand-by mode with basic functions.

NOTE Operating mode 3.X and 4.X correspond to operating mode 2.X as defined in ISO 21780.

Table 3 — Operating modes for voltage class B DUT (with 12/24 V circuits)

Operating mode	Wire harness connected	12/24 V system supply voltage	Class B circuit supply voltage	Load condition	Auxiliary device (e.g. cooling system)
1.1	No	No applied voltage	No applied voltage [c]	Not applicable	Deactivated
1.2	Yes	No applied voltage	No applied voltage [c]	Not applicable	Deactivated
2.1	Yes	U_B [a]	No applied voltage [c]	Sleep mode	Deactivated
2.2	Yes	U_B [a]	No applied voltage [c]	Typical mode	Deactivated
2.3	Yes	U_B [a]	No applied voltage [c]	Minimum load	Deactivated
2.4	Yes	U_B [a]	No applied voltage [c]	Maximum load	Deactivated
3.1	Yes	U_A [a]	U_X	Stand-by mode [b]	Deactivated
3.2	Yes	U_A [a]	U_X	Typical mode	Deactivated
3.3	Yes	U_A [a]	U_X	Minimum load	Deactivated
3.4	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
4.1	Yes	U_A [a]	U_X	Stand-by mode [b]	Activated
4.2	Yes	U_A [a]	U_X	Typical mode	Activated
4.3	Yes	U_A [a]	U_X	Minimum load	Activated
4.4	Yes	U_A [a]	U_X	Maximum load	Activated

[a] For electrical testing, other voltage levels and voltage profiles are specified in the individual test descriptions (see ISO 16750-2).

[b] ECUs with microprocessors such as audio, head up display, instrument cluster, etc. are activated and kept in stand-by mode with basic functions.

[c] For voltage class B circuit, no applied voltage normally means the contactor is open.

5.2 Operating mode 1

No voltage is applied to the DUT.

— Operating mode 1.1: not connected to wiring harness.

— Operating mode 1.2: connected to wiring harness simulating vehicle installation.

5.3 Operating mode 2

The DUT is electrically operated with a test voltage U_B as in a vehicle with shut-off combustion engine, high voltage battery and/or DC-DC converter disconnected, and all electrical connections made. For specific test cases, other test voltages or other voltage profiles can apply.

— Operating mode 2.1: systems/components functions are not activated (e.g. sleep mode).

— Operating mode 2.2: systems/components with electric operation and control in typical operating mode.

— Operating mode 2.3: systems/components with electric operation and control in minimum load.

— Operating mode 2.4: systems/components with electric operation and control in maximum load.

5.4 Operating mode 3

The DUT is electrically operated with test voltages U_A and U_X with all electrical connections made. However, an auxiliary machine (e.g. cooling system) is not installed.

For all voltage systems, operating mode 3.4 can be changed to 3.2 by agreement between the customer and the supplier to avoid overheating of the DUT or unfeasible test setup.

In the case of the DUT having 48 V circuits and not having the circuits of voltage class B, apply U_{48N} instead of U_X. In case of the DUT having only 12/24 V circuits, supply only the voltage of 12/24 V. For specific test cases, other test voltages or other voltage profiles can apply.

— Operating mode 3.1: systems/components functions are not activated.

— Operating mode 3.2: systems/components with electric operation and control in typical operating mode.

— Operating mode 3.3: systems/components with electric operation and control in minimum load.

— Operating mode 3.4: systems/components with electric operation and control in maximum load.

NOTE 1 Operating mode 3.4 is not applied to voltage class B components and systems.

NOTE 2 The operating mode for the DUT with 48 V circuits load corresponds to operating mode 2 as defined in ISO 21780.

5.5 Operating mode 4

The DUT is electrically operated with test voltages U_A and U_X with all electrical connections made. Also an auxiliary machine (e.g. cooling system) is installed. Operating modes (minimum, typical, maximum) shall be agreed between the customer and the supplier. Operating mode 4.4 can be changed to 4.2 by agreement between the customer and the supplier to avoid overheating of the DUT or unfeasible test setup.

In the case of the DUT having 48 V circuits and not having the circuits of voltage class B, apply U_{48N} instead of U_X. In case of the DUT having only 12/24 V circuits, supply only the voltage of 12/24 V. For specific test cases, other test voltages or other voltage profiles can apply.

— Operating mode 4.1: systems/components functions are not activated.

— Operating mode 4.2: systems/components with electric operation and control in typical operating mode.

— Operating mode 4.3: systems/components with electric operation and control in minimum load.

— Operating mode 4.4: systems/components with electric operation and control in maximum load.

NOTE The operating mode for the DUT with 48 V circuits load corresponds to operating mode 2 as defined in ISO 21780.

6 Functional status classification

6.1 General

This element describes the functional status of a DUT during and after a test.

The minimum functional status shall be given in each test. Functions of the device/system and their specified tolerances shall be agreed between the customer and the supplier. Additional test requirements and limitations due to test set-up may be agreed between the customer and the supplier.

Unwanted operations of the DUT are not allowed in any of the following classes (see 6.2 to 6.6).

Electrical safety in accordance with ISO 6469-3 shall be maintained in all of the following classes except class E in which the DUT shall be handled with special care.

6.2 Class A

All functions of the device/system perform as designed during the test (for the periods with active operating mode) and after the test.

6.3 Class B

All functions of the device/system perform as designed during the test. However, one or more of them may go beyond the specified tolerance. All functions automatically return to within normal limits after the test. Memory functions shall remain in class A.

The vehicle manufacturer specifies which functions of the DUT shall perform as designed during the test and which functions can be beyond the specified tolerance.

6.4 Class C

One or more functions of a device/system do not perform as designed during the test, but automatically return to normal operation after the test.

6.5 Class D

One or more functions of a device/system do not perform as designed during the test and do not return to normal operation after the test until the device/system is reset by a simple operator/user action.

6.6 Class E

One or more functions of a device/system do not perform as designed during and after the test and cannot be returned to proper operation without repairing or replacing the device/system.

7 Tests and requirements

7.1 General

The values specified in ISO 16750-2 to ISO 16750-5 are applied as basic requirements.

DUTs with several mounting locations shall be tested to meet the strictest requirements. Appropriate test profiles for mechanical and climatic loads should be selected in ISO 16750-3 and ISO 16750-4, referencing an example of mass classification shown in Annex C.

The DUT shall be submitted to the visual, dimensional and functional tests prescribed by the relevant specification, which shall provide the criteria (e.g. electrical, thermal or mechanical permissible limit values) to be used for the acceptance or rejection of the DUT before and after all tests.

Software programs and memory devices equipped in the DUT shall be completely functional until the DUT is deactivated. If the device has non-volatile memory, the integrity (not the current status) of the non-volatile memory shall be ensured as required at all times.

7.2 General test conditions

Unless otherwise specified, all tests shall be performed at a room temperature (RT) of (23 ± 5) °C and a relative humidity of 25 % to 75 %.

The test voltages shall be as shown in Table 4, unless other values are specified in the relevant parts of the ISO 16750 series or are agreed upon by the users of the ISO 16750 series, in which case such values shall be documented in the test reports.

Table 4 — Test voltages for operating modes 2 to 4 (see 5.3 to 5.5)

Voltage in volts

Test voltage	Voltage class A system			Voltage class B system
	12 V system	24 V system	48 V system	
U_A	14 ± 0,2	28 ± 0,2	—	—
U_B	12 ± 0,2	24 ± 0,2	—	—
U_{48N}	—	—	48 ± 0,24	—
U_X	—	—	—	Voltage for unlimited operating capability [a], with tolerance of ±1 %

[a] The voltage for unlimited operating capability is specified by agreement between the customer and the supplier in accordance with ISO 21498-1.

7.3 Test sequence

Prior to testing, a test plan shall be agreed upon, stating the type, number, group of tests to be conducted in series or in parallel, considering the economy and duration of testing.

Life test(s) shall be defined specifically for the product and be taken into account in the test plan.

An example is given in Annex A.

EXAMPLE For a DUT with both mechanical actuations as well as electrical circuit that could have an electrical failure, both a life test for the electrical circuit as well as a life test for the wear out of the mechanical parts, could be relevant.

7.4 Test setup

Details of the test setup, operating loads (e.g. triggering, original sensors, original actuators and replacement circuitry) and the required boundary conditions shall be agreed between the customer and the supplier. These details shall be documented in the test plan and in the test report.

The test equipment shall ensure that all interfaces which are required to meet the specified performance of the DUT are populated and functional to the required level. Signals or messages which shall be received from or transmitted to the vehicle controller in order to ensure the DUT functions as expected may be simulated if a full vehicle or Hardware In the Loop (HIL) simulation is not used.

7.5 Test procedure

The test procedure shall be decided between the customer and the supplier and documented within the test plan.

At the beginning of each test, the DUT shall be in a steady state of temperature and humidity of defined test conditions.

The DUT shall be started up completely and checked through a functional test.

Before and after every test, the DUTs shall be subjected to a parameter check as described in 7.6 in accordance with specifications. The key parameters as described in 7.6 from the before/after tests may differ only within the specified permissible tolerances. Any changes in the measured values exceeding the measurement accuracies shall be indicated as such. The results shall be examined for root cause so that any abnormalities, ageing or malfunctions of the component can be identified.

Damage to the DUT is not permitted in functional status class A to class D. Evidence of functional status is provided at least by the parameter check as described in 7.6.

Damaged DUTs (functional status class E) shall be removed from the test cycle, analysed regarding the root cause for the failure and documented. In such cases, the test shall be repeated with a new DUT, or the following test in the test plan shall be performed with a new DUT. The procedure shall be agreed between the customer and the supplier.

The physical analysis as described in 7.7 shall be carried out on at least one DUT after each test sequence. All component parts of the DUT undergoing final validation stage, shall be recorded.

Any change in these parts shall require revalidation or justification of no impact.

7.6 Parameter check

A set of sensitive parameters called key parameters shall be defined both in the component specifications and in consultation with the customer (e.g. quiescent current consumption, operating currents, output voltages, contact resistances, input impedances, signal and bus performance, for instance rise and fall times, signal levels and communication speed).

The key parameters shall be measured and the functional behaviour of the DUT at room temperature and test voltage as defined in Table 4 shall be checked. For components that provide an error memory functionality (e.g. past diagnostic results), the memory shall be cleared before the test and the memory function shall be activated during the test. After the test, the error memory (e.g. diagnostic results) shall be read out and documented.

If continuous monitoring of the key parameters during the test is required, it shall be agreed between the customer and the supplier in the test plan.

All the results shall be documented in the test report.

7.7 Physical analysis (visual inspection)

The DUT shall be opened and a visual inspection including external check shall be performed in accordance with EN 13018. Damage/changes are for example cracks, chipping/peeling, discolouration and distortion.

NOTE IPC-A-610 and/or IPC-J-STD-001 can be used as visual quality acceptability requirements. Depending on the properties of the DUT that is inspected as well as the expected type of damage/change, other standards can also be applicable to define the visual inspection in more detail.

Component level physical analysis and additional analyses (e.g. X-ray, SEM analysis, cross section investigation and metallographic examination of the hardware design and connecting technology) are optional. The results shall be documented in the test report.

8 Designation

8.1 Coding

Figure 1 describes the referred tests for the device(s) by a code form for technical specifications and/or other documentation. The different elements of the code shall be in accordance with the relevant documents as mentioned in Figure 1.

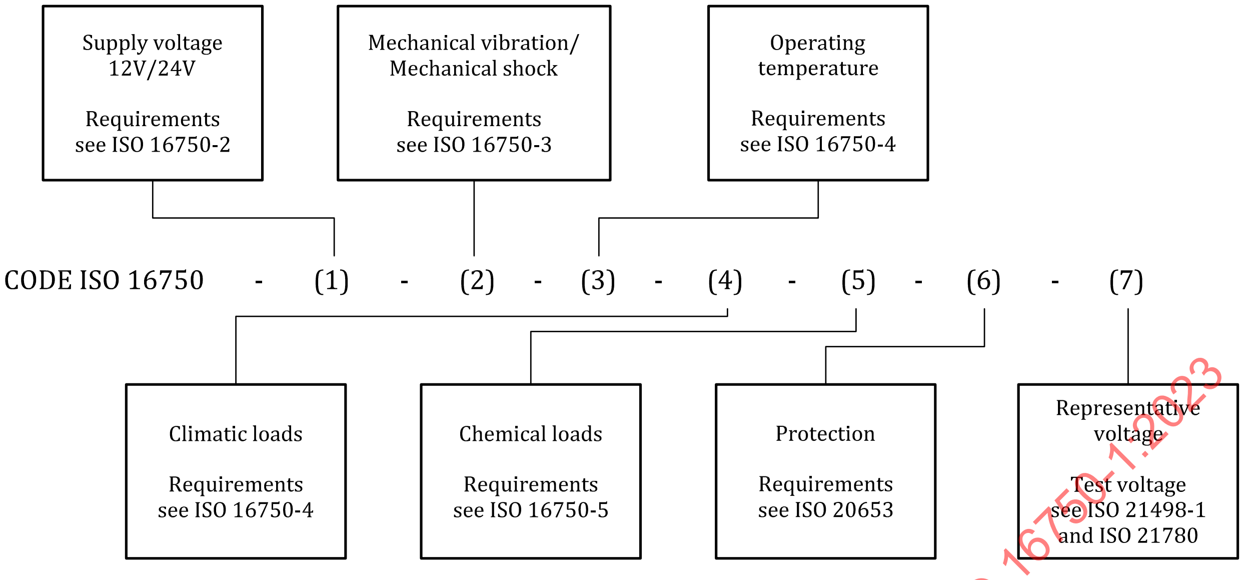


Figure 1 — Code allocation

EXAMPLE ISO 16750-A-A-Ha-A-A-IP6K9K-A_48/B_420.

This example shows the designation of an environmental requirement for a system/component with:

— a supply voltage requirement as defined in code letter A in ISO 16750-2;

— a mechanical load requirement as defined in code letter A in ISO 16750-3;

— an operating temperature requirement as defined in code letter Ha in ISO 16750-4;

— a climatic load requirement as defined in code letter A in ISO 16750-4;

— a chemical load requirement as defined in code letter A in ISO 16750-5;

— a degree of protection IP6K9K in accordance with ISO 20653;

— a voltage class A test voltage 48 V, and voltage class B test voltage 420 V, as defined in Table 4 by code letter A_48/B_420.

8.2 Use of Code Z "as agreed"

The ISO 16750 series accommodates special needs and situations through the use of Code Z "as agreed". The use of Code Z should be restricted to cases in which the customer and/or the supplier determine that the conditions or tests defined in the ISO 16750 series are:

— not suitable to achieve desired product quality/reliability objectives; and/or

— not practical.

When Code Z "as agreed" is used, the following requirements and recommendations apply:

— the rationale (reason) for not using the provided conditions or tests shall be documented;

— a complete description of the "as agreed" condition or test should be documented;

— data and the rationale supporting the suitability of the "as agreed" condition or test shall be documented;

— any specific information regarding Code Z "as agreed" contained in ISO 16750-2 to ISO 16750-5 shall be documented;

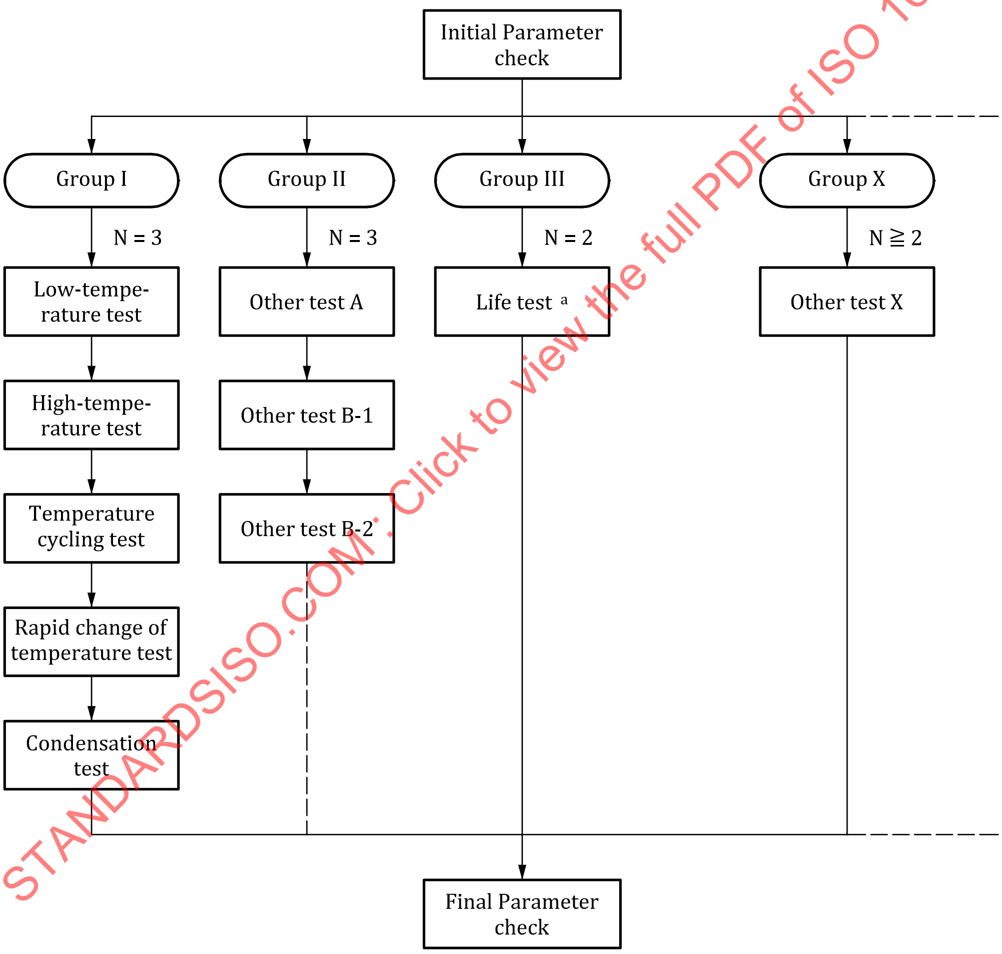
— the customer and the supplier shall agree that the “as agreed” documentation is adequate.

Annex A
(informative)

Example of a test plan

A test plan is a document describing detailed requirements, criteria, methodology, responsibilities, and general planning for test and evaluation of a system/component, general test conditions (see 7.2), test sequence (see 7.3), test setup (see 7.4), test procedure (see 7.5) and necessary check and analysis (see 7.6 and 7.7). Figure A.1 shows an example of test groups conducted as test sequences in a test plan. It is just an example not intended to be carried over as an exact template for an actual test plan. Depending on the failure mechanisms of an individual component, a suitable test sequence needs to be designed.

Individual test sequences can be conducted in parallel, considering the economy and duration of testing.



a See Annex B.

NOTE N is sample size for each test group.

Figure A.1 — Example of test groups/test sequence

Annex B
(informative)

Example of life test/reliability statement

B.1 General

In addition to environmental loads, a product used in the vehicle is subjected to loads induced by its own function, hereafter referred to as functional loads.

The loads are simulated by life tests, which generally comprise a combination of functional loads and relevant environmental loads occurring simultaneously.

These tests are performed according to programmes derived from in-practice operation.

B.2 Aim of life tests

B.2.1 General

Two fundamentally different cases are to be distinguished, depending on the type of problem.

B.2.2 Potential design weakness

Using real-time life tests or accelerated life tests (with corresponding load increase), the design can be checked for functional loads combined with further environmental loads in order to discover design weaknesses. Generally, only a small number of DUTs is enough to achieve this. This case is by far the most frequent. However, the results are not suitable for deriving a statement on reliability as the number of DUTs is too low for a statistically correct statement.

B.2.3 Reliability

Determining reliability is a totally different task. The following step-by-step method is suggested.

a) Determine the type of load which is relevant for service life and specific to the product and determine the test to be conducted.

b) Determine the in-practice load (e.g. running time, mean temperature, etc.).

c) Specify the survival probability and confidence levels and calculate the necessary number of DUTs or test duration on the basis of in-practice load, based on statistical correlation. Generally, this calculation requires extensive testing.

d) A reduction of this extensive testing resulting from step c) to feasible values can be performed by a permissible increase of load on the basis of an appropriate correlation between in-practice experience and testing. The increase in load cannot lead to a change of the expected damage process. Generally, compared to the check of potential design weaknesses, considerably more extensive testing will be required.

The step-by-step method should also be used in the first case for checking design; however, step c) is omitted (statistics calculation).