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Electrical Characteristics and Electrical Safety of High-Voltage Components in Road Vehicles – Requirements and Tests

Foreword

The current edition of this standard is based on the document LV 123, which was established by representatives of the automotive manufacturers AUDI AG, BMW AG, Daimler AG, Dr. Ing. h. c. F. Porsche AG and Volkswagen AG within Working Group AK4.14.3 "HV Safety for Systems and Components".

The contents of LV 123 edition 2014-02 have been taken over unchanged into this standard.

Application note:
Application of the present version of this standard is binding for new vehicle projects or components of this scope for which concept/basic specifications or component requirement specifications have not yet been approved on the date of issue of this version.
The respective contract documents regulate the mandatory application of the present version of this company standard by the supplier.

General requirements

For safety requirements, homologation (in particular exhaust emissions) and quality, the existing statutory requirements and laws shall be complied with. In addition, the relevant requirements of the Daimler Group apply.
All materials, procedures, processes, components, and systems shall conform to the current statutory requirements regarding regulated substances and recyclability.
Deviations from safety-relevant requirements contained in the standard MBN LV 123 for components due to material reasons are only possible following prior written confirmation by the OEM if the relevant protection goal for the vehicle or the component is verifiably fulfilled or is verifiably fulfilled in a comparable manner.

Changes

In comparison with edition MBN LV 123: 2009-12, the following changes have been made:

- Cover sheet updated
- For further changes, refer to Section "Change history" of LV 123.

NOTE: This translation is for information purposes only.
The German version shall prevail above all others.

LV 123

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Electrical Characteristics and Electrical Safety of High Voltage Components in Road Vehicles - Requirements and Tests

Change history (LV123-2)

LV123-3

Edition	Changes
2009-11	First edition
2014-02	Second edition - All sections revised - Most important content revisions by section: - 3 "Terms and definitions": Terms and definitions revised and augmented - 5.1 "HV system": Overview for HV systems with connection to an external power supply augmented - 7.1 "Marking": Requirement pertaining to removable covers made more precise - 7.2 "Protection against direct contact": Requirement pertaining to HV contacting made more precise - 7.2.4 "Protection against direct contact by 'Complex disassembly": possible characteristics augmented - 7.3 " Equipotential bonding": Requirements pertaining to design and fastening of equipotential bonding augmented - 7.6 "Isolation resistance": Requirement for isolation resistances adapted and augmented for voltage range HV_3 - 7.7 "Insulation coordination": Requirements for clearances and creepage distances, solid insulating materials and withstand voltage revised. Requirements for the specification of clearances and creepage distances and of solid insulating materials augmented. Requirement for withstand voltage revised - 7.11 "X capacitors": Requirements for the selection of capacitors augmented - 7.12 "Y capacitors": Requirements for the selection of capacitors augmented - 7.14 "HV contacting and reverse polarity protection": Requirements for reverse polarity protection and protection against mix-ups made more precise - 7.17 "Behavior in the event of a crash": Criterion for the relevance of requirements augmented - 7.20 "Electrical equivalent circuit diagrams": Requirement for the DC HV circuit made more precise - 7.26.2 "Safety and certification relevant characteristics HV": Topic for discharge in the event of a crash augmented - 7.24 "EMC": Requirement replaced with a reference to the corresponding requirements document - 8.1 "Isolation monitoring": Requirements augmented - 8.2 "Service Disconnect function": Requirements adapted to function - 8.3 "Pre-charging": Requirements adapted to function - 8.4 "Detection of open HV cables": Requirements augmented with reference to possible measures - 8.5.3 "Overcurrent protection HV battery": Requirements for overcurrent protection device and for the combination of switching equipment and overcurrent protection device augmented - 10.4 "Test on voltage ranges": Requirement for test parameters and test pulses for the individual tests augmented - 10.5.7 "Test: Insulation coordination": Test requirements completely revised in line with changed requirements in Section "Insulation coordination" - Annex A (informative) Bibliographic references: References updated and augmented - The following sections have been augmented - 7.4 "Overcurrent protection" instead of Section "Short circuit" - 7.7.6 "Insulation coordination for connection to external power supply" - 7.8 "Residual voltage" - 7.13 "Isolation-bridging parts" - 8.5.2 "Switching equipment HV battery" in Section "Additional requirements for HV battery" - 9 "Additional requirements for connection to an external electric power supply" with sub-sections - 10.2 "Test parameters and general test requirements" - 10.3 "Testing of HV components following repair" - 10.7 "Tests regarding additional requirements for the connection to an external electric power supply"

Contents

Foreword (LV123-4)

LV123-5 This edition of this Supply Specification was prepared by representatives of the automotive manufacturers AUDI AG, BMW AG, Daimler AG, Dr. Ing. h. c. F. Porsche AG and Volkswagen AG in Working Group 3, "HV Safety for Systems and Components" of the EE-Director Team 4.14.

LV123-7 This Supply Specification is stored as a Word file in the Standardization Department of AUDI AG.

LV123-8 This Supply Specification does not claim to be complete. Automotive manufacturers are free to request additional state-of-the-art tests at any time.

LV123-9 As the individual automotive manufacturers (referred to as OEMs in this document) may make changes, only the company standards of the respective automotive manufacturers created on the basis of this LV shall apply.

LV123-2368 Deviations from this LV are to be listed on the cover sheet of the company standards. If in individual cases modifications to individual test sections are required, such modifications shall be agreed separately between the departments responsible of the automotive manufacturer and the supplier.

LV123-2369 Within the framework of common development projects of the automotive manufacturers, test reports will be recognized provided that the tests have been performed by an independent institute accredited in accordance with DIN EN ISO/IEC 17025. Approval does not automatically follow from acceptance of the test reports. Other test reports may be recognized at the discretion of the automotive manufacturer.

1 Scope (LV123-12)

LV123-10 Various different types of electrically-driven vehicles, such as hybrid, plug-in hybrid, electric, and fuel cell vehicles, require the use of HV systems which consist of different HV components, in addition to an LV powernet.

LV123-11 The objective of this Supply Specification is to specify standardized requirements and tests regarding electrical characteristics and electrical safety for HV components.

LV123-13 This supply specification applies to HV components intended to operate in HV circuits of electrical drive systems in vehicles.

LV123-15 This document specifies requirements for electrical operating ranges, electrical characteristics, and electrical safety, as well as corresponding tests for product validation and 100% standard production testing for HV components.

LV123-1529 This Supply Specification does not apply to components of 48 V powernets.

LV123-17 Unless otherwise specified, the requirements set forth in this document apply to HV components in the original installed condition of a vehicle.

LV123-18 This document is intended as a further applicable document. The validity for HV components is specified in the OEM's requirements documentation.

2 Normative references (LV123-19)

LV123-23 The following referenced documents are indispensable for the application of this document.

LV123-24 For undated references, the latest edition of the referenced document including revisions applies. For dated references, only the edition cited applies.

LV123-2061 IEC 60384-1
Fixed capacitors for use in electronic equipment – Part 1: Generic specification

LV123-2251 Note: German edition
DIN EN 60384-1
Festkondensatoren zur Verwendung in Geräten der Elektronik – Teil 1: Fachgrundspezifikation

LV123-2252 IEC 60384-14
Fixed capacitors for use in electronic equipment – Part 14: Sectional specification – Fixed capacitors for electromagnetic interference suppression and connection to the supply mains

LV123-2253 Note: German edition
DIN EN 60384-14
Rahmenspezifikation – Festkondensatoren zur Unterdrückung elektromagnetischer Störungen, geeignet für Netzbetrieb

LV123-1531 IEC 60364-5-54
Low-voltage electrical installations - Part 5-54: Selection and erection of electrical equipment - Earthing arrangements and protective conductors

LV123-2254 Note: German edition:
DIN VDE 0100-540
Errichten von Niederspannungsanlagen - Teil 5-54: Auswahl und Errichtung elektrischer Betriebsmittel - Erdungsanlagen und Schutzleiter

LV123-1532 IEC/TS 60479-1
Effects of current on human beings and livestock - Part 1: General aspects

LV123-2255 Note: German edition:
DIN IEC/TS 60479-1
Wirkungen des elektrischen Stromes auf Menschen und Nutztiere –
Teil 1: Allgemeine Aspekte

LV123-31 IEC 60664 (all parts)
Insulation coordination for equipment within low-voltage systems

LV123-2256 Note 1: German edition:
DIN EN 60664 (alle Teile)
Isolationskoordination für elektrische Betriebsmittel in Niederspannungsanlagen

LV123-2257 Note 2: Chinese edition:
GB/T 16935 (all parts)
Insulation coordination for equipment within low-voltage systems

LV123-43 ISO 20653
Road vehicles - Degree of protection (IP-Code) - Protection of electrical equipment against foreign objects, water and access

LV123-2258 VDI/VDE 2862 Blatt 1
Mindestanforderungen zum Einsatz von Schraubsystemen und - werkzeugen - Anwendungen in der Automobilindustrie

LV123-2259 Note: English edition:
VDI/VDE 2862 Part 1
Minimum Restrictions for Application of Fastening Systems and Tools - Applications in the Automotive Industry

LV123-1503 Note: Additional standards, regulations or legal regulations are noted as bibliographic references in Section "Annex A (informative) Bibliographic references".

3 Terms, definitions and abbreviations (LV123-73)

3.1 Terms and definitions (LV123-74)

LV123-2079 **Leakage current**
Electric current in an unwanted conductive path under normal operating conditions.

LV123-75 **Live parts**
All conductors or conductive parts to which electric voltage is applied during normal use.

LV123-1534 **Asymmetrical isolation fault**
Isolation fault that occurs when the isolation resistance, for example, of a terminal (conductor) of a circuit is reduced significantly more than that of the other terminals (conductors).

LV123-2080 **Complex disassembly**
Design feature that describes the effort required for the removal (disassembly) of parts or components from a vehicle.

LV123-1535 **Basic insulation**
Insulation of live parts as basic protection.

LV123-2260 Note: Basic insulation does not include any insulation serving exclusively functional purposes.

LV123-2370 **Basic protection**
Protection against electric shock under fault-free conditions.

LV123-2081 **Touch current**
Electric current passing through a human body or through an animal body when it touches one or more exposed conductive parts of electric equipment.

LV123-76 **Operating voltage**
RMS value of the voltage of an electric circuit that can be measured with any insulation, in an open electric circuit, or under normal operating conditions.
Transient effects may be ignored.

LV123-77 **Boost mode**
Operating mode of a DC/DC converter that provides the corresponding electrical power flow while converting from a lower voltage level to a higher voltage level.

LV123-1536 **On-board charger**
Power electronics in the vehicle which convert the alternating voltage of an external AC power supply or from the low-voltage supply network into a direct voltage for an HV circuit of the vehicle.

LV123-78 **Buck mode**
Operating mode of a DC/DC converter that provides the corresponding electrical power flow while converting from a higher voltage level to a lower voltage level.
For a DC/DC converter HV/LV, this mode corresponds to the function of an LV alternator.

LV123-1553 **Control pilot, control pilot function**
Insulated conductor which is incorporated in the charging cable assembly and that together with the protective conductor (PE) forms a CP circuit. The control pilot circuit is designed for the transmission of signals between the vehicle and equipment of the external electric power supply and can be used for different functions referred to as control pilot functions.

LV123-2082 **DC interconnection circuit**
Vehicle circuit used to connect to an external electric power supply and which includes all HV components including HV cables which are galvanically connected to the DC vehicle inlet when the switching equipment for the DC power supply is switched to off. When DC power supply is active, the DC interconnection circuit forms a sub-circuit of the DC power supply circuit.

LV123-79 **DC/DC converter**
Power electronics unit that, when a certain DC voltage is input, generates a different DC voltage. Bi-directional operation can be possible, see Boost mode, Buck mode.

LV123-80 **Direct contact**
Contact with live parts by persons or animals (pets).

LV123-1537 **Double insulation**
Insulation comprising both basic insulation and supplementary insulation.

LV123-81 **Electrical ground, vehicle ground**
A set of conductive parts that are connected to each other electrically (galvanically) and all other conductive parts that are connected to this electrically (galvanically), and the potential of which is used as reference value.

LV123-16 **Electrical safety**
Protection of persons and animals against electrical hazards.

LV123-1538 **Simple separation**
Separation between electric circuits or between an electric circuit and conductive parts by means of basic insulation.

LV123-2261 Note: The term "separation" is not synonymous with the term "isolation" and the related functional requirements.

LV123-82 **Electric drive system**
The electric drive system is an integral part of the HV system.
It consists of an electric machine and an inverter.

LV123-1539 **External electric power supply**
Equipment outside the vehicle intended for the electric power supply for the vehicle HV system, e.g. AC or DC power supply for the charging of the HV battery.

LV123-1540 **Vehicle coupler**
Coupler for the connection of a flexible charging cable to a vehicle used for connection to an external electric power supply.

LV123-2262 Note: The vehicle coupler consists of two parts, a vehicle connector and a vehicle inlet.

LV123-83 **Exposed conductive part**
Conductive part of equipment which can be touched and which is not normally live, but that can become live when basic insulation fails.

LV123-2083 **Fuel cell stack (FC stack)**
Electrochemical energy converter consisting of multiple fuel cells and parts for conducting oxidation, fuel and cooling media. HV component of the HV system.

LV123-1541 **Galvanic separation**
Separation between circuits such that no electrons can flow between the individual circuits.

LV123-2263 Note 1: Galvanic separation can be provided by means of simple separation or

protective separation.

LV123-2264 Note 2: Galvanic separation can be provided, for example, by an isolating transformer or an optocoupler.

LV123-1542 **Controlled HV component**
HV component with switching equipment acting on an HV circuit (switching on, off) or power-electronic control, e.g. HV battery, power electronics.

LV123-84 **HV battery**
Electric energy storage intended for supplying power to the HV system or the HV circuits.
The HV battery can include the following subcomponents:

- Battery cells and modules
- Internal battery cooling
- Electronics for cell monitoring
- Fuses and HV switching devices
- Electronic control unit for battery management
- Housing
- All corresponding connections.

LV123-85 **HV component**
Components including wiring harnesses which are part of HV circuits or an HV system and that are operated with voltages of voltage class B in accordance with Section "Voltage class".

LV123-2265 Note: HV components can include LV sub-assemblies, e.g. electronic control units, measuring systems, and sensor systems.

LV123-2084 **HV contacting**
Connection established by means of plug connections or screw terminal connections for HV components, HV cables and HV wiring harnesses.

LV123-1543 **HV cable**
Insulated cable without assembled HV contacting for the electrical connection between HV components in the HV circuit.

LV123-1544 **HV wiring harness**
Insulated cable or cables with assembled HV contacting for the electrical connection between two HV components in the HV circuit, but without any other attached parts.

LV123-2085 **HV source**
HV component that contains stored energy or that converts externally supplied other types of energy into electric energy and that can feed electric energy into a DC HV circuit.

LV123-2266 Note 1: Examples include HV battery, rechargeable energy storage, ultracapacitor, FC stack.

LV123-2267 Note 2: Parts of HV components, e.g. X capacitors, are not designated as HV sources under this definition.

LV123-86 **HV circuit**
The entire set of galvanically connected live parts of HV components carrying electric current under normal operating conditions. The following electric circuits are distinguished:

- DC HV circuits (direct current)
- AC HV circuits (alternating current)
- DC power supply circuit
- AC power supply circuit
- DC interconnection circuit.

LV123-87 **HV system**
System of voltage class B in accordance with Section "Voltage class", consisting of the HV wiring harness and all HV components (e.g. load, generator, energy storage).

LV123-88 **Indirect contact**
Electric contact of persons or animals with exposed conductive parts (bodies of electric equipment) which have become live under fault conditions.

LV123-2371 **I^2t (Joule integral)**
Integral of the square of the current over a given time interval.

LV123-2372 Note: Criterion for short-term overload.

LV123-2086 **Isolation-bridging part**
Electrical or electronic part or arrangement of parts that bridges isolation (basic insulation, double or reinforced insulation) and establishes a conductive connection.

LV123-89 **Creepage distance**
The shortest distance between two conductive parts along the surface of an insulating material.

LV123-1545 **Short-circuit**
Accidental or intentional conductive path between two or more conductive parts forcing the electric potential differences between these conductive parts to be equal to or close to zero.

LV123-1546 **Short-circuit current**
Current in the case of a short-circuit.

LV123-1547 **Vehicle inlet**
Part of the vehicle coupler which is permanently attached to the vehicle.

LV123-1548 **Vehicle connector**
Part of the vehicle coupler which is permanently attached to the charging cable.

LV123-90 **Power electronics**
A device for the control or transmission of electrical power, including integrated electronic control units, e.g. inverter or DC/DC converter.

LV123-1549 **HV component controlled by power electronics**
HV component with related power electronics which can also include an integrated electrical load, e.g. electrical air conditioner compressor, drive system inverter, DC/DC converter.

LV123-2268 Note: A HV component controlled by power electronics can be designed such that it can feed electric energy into a DC HV circuit under operational conditions, e. g. a drive system inverter, DC/DC converter or on-board charger.

LV123-91 **Conductive part**
Part which can carry electric current.

LV123-2269 Note: Includes parts that are not necessarily live under normal operating conditions.

LV123-92 **Clearance**
The shortest distance in air between two conductive parts.

LV123-93 **LV powernet, also LV system**
Infrastructure for the electrical power supply for a vehicle (12 V or 24 V) including all LV circuits.

LV123-1550 **Mechanical switching device**
Switching device designed to close and to open one or more circuits by means of separable contacts.

LV123-94 **Nominal voltage**
The rms voltage value, specified by the manufacturer, for which the electric circuit is designed and on which its characteristic values are based.

LV123-95 **Nominal value**
An adequate, rounded value of a quantity used to designate or identify an element, a group, or equipment.

LV123-1551 **Low-voltage supply network**
Intended for the supply of household and industrial loads through standardized plugs and sockets with electric energy and is operated, depending on the country, as single phase or multiphase at different nominal voltages.

LV123-1552 **Neutral conductor**
Conductor electrically connected with the neutral point of an electric supply circuit and which is capable of contributing to the distribution of electric energy.

LV123-2373 **Equipotential bonding**
Provision of electric connections between conductive parts, intended to achieve equipotentiality.

LV123-1554 **Rescue disconnect**
Manually operated means to shut off the HV system, e.g. by rescue personnel after an accident. This is no equipment for actuation during normal operation.

LV123-1555 **Contactor**
Mechanical switching device having only one position of rest, which is not actuated manually, capable of making, carrying and breaking currents under operating conditions in the circuit, including overload.

LV123-1558 **Protective conductor (PE)**
Conductor provided for purposes of safety, for example protection against electric shock.

LV123-2087 **Protective conductor current**
Electric current appearing in a protective conductor, such as leakage current or electric current resulting from an isolation fault.

LV123-2088 **Service case**
Maintenance or repair procedure that is described in an OEM instruction.

LV123-1556 **Protective separation**
Separation of one electric circuit from another by means of double or reinforced insulation.

LV123-2270 Note: The term "separation" is not synonymous with the term "isolation" and the related functional requirements.

LV123-1557 **Standstill function**
Function of the HV system which is executed with or without connection to an external electric power supply during vehicle standstill (parked, driving not enabled) (e.g. charging of HV battery, air conditioning).

LV123-96 **Electric circuit**
The entire set of connected live parts carrying electric current under normal operating conditions.

LV123-1559 **Symmetrical isolation fault**
Isolation fault which occurs when the isolation resistances of all terminals (conductors) of a circuit are reduced equally.

LV123-2374 **TN system**
Type of network in a power supply system (low-voltage supply network) designated for the type of connection with earth used.

- T (first letter): Direct connection of a point with earth (indicates the relation between power-supply system and earth).
- N (second letter): Direct electric connection of exposed conductive parts of equipment with the earthed point of the power-supply system (indicates the relation between exposed conductive parts of equipment and earth).

LV123-2375 **TT system**
Type of network in a power supply system (low-voltage supply network) designated for the type of connection with earth used.
- T (first letter): Direct connection of a point with earth (indicates the relation between power-supply system and earth).
- T (second letter): Direct electric connection of exposed conductive parts of equipment to earth, regardless of how the power-supply system is earthed (indicates the relation between exposed conductive parts of equipment and earth).

LV123-1560 **Overcurrent**
Electric current exceeding the rated electric current.

LV123-1561 **Overload current**
Overcurrent occuring in an electric circuit, which is not caused by a short-circuit or an earth fault.

LV123-2089 **Underload factor**
Factor for electrical and electronic parts that indicates the ratio between operating requirements and rated values of parts.

LV123-1562 **Power supply circuit**
Vehicle electric circuit which includes all HV components including HV cables which are galvanically connected to the vehicle inlet and which are operational when connected to an external electric power supply. The following power supply circuits are distinguished:
- DC power supply circuit
- AC power supply circuit
- DC interconnection circuit.

LV123-1563 **Reinforced insulation**
Insulation of live parts which provides a degree of protection against electric shock equivalent to double insulation.

LV123-2271 Note: Reinforced insulation may comprise several layers which cannot be tested separately as basic insulation or supplementary insulation.

LV123-97 **Inverter**
Power electronics unit that generates an AC voltage with a desired amplitude and frequency from a given DC voltage. An operating mode for the generation of a DC voltage from a given AC voltage can be possible.

LV123-2090 **Rechargeable energy storage**
HV component that stores energy to be supplied to the electric drive system and that is rechargeable.

LV123-2272 Note: Examples include HV battery, HV capacitor.

LV123-488 **X capacitors**
X capacitors are input capacitors in HV components located between the poles of the relevant HV circuit.

LV123-2273 Note: Examples include X capacitors located between the poles of a DC HV circuit and X capacitors located between the phases, or between a phase and a neutral conductor, of the AC power supply circuit.

LV123-2091 **Y capacitors**
Y capacitors are input or filter capacitors in HV components located between a pole of the relevant HV circuit and the vehicle ground. Y capacitors are bridging an isolation.

LV123-2274 Note: Examples include Y capacitors located between a pole of a DC HV circuit and the vehicle ground and Y capacitors located between a phase or a neutral conductor of the AC power supply circuit and the electric vehicle ground.

LV123-1564 **Supplementary insulation**
Independent insulation applied in addition to basic insulation for fault protection.

3.2 Abbreviations (LV123-98)

LV123-99

LV123-100

Table: Abbreviations, part 1/2

AC, a.c.	Alternating current
ANSI	American National Standards Institute
AOI	Automatic Optical Inspection
BEV	Battery -Electric Vehicle
BOL	Beginning Of Life; new condition, brand-new
C	Capacitor, Capacitance
CAD	Computer-aided design
CCS	Combined Charging System, DC system for external electric power supply
CFRP	Carbon-fiber reinforced plastic (Carbon-Faserverstärkter Kunststoff, CFK)
CHAdeMO	Charge for move, DC system for external electric power supply
CMVSS	Canada Motor Vehicle Safety Standards
CNCA	Certification and Accreditation Administration of the People’s Republic of China
CTI	Comparative tracking index
DC, d.c.	Direct current
DIN	German Institute for Standardization (Deutsches Institut für Normung)
DS	Identification and documentation of safety relevance
DUT	Device under test
DZ	Identification and documentation of certification relevance
ECE	Economic Commission for Europe
EMC	Electromagnetic Compatibility
EOL	End Of Life; end of specified service life
FC	Fuel Cell
FCV	Fuel Cell Vehicle
FMVSS	Federal Motor Vehicle Safety Standards
GB, GB/T	National Standard of the People’s Republic of China
HEV	Hybrid Electric Vehicle
HV	High Voltage
HV+	Positive potential of DC HV circuit
HV-	Negative potential of DC HV circuit

LV123-101

Table: Abbreviations, part 2/2

LV123-102

I	Current
ICT	Integrated Circuit Test
IEC	International Electrotechnical Commission
IECQ	IEC Quality assessment system for electronic components
IP	International Protection, Ingress Protection
IP Code	A coding system to indicate the degrees of protection provided by an enclosure against access to hazardous parts, against ingress of solid foreign objects and/or ingress of water and to give additional information in connection with such protection
IPXXB	IP code for the degree of protection in accordance with ISO 20653 which refers to a jointed test finger
IPXXD	IP code for the degree of protection in accordance with ISO 20653 which refers to test wire of probe D
ISO	International Organization for Standardization
KMVSS	Korea Motor Vehicle Safety Standards
LV ###	Supply specification (Liefervorschrift)
LV	Low voltage, voltage of LV powernet (12 V, 24 V or 48 V)
NCS	Natural Color System, designation of a color model
OEM	Original Equipment Manufacturer, automotive manufacturer
PE	Protected Earth, protective conductor
PHEV	Plug-in Hybrid Electric Vehicle
pk	Peak
PMS	Pantone Matching System, designation of a color model
PTC	Positive Temperature Coefficient
QC, QC/T	Professional Standard of Automotive Industry of the People's Republic of China
R	Resistance
RAL	Reichsausschuss für Lieferbedingungen, designation of a color model
rms	Root mean square
SAE	Society of Automotive Engineers
SOC	State Of Charge
t	Time
U	Voltage
UL	Underwriters Laboratories Inc., USA
U, V, W	AC HV connections for electric machine

4 General requirements (LV123-103)

LV123-25 In the event of possible conflicts between requirements as stated in this document and requirements as stated in the listed normative references in Section "Normative references", the supplier shall report said conflicts and clarify the issue with the OEM.

LV123-26 If further standards, regulations or legal regulations apply to individual HV components, said references shall be indicated to the OEM by the supplier. In the event of possible conflicts between requirements as stated in these normative references and requirements as stated in this document, the supplier shall report said conflicts and clarify the issue with the OEM.

LV123-287 In principle, the requirements for electrical characteristics and HV safety shall be met in all sample versions of HV components. Deviations and substitute measures shall be reported by the supplier and shall be coordinated with and authorized by the OEM.

LV123-2093 Unless otherwise specified, all requirements pertaining to HV components shall be fulfilled over the specified service life (EOL).

LV123-749 If repairs for an HV component are planned, the HV component shall be tested after the repairs. Testing shall be performed in accordance with Section "Testing of HV components following repair".

5 Overview of HV system (LV123-105)

5.1 HV system (LV123-106)

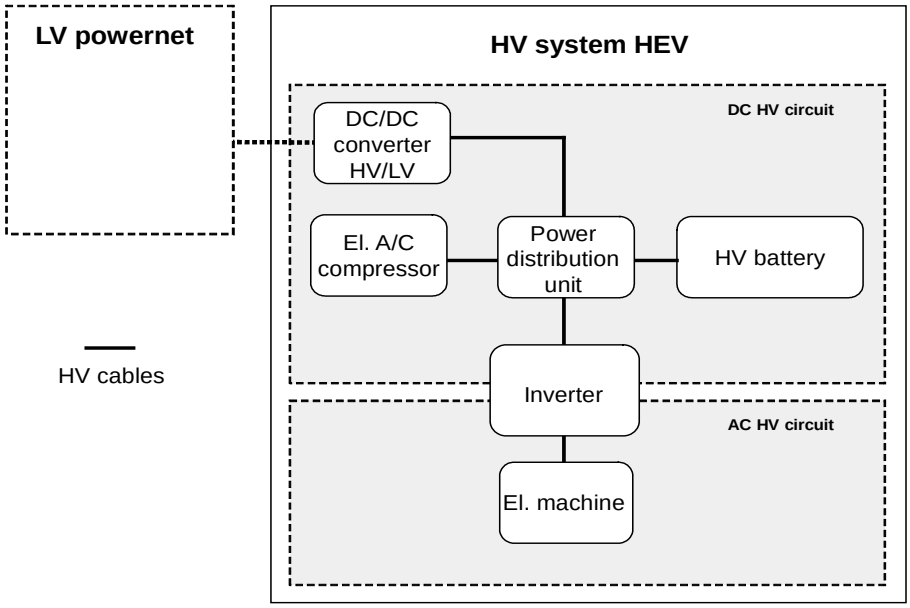
LV123-107 The HV system of a vehicle with an electric drive system consists of several HV components.

LV123-108 Figures "Sample system overview HEV" and "Sample system overview BEV, PHEV - Connection to external DC power supply switched on" provide sample overviews of the HV systems of electrically propelled vehicles, including the interface to the LV powernet.

LV123-109 Note: The system overview depends on the system configuration of the vehicle and on the type of electric vehicle, e.g. hybrid vehicle, fuel cell vehicle, or battery electric vehicle.

LV123-110 The system overview that applies to the dedicated vehicle shall be gathered from the OEM's requirements documentation.

LV123-111



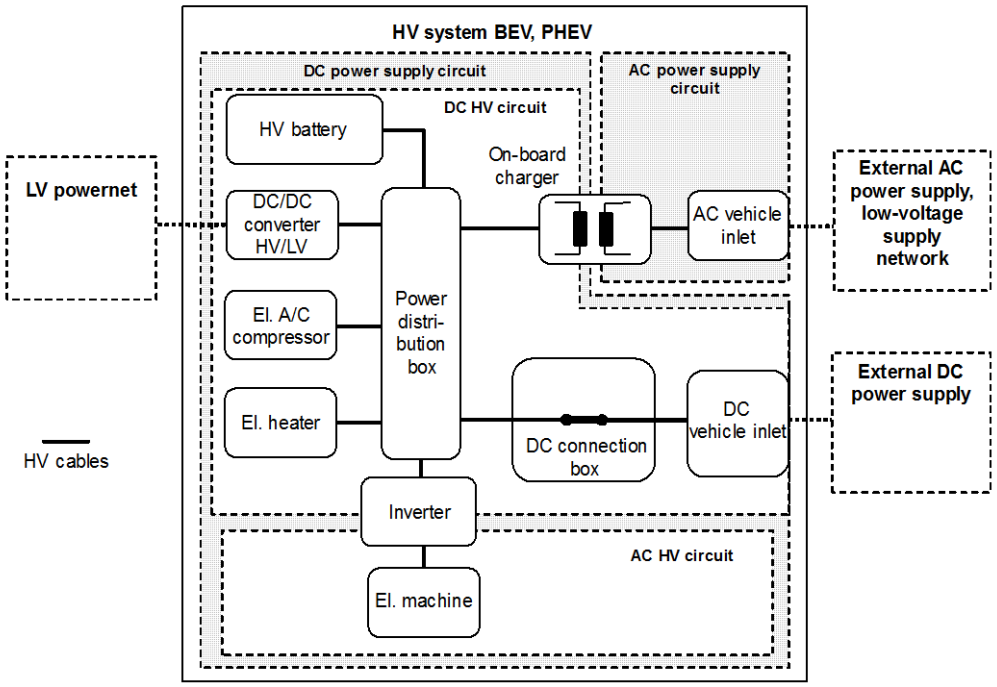
LV123-112 Figure: Sample system overview HEV

LV123-2094 For vehicles with a connection to an external electric power supply, the connections to an external AC and DC power supply are shown in Figure "Sample system overview BEV, PHEV - Connection to external DC power supply switched on". With respect to the vehicle power supply circuit, a distinction is drawn between an AC power supply circuit and a DC power supply circuit depending on which connection is used.

LV123-2095

For vehicles with a connection to an external DC power supply, the DC interconnection circuit is shown in Figure "Sample system overview BEV, PHEV - Connection to external DC power supply switched off". When the DC power supply is switched on, this circuit forms a part of the DC power supply circuit. The DC inter-connection circuit is considered as a separate circuit when the external DC power supply is connected to the vehicle inlet and the DC power supply circuit is switched off.

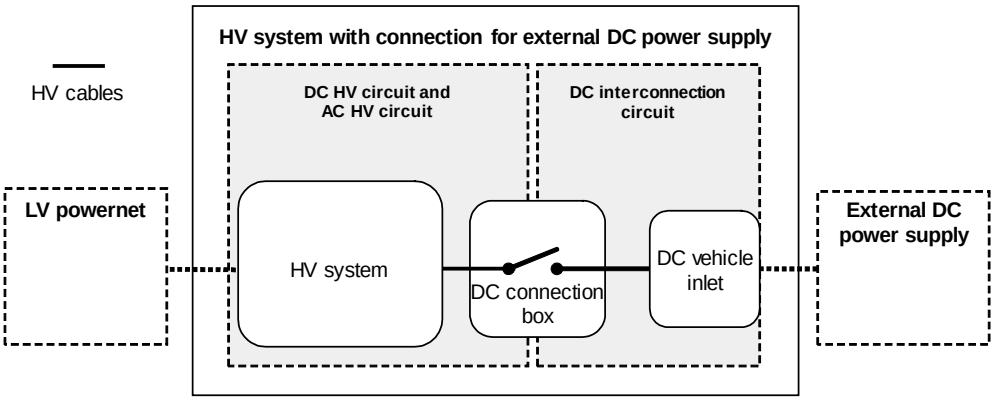
LV123-1565



LV123-1566

Figure: Sample system overview BEV, PHEV - Connection to external DC power supply switched on

LV123-2096



LV123-2097

Figure: Sample system overview BEV, PHEV - Connection to external DC power supply switched off

5.2 HV components (LV123-113)

LV123-114 **Typical HV components of an HV system:**

- Energy storage, such as an HV battery or an HV battery system
- Power distribution unit; if necessary, with fuse protection for HV sub-circuits
- Inverter for the motor-based and generation-based operation of an electric machine in an AC HV circuit; integral part of drive system
- Transmission with one or more integrated electric machines and/or integrated electrical transmission oil pump
- Electrical machine as individual component of, for example, an AC HV circuit designed as a three-phase current electric circuit by means of an inverter; integral part of the drive system
- Loads such as electrical air conditioning compressor, electrical transmission oil pump, and HV heater; including, in each case, power electronics, electric motor, corresponding electrics/electronics with integrated LV electronic control units included
- DC/DC converter HV/LV for exchanging electric energy from the DC HV circuit to the LV powernet in buck mode operation (if necessary, also bi-directional, i.e., from the LV powernet to the DC HV circuit in boost mode operation)
- HV wiring harness for DC HV circuits (HV+ and HV- potentials) and AC HV circuit for an electric motor (U, V, W potentials)
- On-board charger, vehicle inlet
- HV wiring harnesses for AC and DC power supply circuits for connection to an external electric power supply.

LV123-115 HV components may be designed as

- devices or
- built-in vehicle part.

LV123-116 Devices are HV components that meet the requirements regarding electrical characteristics and electrical safety that apply when HV contacting is disconnected.

LV123-117 Built-in vehicle parts are HV components that meet the requirements regarding electrical characteristics and electrical safety in the original installed condition inside the vehicle (e.g. electric machine outside of a transmission).

LV123-286 For HV components designed as built-in vehicle parts, adjustments may be necessary for individual requirements. These shall be specified by the supplier and agreed upon with the OEM.

LV123-118 The specification as to which components are an integral part of an HV system, as well as the designations of the HV components, shall be gathered from the OEM's requirements documentation.

LV123-119 The design of an HV component as a device or as a built-in vehicle part shall be gathered from the OEM's requirements documentation.

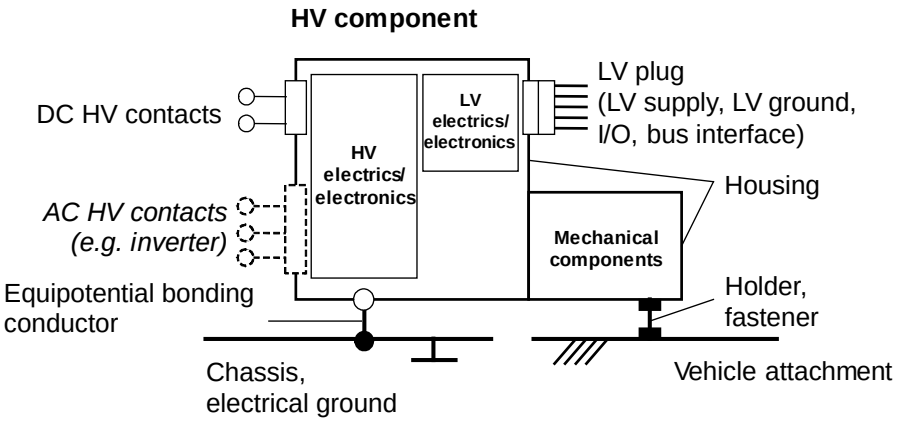
LV123-120

Typical main integral parts of an HV component:
Following is a list of typical main integral parts of an HV component, see Figure "HV component diagram":

- Mechanical component (e.g. air conditioning compressor, pump, transmission)
- LV control electronics/control unit with I/Os and, if necessary, an interface to a bus system (e.g. CAN, LIN, Flexray)
- LV contacting
- Contacting for equipotential bonding; if necessary, equipotential bonding conductor
- HV electrics, -electronics
- HV contacting
- Cooling, connections for media
- Housing, cover, marking
- Bracket and fasteners.

For details, see OEM's requirements documentation.

LV123-121



LV123-122

Figure: HV component diagram

LV123-123

Additional integral parts or add-on parts of an HV component
Following is a list of possible additional integral parts or add-on parts that complete an HV component to form an assembly:

- LV cables and contacting
- HV cables and contacting
- Cooling hoses or ducts
- Operating media
- Brackets, fasteners.

For details, see OEM's requirements documentation.

6 Electrical operating ranges of the HV system (LV123-126)

6.1 Voltage class (LV123-128)

LV123-136 Note: Bibliographic references: ECE-R100, GB/T 18384.3, ISO 6469-3

LV123-137 Voltage class B is a classification of HV components or HV circuits with a maximum operating voltage of:

- 60 V d.c. < U ≤ 1500 V d.c. or
- 30 V a.c. (rms) < U ≤ 1000 V a.c. (rms).

LV123-140 The specification of voltage class B for AC voltage is relevant to the circuits of HV systems in which alternating current or three-phase current components, e.g. the electric drive system, are used.

LV123-1567 Components for 48 V powernets assigned to voltage class B are not covered by this document.

6.2 HV operating status (LV123-141)

LV123-142 The HV operating statuses in Table "HV operating status" apply to HV components.

LV123-143 Table: HV operating status

LV123-144

HV operating status	Description of HV operating status
B0	The HV components are operational and there is no power demand.
B1	The HV components are fully operational, and provide their intended performance.
B2	The HV components are still fully operational. The HV components provide a performance within the deviations permissible for operating status B2. When the HV components revert to operating status B1, they shall automatically provide their intended performance.
B3	The HV components are still operational, shall not assume any undefined states and, in particular, shall not cause any malfunctions in other HV components. The HV components may reduce their output for self-protection purposes. When the HV components revert to operating status B1 or B2, they shall automatically provide their intended performance.
B4	The HV components are still operational and shall not assume any undefined states. The HV components may switch off their output. When the HV components revert to operating status B1, B2 or B3, they shall provide their intended performance by means of a reset or a simple intervention (e.g. change of ignition status, restart vehicle).

LV123-145 Details regarding the requirements for HV operating statuses for individual HV components shall be gathered from the OEM's requirements documentation.

LV123-146 In this document, the HV operating statuses are limited exclusively to functions that depend directly on the voltage in HV circuits.

LV123-147 The requirements for the HV operating statuses are also valid if power is internally supplied to the electronic control unit exclusively, or additionally, via the DC HV circuit.

LV123-1568 The operating status of an HV component shall be available for read-out via a corresponding diagnostic request if the HV component is also a LIN, CAN, or Flexray control unit.

6.3 Voltage ranges (LV123-148)

6.3.1 Voltage levels (LV123-149)

LV123-150 Various different HV voltage levels apply to different HV system power classes or to different types of vehicles featuring HV systems respectively.

LV123-151 The following voltage levels are defined for DC HV circuits:

- HV_1
- HV_2a
- HV_2b
- HV_3.

LV123-152 For vehicles with HV systems with higher power, an agreement regarding additional voltage levels with higher voltages and adjusted test voltages is required if necessary. See OEM's requirements documentation.

LV123-153 The parameters and values for the HV voltage levels shall be gathered from the subsections of Section "HV voltage ranges".

6.3.2 HV voltage ranges (LV123-154)

LV123-156 Table "HV voltage ranges" specifies the corresponding HV voltages and HV operating statuses for the introduced voltage levels for power demand. The specifications apply to HV system DC HV circuits. The voltage values are steady-state values up to the maximum HV operating voltage.

LV123-157 The assignment of the HV system and the HV components to the voltage levels in Table "HV voltage ranges" shall be gathered from the OEM's requirements documentation.

LV123-1569 The numerical values of the introduced HV voltage levels may be adjusted by the OEM specific to each project. The specifications shall be gathered from the OEM's requirements documentation.

LV123-158 Table: HV voltage ranges

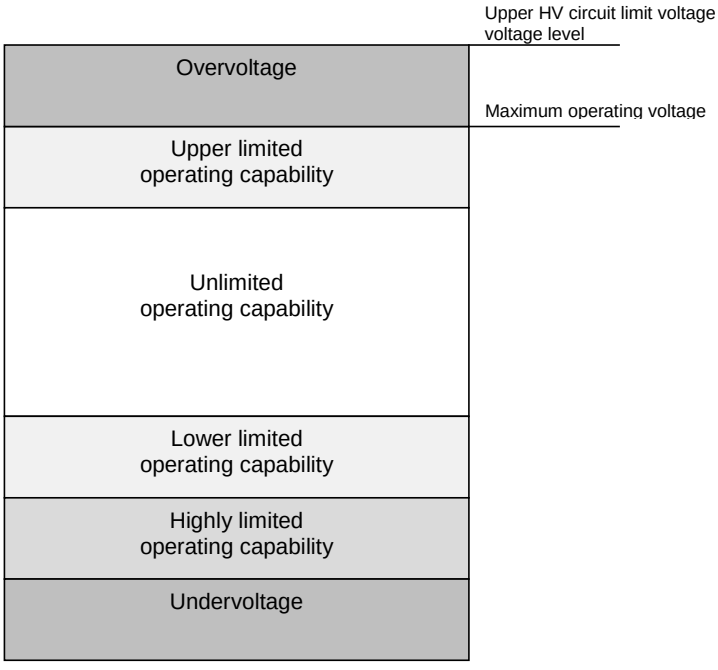
LV123-159

HV voltage ranges	HV operating status	Unit	HV_1	HV_2a	HV_2b	HV_3
Overvoltage at load dump [d]	B3/B4	V pk	220	410	500	800
Upper HV circuit limit voltage [d]	B3/B4	V pk	220	410	500	800
Maximum operating voltage [c]	B2	V d.c.	200	360	470	770
Upper limited operating capability [c]	B2	V d.c.	>190 - 200	> 340-360	>450 - 470	>750 - 770
Unlimited operating capability [c]	B1	V d.c.	90 - 190	170 - 340	250 -450	520-750
Lower limited operating capability [c]	B2	V d.c.	80 - < 90	160 - < 170	200 - < 250	450 - < 520
Highly limited operating capability [c]	B2 [a] B3 [b]	V d.c.	60 - < 80	120 - < 160	150 - < 200	-
Undervoltage [d]	B3	V d.c.	0 - < 60	0 - < 120	0 - < 150	0 - < 450

[a] : Components which are relevant for establishing readiness-for-driving
[a] : Components which are not relevant for establishing readiness-for-driving
[c] : Operating voltage ranges
[d] : Deviations from operating voltage ranges

LV123-1570 Below, the HV voltage ranges are represented as a graph. The relevant numerical values of the corresponding voltage level shall be gathered from the Table "HV voltage ranges".

LV123-1571



LV123-1572 Figure: HV voltage ranges

6.3.3 Operating voltages (LV123-1573)

6.3.3.1 Overview of operating voltages (LV123-1574)

LV123-160 All HV components shall comply with the HV voltage ranges in accordance with Table "HV voltage ranges" for the applicable voltage level in accordance with Table "HV voltage ranges".

LV123-161 All HV components shall comply with HV operating status requirements in accordance with Table "HV operating status" for the applicable voltage level in accordance with Table "HV voltage ranges".

LV123-162 The voltage value requirements in accordance with Table "HV voltage ranges" shall be taken into account for all HV components considering the exceptions described as follows.

LV123-163 The maximum operating voltage shall be complied with for the HV battery when the switching equipment of the HV battery is switched off.

LV123-164 Separate requirements within the voltage limits in accordance with Table "HV voltage ranges" apply to the operating voltage ranges of the HV battery when the switching equipment is switched on. These requirements shall be gathered from the related OEM's requirements documentation.

LV123-165 Separate requirements apply to the operating voltage ranges of the electrical machines in the AC HV circuit. These requirements shall be gathered from the related OEM's requirements documentation.

LV123-1575 This requirements document is based on the assumption that all AC HV voltages (peak) lie within the DC HV voltage ranges under intended operating conditions.

LV123-166 During pre-charging of the HV system, passing through the voltage range going from

- 0 V d.c. up to
- the minimum operating voltage in the range of highly limited operating capability, see Table "HV voltage ranges",

shall not be detected as an undervoltage, see Section "Undervoltage".

LV123-167 During pre-charging of the DC HV circuit, the requirements necessary for this purpose shall be complied with; see the OEM's requirements documentation.

6.3.3.2 Range of unlimited operating capability (LV123-168)

LV123-169 For testing, see Section "Test: Range of unlimited operating capability"

LV123-170 In the range of unlimited operating capability in accordance with Table "HV voltage ranges", it shall be possible for the HV components to be operated with the intended performance without time-based limitations.

LV123-171 The HV components shall comply with HV operating status B1, see Table "HV operating status".

6.3.3.3 Range of upper limited operating capability (LV123-172)

LV123-173 For testing, see Section "Test: Range of upper limited operating capability"

LV123-174 The operating voltages in the range of upper limited operating capability apply to the continuous operation of the HV components, excluding the HV battery.

LV123-175 In the range of upper limited operating capability in accordance with Table "HV voltage ranges", the HV components shall be fully operational without time-based limitations.

LV123-176 The HV components shall comply with HV operating status B2, see Table "HV operating status".

LV123-177 If, following a deviation, the HV voltage falls within the range of unlimited operating capability again, unlimited operating capability or the HV operating status B1 shall be complied with again automatically.

6.3.3.4 Range of lower limited operating capability (LV123-178)

LV123-179 For testing, see Section "Test: Range of lower limited operating capability"

LV123-180 The specified operating voltages shall apply to the continuous operation of the HV components, excluding the HV battery or the electric energy storage.

LV123-181 In this operating voltage range, the HV battery shall comply with the HV operating status B2 for the maximum duration of a sequence for establishing readiness-for-driving.

LV123-182 In the range of lower limited operating capability in accordance with Table "HV voltage ranges", the HV components shall be fully operational without time-based limitations.

LV123-183 The HV components shall comply with HV operating status B2, see Table "HV operating status".

LV123-184 If, following a deviation, the HV voltage falls within the range of unlimited operating capability again, unlimited operating capability or the HV operating status B1 shall be complied with again automatically.

6.3.3.5 Range of highly limited operating capability (LV123-185)

LV123-186 For testing, see Section "Test: Range of highly limited operating capability"

LV123-187 The specified operating voltages shall apply to the continuous operation of the HV components, excluding the HV battery or the electric energy storage. The requirements pertaining to continuous operation shall be gathered from the OEM's requirements documentation.

LV123-188 In the range of highly limited operating capability, the HV battery shall comply with the HV operating status B2 for the maximum duration of a sequence for establishing readiness-for-driving.

LV123-189 In the range of highly limited operating capability in accordance with Table "HV voltage ranges", the HV components shall be functional without time-based limitations.

LV123-190 If HV components are relevant for establishing readiness-for-driving, they shall comply with the HV operating status B2, see Table "HV operating status".

LV123-191 If HV components are not relevant for establishing readiness-for-driving, they shall comply with the HV operating status B3, see Table "HV operating status".

LV123-192 If, following a deviation, the HV voltage falls within the range of unlimited operating capability again, unlimited operating capability or the HV operating status B1 shall be complied with again automatically.

LV123-193 If, following a deviation, the HV voltage falls within the range of limited operating capability again, limited operating capability or the HV operating status B2 shall be complied with again automatically.

LV123-194 The assignment whether or not the HV component is relevant for establishing readiness-for-driving, as well as the HV operating status required for the HV component, shall be gathered from the OEM's requirements documentation.

6.3.4 Dynamic parameters (LV123-195)

6.3.4.1 Overview of dynamic parameters (LV123-196)

LV123-197 The dynamic parameters in Table "Dynamic parameters" apply to HV components.

LV123-198 Table: Dynamic parameters

LV123-199

Parameter	Unit	HV_1	HV_2a HV_2b	HV_3
Generated voltage dynamics (slope) between two different steady-state voltage levels (holding time > 2 s), generated by individual HV component (i.e. operating voltage without ripple)	V/ms	+/- 15	+/- 15	+/- 15
Present voltage dynamics (slope) between two different steady-state voltage levels (holding time > 2 s), robustness during operation in DC HV circuit (i.e. operating voltage without ripple)	V/ms	+/- 20	+/- 20	+/- 20
Present and generated voltage ripple with HV battery switched on (at specified continuous output)	V pk	+/- 8	+/- 8	+/- 8
Present and generated voltage ripple with HV battery switched off (at specified continuous output)	V pk	+/- 15	+/- 15	+/- 15

LV123-200 The specification of whether or not operation with the HV battery switched off (switching equipment switched off) is intended for the HV system shall be gathered from the OEM's requirements documentation.

LV123-201 For the operation of the HV components, the dynamic parameters for the various HV voltage levels are specified in Table "Dynamic parameters".

LV123-203 If operation with the HV battery switched off (switching equipment switched off) is intended for the HV system, a modified HV operating status can apply, in which case it shall be gathered from the OEM's requirements documentation.

6.3.4.2 Voltage dynamics (LV123-204)

LV123-205 For testing, see Section "Test: Voltage dynamics"

LV123-206 **Generated voltage dynamics (slope)**

LV123-207 The change of the DC HV circuit voltage over time shall be limited to the specified maximum generated voltage dynamics (slope) for every HV component that is controlled by power electronics; see Table "Dynamic parameters". The requirement shall be fulfilled for all HV operating statuses in accordance with Table "HV operating status".

LV123-208 The HV operating status of the HV component in the respective operating voltage range shall not change due to generated voltage dynamics (slope). It shall be taken into account that the specified operating voltage ranges are described by steady-state values; see Table "HV voltage ranges". Additionally, the requirements regarding voltage ripple shall be complied with, see Section "Voltage ripple".

LV123-209 The technical specifications of the HV component regarding the voltage dynamics actually generated shall be documented by the supplier for the entire operating range.

LV123-1576 The supplier shall deliver equivalent circuit diagrams of the power path of the HV components to the OEM. Details shall be gathered from the OEM's requirements documentation.

LV123-210 **Present voltage dynamics (slope)**

LV123-211 For every HV component, robustness in the sense of stable electrical operation shall be provided during a change over time of the DC HV circuit voltage with the maximum present voltage dynamics (slope) in accordance with Table "Dynamic parameters". With regard to this requirement, all HV operating statuses shall be complied with in accordance with Table "HV operating statuses" for all HV voltage ranges in accordance with Table "HV voltage ranges".

LV123-212 The HV operating status of the HV component in the respective operating voltage range shall not change due to present voltage dynamics (slope). It shall be taken into account that the specified operating voltage ranges are described by steady-state values; see Table "HV voltage ranges". Additionally, the requirements regarding voltage ripple shall be fulfilled, see Section "Voltage ripple".

LV123-213 The technical specifications of the HV components regarding robustness or sensitivity with respect to the HV operating statuses when there are voltage dynamics present shall be documented by the supplier for the entire operating range.

6.3.4.3 Voltage ripple (LV123-214)

LV123-215 For testing, see Section "Test: Voltage ripple"

LV123-216 **Generated voltage ripple**

LV123-218 For every HV component controlled by power electronics, the generated voltage ripple in HV system operation with HV battery (switching equipment switched on) shall be complied with in accordance with Table "Dynamic parameters".

LV123-219 For every HV component controlled by power electronics, the generated voltage ripple in HV system operation without the HV battery (switching equipment switched off) shall be complied with in accordance with Table "Dynamic parameters".

LV123-220 The HV operating status of the HV component in the respective operating voltage range shall not change due to the superimposition of the specified voltage ripple.

LV123-221 For every HV component controlled by power electronics, the technical specifications regarding the generation of voltage ripples shall be documented by the supplier for the operating status of the HV system, both with and without an HV battery. The frequency response shall be documented by the supplier.

LV123-222 **Present voltage ripple**

LV123-223 For every HV component, robustness and stable operation shall be provided when there is a voltage ripple present during the operation of the HV system with an HV battery (switching equipment switched on) in accordance with Table "Dynamic parameters".

LV123-224 For every HV component, robustness and stable operation shall be provided when there is a voltage ripple present during the operation of the HV system without an HV battery (switching equipment switched off) in accordance with Table "Dynamic parameters".

LV123-225 The HV operating status of the HV component in the respective operating voltage range shall not change due to the superimposition of the specified voltage ripple.

LV123-226 For every HV component, the technical specifications regarding robustness or sensitivity shall be specified for the case in which there is a voltage ripple present. The operating statuses of the HV system with an HV battery and with the HV battery switched off shall be taken into account for the voltage ripple present. The frequency response shall be documented by the supplier.

6.3.5 Operating voltage deviations (LV123-227)

6.3.5.1 Overvoltage (LV123-232)

LV123-233 For testing, see Section "Test: Overvoltage"

LV123-234 The overvoltage range is the range between
- the maximum operating voltage and
- the upper HV circuit limit voltage.

LV123-2098 HV components shall fulfill the following requirements in the overvoltage range for the specified number of overvoltage events.

LV123-1577 In the overvoltage range (see Table: "HV voltage ranges") for isolated and temporary dynamic overvoltage events lasting 10 seconds each,
HV components shall be designed such that the specified service life (EOL) is complied with. The number of these overvoltage events for which compliance with the specified service life (EOL) is required shall be specified by the supplier and agreed upon with the OEM.

LV123-236 HV components shall fulfill the requirements in the overvoltage range regardless of whether the switching equipment of the HV battery is switched on or off.

LV123-237 The HV components shall comply with HV operating status B3 or B4 in the overvoltage range, see Table "HV operating status". See OEM's requirements documentation for information on the HV operating status.

LV123-238 An "Overvoltage" fault memory entry shall be set in the overvoltage range. After this, other fault memory entries shall not be set.

LV123-239 The behavior of the HV components in the event of overvoltage shall be specified by the supplier.

6.3.5.2 Undervoltage (LV123-246)

LV123-247 For testing, see Section "Test: Undervoltage"

LV123-248 The undervoltage range is the range between
- 0 V d.c. and
- the minimum operating voltage in the range of highly limited operating capability, see Table "HV voltage ranges".

LV123-249 Undervoltage shall only be detected after the HV system been powered up under operational conditions.

LV123-250 In the event of undervoltage, an adjustment of the performance of the HV components according to the technical boundaries of the HV component and to protect the HV component is permissible.

LV123-251 In the event of undervoltage, the HV components shall remain operational to a limited extent as far as allowed by the electric power supply. The HV operating status B3 shall be complied with, see Table "HV operating status".

LV123-252 If an HV component simultaneously receives a power demand and has been switched off due to undervoltage or cannot be started at all, an "Undervoltage" fault memory entry shall be set.
Other fault memory entries shall not be set during the presence of undervoltage.

LV123-253 The behavior of the HV component shall be reported by the supplier.

LV123-254 If the HV voltage returns to an operating voltage range in accordance with Table "HV voltage ranges" after the occurrence of an undervoltage, the corresponding HV operating status shall be complied with again automatically.

6.3.5.3 Load dump and voltage limiting (LV123-255)

LV123-256 For testing, see Section "Test: Load dump and voltage limiting"

LV123-257 The following event is designated as load dump:
An HV component feeds electric energy into the DC HV circuit, and the maximum load is switched off under abnormal operational conditions at the same time. In this case, the switch-off under abnormal operational conditions is caused by the load current consuming HV components, e.g. switching off the switching equipment of the HV battery in charging operation.

LV123-258 HV components shall meet the HV operating status B3 or B4 in accordance with Table "HV operating status" in the event of overvoltage due to load dump. See OEM's requirements documentation for information on the HV operating status.

LV123-1578 HV components shall be designed for the maximum voltage dynamics in accordance with Table "Maximum voltage dynamics" in the event of overvoltage due to load dump.

LV123-1579 Table: Maximum voltage dynamics

LV123-1580

Parameter	HV operating status	Unit	HV_1	HV_2a	HV_2b	HV_3
Maximum voltage dynamics (slope), load dump	B3	V/ms	+/- 250	+/- 250	+/- 250	+/- 250

LV123-259 Technical control measures shall be provided for the HV components specified by the OEM in order to ensure the controlled limitation of overvoltages caused by load dump; see OEM's requirements documentation.

LV123-648 The respective HV component shall detect the occurrence of load dump and initiate the measures for voltage limiting.

LV123-649 Possible voltage limiting measures include, e.g.:

- Short-time high power consumption of HV components
- Disabling the power output into the DC HV circuit.

LV123-650 HV components that are controlled by power electronics and that can feed electric energy as intended into a DC HV circuit shall be designed in such a way that the increase in the DC HV circuit voltage that can occur during load dump due to the electric energy fed by this HV component is actively limited by appropriate control measures.

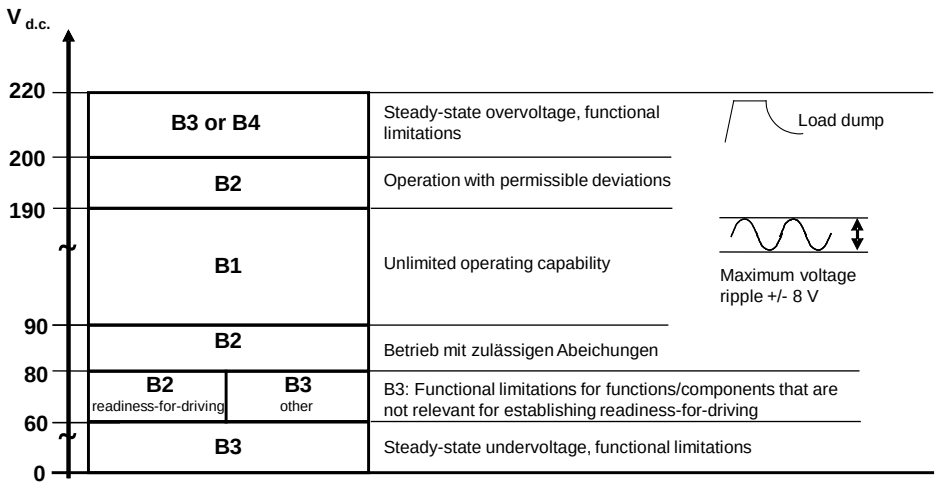
LV123-651 The control measures of an HV component that is controlled by power electronics shall be adequate for limiting the overvoltage during load dump, in accordance with the requirements in Table "HV voltage ranges".

6.3.6 Summary of voltage ranges (LV123-260)

LV123-261 The following characteristics are specified for the HV_1 voltage level example in Figure "Voltage ranges and HV operating status for HV_1 example":

- HV operating statuses
- Operating voltages
- Dynamic parameters
- Voltage deviations.

LV123-262



LV123-263 Figure: Voltage ranges and HV operating status for HV_1 example

6.3.7 Design according to test voltages (LV123-264)

LV123-1581 For HV components, the requirements for the design according to required test voltages are specified in Section "Withstand voltage" in Section "Insulation coordination".

6.3.8 Voltage offset (LV123-271)

LV123-272 For testing, see Section "Test: Voltage offset"

LV123-273 The HV components shall be fully functional in the event of an asymmetrical distribution of the DC HV voltage between the DC HV potentials and the vehicle ground.

LV123-274 The HV components shall be designed in such a way that all electronic parts and integral parts of electronic circuits that are placed between DC HV potentials and the vehicle ground are permanently operational for voltages extending up to the maximum operating voltage and short-term (see Section "Overvoltage") up to the upper HV circuit limit voltage in accordance with Table "HV voltage ranges".

LV123-275 The HV components shall be fully functional in the event of voltages extending up to the maximum operating voltage between DC HV potentials and the vehicle ground.

6.4 Interactions between LV and HV system (LV123-276)

LV123-277 For testing, see Section "Test: Interactions between LV and HV system"

LV123-278 All electrical requirements for the LV powernet apply to the partial scopes of HV components connected to the LV powernet as well. These requirements shall be complied with for all the operating conditions of the HV circuits.

LV123-279 The specified operating conditions of the HV components in HV circuits shall be complied with for all electrical operating conditions of the LV powernet.

7 Requirements for electrical characteristics and HV safety
(LV123-283)

7.1 Marking (LV123-288)

LV123-289 Note: Bibliographic references: ECE-R100, GB/T 18384.3, GB/T 19751, GB/T 24549, ISO 6469-3, KMVSS Art. 18-2, 18-3, 91, SAE J1673, SAE J2344, SAE J2578

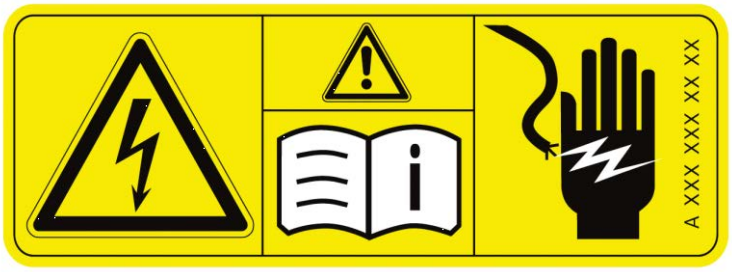
Bibliographic references for general marks and symbols: ANSI Z535.3, GB/T 4094.2, ISO 3864-1, ISO 3864-2, ISO 7000

LV123-290 For testing, see Section "Test: Marking"

LV123-292 The technical specifications regarding the safety and certification-relevant characteristics pertaining to the obligation for documentation for the topic "Marking" shall be documented by the supplier in accordance with Section "Safety and certification-relevant scopes HV" and shall be agreed upon with the OEM.
Details on these characteristics shall be gathered from the OEM's requirements documentation.

LV123-293 The marking in accordance with Figure "HV marking" shall be used as the HV marking.

LV123-294



LV123-295 Figure: HV marking

LV123-296 **Marking of protective covers for live parts**

LV123-297 If protective covers or barriers for live parts of voltage class B are provided outside of HV components, these shall be marked with an HV marking in accordance with Figure "HV marking".

LV123-298 **Marking of HV components**

LV123-299 All HV components that have a housing intended as a protective cover against direct contact with live parts shall be marked with an HV marking in accordance with Figure "HV marking".

LV123-300 If the assembly of the HV components is intended for the installation of the vehicle, each individual HV component shall be marked with the HV marking.

LV123-301 If access to live parts becomes possible after removing covers, covers of HV contactings or parts of a housing of an HV component, such covers or parts of the housing shall be marked separately if the following conditions are met:

- The opening or removal of such covers or parts is possible without removing other vehicle parts using tools.
- Such covers or parts can be opened or removed for an intended use, e.g. for servicing.

LV123-302 The HV marking(s) of an HV component shall be placed in such a way that at least one HV marking is easily visible when the vehicle is completely assembled if the following conditions are met:

- Direct access to the HV component is possible
- Access to the HV component is possible after disassembly of all parts or covers which can be removed manually.

LV123-303 The following details on the marking of the HV components shall be gathered from the OEM's requirements documentation:

- Use of other HV markings
- Installation situation and accessibility of the HV component in the completely assembled vehicle
- Arrangement of all HV markings on housings and covers which can be dismantled.

LV123-304 For HV components that satisfy the "Complex disassembly" design feature, the marking and the design of the marking shall be agreed upon with the OEM by the supplier.

LV123-305 **Implementation of the HV marking**

LV123-306 The following requirements shall be met for the implementation of the HV marking in accordance with Figure "HV marking":

LV123-307
- HV marking:
  - Yellow color: Pantone 123 C (PMS)
  - Black printing color: Pantone 419 C (PMS) or RAL 9005

LV123-308
- Warning symbol, triangle with flash of lightning:
  - Symbol based on ISO 3864-2
  - Yellow color: Pantone 123 C (PMS).
  - Black color: Pantone 419 C (PMS) or RAL 9005

LV123-309
- Warning level symbol:
  - Triangle symbol with exclamation mark, based on ANSI Z535.3, ISO 3864-2
  - Yellow color: Pantone 123 C (PMS).
  - Black color: Pantone 419 C (PMS) or RAL 9005

LV123-310
- Operator's manual symbol
  - Symbol based on ISO 7000, Symbol No. 1641
  - White color: RAL 9003
  - Black color: Pantone 419 C (PMS) or RAL 9005

LV123-311
- Warning symbol, hand with cable and flash of lightning:
  - Symbol based on ANSI Z535.3
  - White color: RAL 9003
  - Black color: Pantone 419 C (PMS) or RAL 9005

LV123-312
- General information on symbols and on making a combined marking consisting of multiple symbols: based on ISO 3864-1 and ISO 3864-2.

LV123-313
- Dimensions: Height: 19 mm, width: 53 mm; the specified dimensions shall be complied with as minimum dimensions.

LV123-314
- Technical design: Adhesive labels or print.

LV123-315
- The marking shall be abrasion-resistant (indelible).

LV123-316
- The marking shall be resistant to all vehicle-typical chemical substances.

LV123-317 Specifications in accordance with Section "Implementation of the HV marking" including the technical design shall be gathered from the OEM's requirements documentation.

LV123-318 **Marking of HV cables**

LV123-319 The outer cover or outer insulation of HV cables arranged outside of housings of HV components shall be marked orange.

LV123-320 For the color orange, a shade similar to RAL 2003 shall be used.

LV123-321 The RAL 2003 color corresponds to the following international color designations:

- Munsell: 8.75R 5.75/12.5
- NCS: 0570-Y70R.

7.2 Protection against direct contact (LV123-322)

7.2.1 General (LV123-2275)

LV123-324 The technical specifications regarding the safety and certification-relevant characteristics pertaining to the obligation for documentation for the topic "Protection against direct contact - Degree of protection" shall be documented by the supplier in accordance with Section "Safety and certification-relevant scopes HV" and shall be agreed upon with the OEM.
Details on these characteristics shall be gathered from the OEM's requirements documentation.

7.2.2 Protection against direct contact by covers (LV123-325)

LV123-326 Note: Bibliographic references: ECE-R100, GB/T 18384.3, GB/T 19751, GB/T 24549, KMVSS Art. 18-2, 18-3, 91, ISO 6469-3, SAE J2344

LV123-327 For testing, see Section "Test: Protection against direct contact"

LV123-328 Protective covers for live parts such as housings, covers and barriers shall reliably prevent any contact with live parts.

LV123-329 Protective covers for live parts shall meet the following requirements over the specified life (EOL); see Section "Installation areas and ambient conditions":

- Fasteners of protective covers shall not come loose during operation.
- Housings, protective covers and their fasteners shall be resistant to the stresses experienced during operation and have an adequate mechanical strength; see Section "Installation areas and ambient conditions".

LV123-330 The opening, disassembly or removal of protective covers shall only be possible with tools.

LV123-333 With the exception of the vehicle inlet, all HV components in a completely assembled HV system shall at least fulfill the degree of protection IPXXD in accordance with ISO 20653.

LV123-2276 Note: Requirements for the vehicle inlet are described in Section "Requirements for the vehicle inlet".

LV123-335 In agreement with the OEM, the degree of protection IPXXB degree in accordance with ISO 20653 may be used for HV components outside of the passenger and luggage compartments (degree of protection when HV system is installed).

LV123-336 HV contacting belonging to HV components shall at least fulfill the degree of protection IPXXD in the completely assembled vehicle and when connected.

LV123-2277 Note: A vehicle inlet is not included under "HV contacting on HV components". Requirements for the vehicle inlet are described in Section "Requirements for the vehicle inlet".

LV123-337 HV plug connections belonging to HV components shall at least fulfill the degree of protection IPXXB when disconnected.

LV123-1582 In the passenger and load compartments, HV plug connections belonging to HV components shall meet one of the following requirements:

- When disconnected, they shall fulfill degree of protection IPXXD
- The HV components shall be designed such that a tool is required to undo their HV plug connections
- The HV components shall be arranged in the fully assembled vehicle such that tools are required to gain access to the HV plug connection for disconnection.

Which measure is appropriate shall be indicated by the supplier and agreed upon with the OEM, or it shall be gathered from the OEM's requirements documentation.

LV123-339 The design of protection against direct contact by means of covers shall be documented by the supplier and agreed upon with the OEM.

LV123-340 **Additional measures if IPXXB is not fulfilled**

LV123-341 Additional measures are required if the degree of protection IPXXB for HV contacting when disconnected is not fulfilled.

LV123-342 If the degree of protection IPXXB is not reached when the covers and partial covers (e.g. cap above HV contacting or above live parts) intended for assembly, disassembly or servicing are removed, additional measures are required.

LV123-343 One of the following alternatives shall be chosen as an additional measure if degree of protection IPXXB is not achieved:

- Design-based measures designed to delay access to live parts, see Section "Delayed access to live parts".
- Design-based measures that prevent access to live parts and therefore fulfill the design feature "Complex disassembly", see Section "Protection against direct contact by "Complex disassembly"".

LV123-344 The additional measure to be used if degree of protection IPXXB is not fulfilled shall be gathered from the OEM's requirements documentation.

7.2.3 Protection against direct contact by insulation (LV123-345)

LV123-346 Note: Bibliographic references: GB/T 18384.3, ISO 6469-3

LV123-2099 For testing, see Section "Test: Protection against direct contact"

LV123-332 HV components with housings or protective covers made from nonconductive materials or insulations shall comply with the requirements regarding a double or reinforced insulation in accordance with Section "Insulation coordination".

LV123-351 HV cables shall be designed such that the insulation completely encloses live parts.

LV123-352 The removal of the insulation from HV cables shall only be possible destructively.

LV123-349 The insulation of HV cables shall comply with the requirements for a basic insulation or with the requirements regarding a double or reinforced insulation in accordance with Section "Insulation coordination".

LV123-2278 Note: With regard to the requirements regarding the insulation of HV cables, see also applicable standards on cables.

LV123-1583 If no HV cable (insulated conductor), but another type of conductor is used for the electric connection between HV components, e.g. a power rail which is not covered with insulation, the requirements applying to all other HV components shall be complied with for this electric connection.

LV123-348 For HV cables the features "easily accessible" and "difficult to access" are distinguished. For these features, the installation condition in the completely assembled vehicle shall be taken into account.

Easily accessible HV cable
HV cable whose insulation can be touched with a commonly used tool or a test finger used for IP degree of protection IPXXB.

Difficult-to-access HV cable
HV cable whose insulation cannot be touched with a commonly used tool or a test finger used for IP degree of protection IPXXB.

The details for the assignment of HV cables of as "easily accessible" or "difficult to access" shall be gathered from the OEM's requirements documentation.

LV123-1584 HV cables may be designed as difficult to access by one of the following means:

- Use of additional covers, see also Section "Protection against direct contact by covers".
- Provision of an additional sheathing; see also Section "Requirements for HV wiring harness".
- Installation in the vehicle according to the design feature "Complex disassembly" in accordance with Section "Protection against direct contact by "Complex disassembly"'.

The measures for HV cables that are difficult to access shall be gathered from the OEM's requirements documentation.

LV123-1518 HV cables of DC HV circuits shall as a minimum comply with the requirements for a basic insulation. The design as HV cable with double or reinforced insulation is recommended. The design as HV cable which is difficult to access may be necessary. The details for the design of the DC HV cables shall be gathered from the OEM's requirements documentation.

LV123-350 HV cables of AC HV circuits shall comply with one of the following requirements at least:

- The HV cable shall be designed as an HV cable which is difficult to access.
- The HV cable shall comply with the requirements regarding a double or reinforced insulation.

The required design of the insulation shall be gathered from the OEM's requirements documentation.

7.2.4 Protection against direct contact by "Complex disassembly"
(LV123-353)

LV123-2100 For testing, see Section "Test: Protection against direct contact"

LV123-354 The protection against direct contact requirement may be fulfilled by the "Complex disassembly" design feature for individual HV components.

LV123-355 The supplier shall agree upon whether or not "Complex disassembly" is permissible or fulfilled for an HV component as a protective measure with the OEM.

LV123-356 The design feature "complex disassembly" shall be specified such that the removal or the re-installation of parts or components shall only be possible through complex procedures and with specialized skills for service personnel.
Below, examples of possible features are described:

- Additional barriers which can only be removed using a tool
- Flaps or covers locked using a key
- Different fasteners, number of fasteners
- Need for the use of different types of tools (tool change)
- Need for the use of complex aids, e.g. lifting platform, lifting gear
- Time period until possible access
- Special technical skills (vehicle, instructions on technology and procedures).

The individual features can be combined to compose the required design feature "Complex disassembly".

LV123-357 If protection against direct contact is implemented by means of "Complex disassembly," the conditions for the "Complex disassembly" design feature shall be gathered from the OEM's requirements documentation.

7.3 Equipotential bonding (LV123-358)

LV123-359 Note: Bibliographic references: DIN 72551-7, ECE-R100, GB/T 18384.3, IEC 60950-1, ISO 6469-3, SAE J2344, SAE J2578

LV123-360 For testing, see Section "Test: Equipotential bonding"

LV123-361 Equipotential bonding shall be implemented as a galvanic connection of exposed conductive parts (e.g. housing, protective covers, partition walls) of an HV component, for HV components among each other and to the vehicle ground.

LV123-362 Adequate equipotential bonding is required for all conductive covers or housings belonging to all HV components.

LV123-1585 The requirements for equipotential bonding shall be fulfilled even if conductive covers or housings are used to protect against direct contact and if the HV component complies with the requirements for a double or reinforced insulation.

LV123-1586 If additional external conductive cover sheaths or covers are attached over covers or housings consisting of solid insulating materials, no equipotential bonding is required for these. Such additional conductive covers shall not be used for protection against direct contact in accordance with Section "Protection against direct contact".

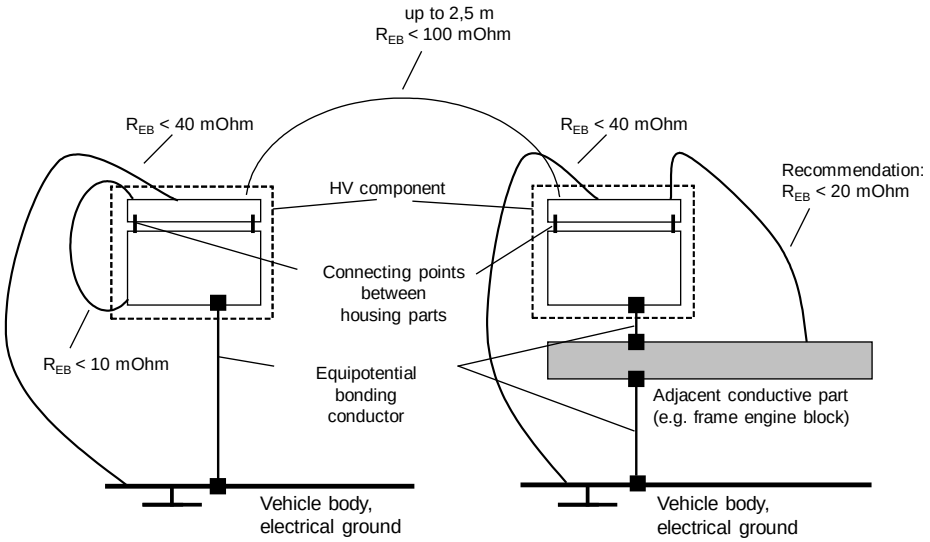
LV123-2279 Note: For requirements for covers made of solid insulating materials, see Section "Protection against direct contact".

LV123-370 The equipotential bonding shall be implemented

- between an HV component and the vehicle body or
- between an HV component and an adjacent conductive part, see Figure "Equipotential bonding implementation examples", or
- in accordance with an appropriate configuration specified by the OEM.

The configuration of the equipotential bonding and the respective vehicle ground shall be gathered from the OEM's requirements documentation.

LV123-368



LV123-369 Figure: Equipotential bonding implementation examples

LV123-383 The requirements for the electrical resistance of the equipotential bonding shall be maintained until the end of the specified service life (EOL) of the HV component.

LV123-363 The electrical resistance of the equipotential bonding between two HV components which are simultaneously accessible for a person and are arranged in a distance up to 2,5 m in the vehicle shall be less than 100 mOhm.

LV123-1519 The electrical resistance of the equipotential bonding between an HV component and the vehicle ground shall in principle be less than 100 mOhm.

LV123-2280 Note: Detailed requirements regarding the electric contact resistance of the equipotential bonding can differ due to different designs of the vehicle ground.

LV123-364 In order to ensure compliance with the corresponding requirement for the vehicle system, a value for the electrical resistance of the equipotential bonding is required for all individual HV components.

LV123-1587 For linked equipotential bonding paths, the required total resistance of the equipotential bonding to the vehicle ground shall be divided up according to the partial paths. In this case, the specifications shall be gathered from the OEM's requirements documentation.

LV123-365 If the vehicle body is designed as a vehicle ground, the electrical resistance of the equipotential bonding between an HV component and the vehicle body shall be less than 40 mOhm, see Figure "Equipotential bonding implementation examples".

LV123-366 If the vehicle body is designed as a vehicle ground and equipotential bonding between the HV component and an adjacent conductive part is intended for an HV component, an electrical resistance of the equipotential bonding that is less than 20 mOhm is recommended, see Figure "Equipotential bonding implementation examples". In this case the electrical resistance of the equipotential bonding between an individual HV component and the vehicle body shall be less than 40 mOhm. If necessary, the resistance values shall be gathered from the OEM's requirements documentation.

LV123-367 If the cover or the housing of an HV component consists of several individual parts, the electrical requirements for the equipotential bonding shall be met in every position on the surface of the cover or housing.

LV123-1588 The electrical resistance between any position on the surface of the cover or the housing of an HV component and the connecting point of the means for equipotential bonding on this HV component shall be less than 10 mOhm, see Figure "Equipotential bonding implementation examples".

LV123-371 The following means shall be used for equipotential bonding:

- Electrical conductors
- Ground straps
- Direct mounting of HV component (e.g. screwed connection, welded connection, etc.).

The means for the equipotential bonding and the indication as to whether or not these means are an integral part of the HV component, shall be gathered from the OEM's requirements documentation.

LV123-379 Note: For welded connections, compliance with equipotential bonding requirements may be assumed.

LV123-1589 A conductor or ground strap which is used as means for equipotential bonding shall comply with one of the following requirements:

- Means for equipotential bonding made of copper shall have a minimum cross-sectional area in accordance with Table "Minimum cross-sectional areas of means for equipotential bonding".
- For means for equipotential bonding not consisting of copper, minimum cross-sectional areas shall be designed with an equivalent ampacity.
- The I^2t value of the means for equipotential bonding shall be greater than the I^2t value of the overcurrent protection device of the HV battery in the event of short-circuit; see Section "Overcurrent protection HV battery". Depending on the design of the HV system, the I^2t value for the protection of the overload current of other HV sources, or the I^2t value of the overcurrent protection device of the HV sources shall be taken into account in the event of a short-circuit.

As a short-circuit event, a short-circuit current via an equipotential bonding path shall be assumed.

Details on the design alternative for the means of equipotential bonding as well as technical values and required details for other HV sources shall be gathered from the OEM's requirements documentation.

LV123-1590 Table: Minimum cross-sectional areas of means for equipotential bonding

LV123-1591

Cross-section of HV cable S mm^2	**Minimum cross-section of equipotential bonding means, conductor or ground strap** mm^2
$S < 4$	4
$4 \leq S \leq 16$	S
$16 < S \leq 35$	16
$S > 35$	0,5 x S
The specifications apply to copper	

LV123-380 Parts that are integral to an equipotential bonding path shall in like manner fulfill the ampacity requirements that apply to cables or ground straps. These include:

- Housing parts of HV components
- Other means of equipotential bonding than cables or ground straps
- Fasteners
- Contact areas.

The materials used shall be taken into account.

LV123-382 If an electrical conductor or a ground strap with protective sheath is used for equipotential bonding, the color brown shall be chosen, if in the vehicle for the electrical connection to the negative pole of the LV powernet (battery) the color black is used.
For the equipotential bonding the color brown shall be generally used for road vehicles with 12 V powernet. In other cases the specification regarding the color (e.g. black) shall be gathered from the OEM's requirements documentation.

LV123-2101 For the color brown, a shade similar to RAL 8003 shall be used, see DIN 72551-7
For the color black, a shade similar to RAL 9005 shall be used, see DIN 72551-7.

LV123-385 The technical specifications regarding the safety and certification-relevant characteristics pertaining to the obligation for documentation for the topic "Equipotential bonding" shall be documented by the supplier in accordance with Section "Safety and certification-relevant scopes HV" and shall be agreed upon with the OEM.
Details on these characteristics shall be gathered from the OEM's requirements documentation.

LV123-1592 Mounting of the means for equipotential bonding

LV123-373 For the mounting of the means for equipotential bonding onto the vehicle body, the following requirements for:

- design of the fasteners and
- the installation location

shall be gathered from the OEM's requirements documentation.

LV123-374 For the mounting of the means for equipotential bonding onto the HV component, the following requirements for:

- design of the fasteners and
- the installation location

shall be specified by the supplier and agreed upon with the OEM, unless otherwise specified by the OEM.

LV123-375 If equipotential bonding is intended between an HV component and an adjacent conductive part, for the mounting of the means for equipotential bonding onto the adjacent conductive part, the following requirements for:

- design of the fasteners and
- the installation location

shall be gathered from the OEM's requirements documentation.

LV123-1593 The following requirements shall be complied with by all fasteners and contacts for equipotential bonding.

LV123-376 Appropriate securing means against loosening shall be provided for threaded joints, e.g. classification of joints using threaded fasteners in accordance with VDI 2862, specification of tightening torque.
These specifications shall be gathered from the OEM's requirements documentation or shall be indicated by the supplier and agreed upon with the OEM.

LV123-377 The fasteners for the equipotential bonding shall not work loose during the specified service life (EOL).

LV123-378 The fasteners for the equipotential bonding shall be resistant to corrosion during the specified life (EOL); see Section "Installation areas and ambient conditions".

LV123-1594 For threaded joints, the following requirements shall be fulfilled.

- The electrical contact shall essentially be provided by means of specified bearing surfaces of the contact surfaces to be connected (e.g. connection of lug with body).
- The contact pressure of the surfaces shall not be established by using plastic screws.

LV123-1595 If threaded joints are used between housing parts of an HV component with electrical contacting by the thread, the requirements regarding the electrical properties shall be fulfilled over the service life.

LV123-1596 If contact pressure is required to establish an electrical connection, a screw shall be turned into a metal plate, a metal nut or a metal insert at least four complete turns deep.

LV123-1597 Tapping screws (coarse-pitch thread screws) shall not be used for the electrical connection of the equipotential bonding.

LV123-1598 Thread cutting (chip removing) screws are not permissible for the connection of the equipotential bonding.
Thread forming (thread rolling) screws are permissible.

LV123-1599 The thickness of the metal part shall not be lower at the joint than three turns of the screw thread. The use of the metal drawing technology in some locations is permissible in order to reach the required thread height.

LV123-1600 If coating of the surface is intended in the environment of the electrical contact point, one of the following requirements shall be complied with:

- The coating of the contact point shall be prevented by appropriate measures.
- The coating of the contact point shall subsequently be removed by means of a mounting process or process step.

LV123-1601 For electrical contacts with material combinations of different metals, the electrochemical potential series in accordance with Table "Electrochemical potential series of selected material combinations" shall be taken into account; see IEC 60950-1. The electrochemical potential of the material combination shall not exceed 0,6 V.

LV123-2281 Note: The limitation of the electrochemical potential is intended to prevent contact corrosion.

LV123-1602 Table: Electrochemical potential series of selected material combinations

LV123-1603

	Magnesium, magnesium alloy	Zinc, zinc alloy	80% tin / 20% ZN on steel, ZN on iron or steek	Aluminum	Cd on steel	AL-MG alloy	Mild steel	Duralumin	Lead	Cr on Stahl, soft solder	Cr on Ni on steel tin on steel, stainless steel with 12% Cr	Stainless steel with high Cr content	Copper, Cu alloy	Silver solder	Ni on steel	Silver	Rh on AG on Cu, silver/gold alloy	Coal	Gold, platinum
Gold, platinum	1,75	1,25	1,20	1,05	0,95	0,90	0,85	0,75	0,70	0,65	0,60	0,50	0,40	0,35	0,30	0,15	0,10	0,50	0,00
Coal	1,70	1,20	1,15	1,00	0,90	0,85	0,80	0,70	0,66	0,60	0,55	0,45	0,35	0,30	0,25	0,10	0,05	0,00	
Rh on AG on Cu, silver/gold alloy	1,65	1,15	1,10	0,95	0,85	0,80	0,75	0,65	0,60	0,55	0,50	0,40	0,30	0,25	0,20	0,50	0,00		
Silver	1,60	1,10	1,05	0,90	0,80	0,75	0,70	0,60	0,55	0,50	0,45	0,35	0,25	0,20	0,15	0,00			
Ni on steel	1,45	0,95	9,00	0,75	0,65	0,60	0,55	0,45	0,40	0,35	0,30	0,20	0,10	0,15	0,00				
Silver solder	1,40	0,90	0,85	0,70	0,60	0,55	0,50	0,40	0,35	0,30	0,25	0,15	0,05	0,00					
Copper, Cu alloy	1,35	0,85	0,80	0,65	0,55	0,50	0,45	0,35	0,30	0,25	0,20	0,10	0,00						
Stainless steel with high Cr content	1,25	0,75	0,70	0,55	0,45	0,40	0,35	0,25	0,20	0,15	0,10	0,00							
Cr on Ni on steel, tin on steel, stainless steel with 12% Cr	1,15	0,65	0,60	0,45	0,35	0,30	0,25	0,15	0,10	0,05	0,00								
Cr on Stahl, soft solder	1,10	0,60	0,50	0,40	0,30	0,20	0,20	0,10	0,50	0,00									
Lead	1,05	0,55	0,50	0,35	0,25	0,20	0,15	0,05	0,00										
Duralumin	1,00	0,50	0,45	0,30	0,20	0,15	0,10	0,00											
Mild steel	0,90	0,40	0,35	0,20	0,10	0,05	0,00												
AL-MG alloy	0,85	0,35	0,30	0,15	0,05	0,00													
Cd on steel	0,80	0,30	0,25	0,10	0,00														
Aluminum	0,70	0,20	0,15	0,00															
80% tin / 20% ZN on steel, ZN on iron or steek	0,55	0,05	0,00																
Zinc, zinc alloy	0,50	0,00																	
Magnesium, magnesium alloy	0,00																		

LV123-1604 For electrical contacts with material combinations of different metals, the cathode area with the more noble metal shall be significantly smaller than the anode area. It is recommended to have the anode area 3 times larger than the cathode area.

LV123-2282 Note: This requirement for electrical contacts that combine different metals is an additional measure for the prevention of contact corrosion.

LV123-1605 To prevent corrosion, electrical contacting to graphitized areas such as carbon fiber (CFRP) shall be avoided.

7.4 Overcurrent protection (LV123-1606)

LV123-1607 Note: Bibliographic references: ECE-R100, ISO 6469-1, ISO/DIS 17409: 2013-09, SAE 2344, SAE J2578

LV123-1608 For testing, see Section "Test: Overcurrent protection"

LV123-1609 For the following HV components, with the exception of an HV battery, the requirements in accordance with Section "Overcurrent protection" shall be fulfilled:

- HV sources
- HV components that are controlled by power electronics and that can feed electric energy as intended into a DC HV circuit
- Controlled HV components that supply electric consumers.

LV123-2283 Note: Overcurrent protection requirements for an HV battery are described in Section "Overcurrent protection HV battery".

LV123-1610 The HV components mentioned shall be provided with a protective measure suited to the relevant HV circuit in case of overload current or short-circuiting.

LV123-2102 The HV components mentioned shall have overcurrent protection for the following relevant HV circuits:

- HV sources: DC HV circuit as feed circuit and as load circuit for rechargeable energy storages
- HV components that are controlled by power electronics and that can feed energy into a DC HV circuit: DC HV circuit as feed circuit and load circuit for the supply of electric consumers
- Controlled HV components that supply electric consumers: load circuit.

LV123-2103 HV components shall fulfill the overcurrent protection requirements even when other HV components that can feed electric energy as operationally intended into the DC HV circuit (e.g. a HV battery) are switched off or if their overcurrent protection device has triggered.

LV123-1611 The protective measure shall be capable of limiting or shutting off overload current in the relevant HV circuits.

LV123-406 The protective measure shall be capable of detecting a short-circuit in the relevant HV circuits and to switch off the current (load or feed current) in case of such a short-circuit.

LV123-1612 The protective measure shall be implemented such as to take account of at least the I^2t characteristic curve for the wiring harness in the relevant HV circuits. The detailed specifications shall be gathered from the OEM's requirements documentation.

LV123-1615 If switching equipment is used for an overcurrent protection device, the number of switch-offs for overcurrent shall be gathered from the OEM's requirements documentation.

LV123-1614 The design and triggering behavior of the overcurrent protective measure shall be specified by the supplier and agreed upon with the OEM. Additional specifications shall be gathered from the OEM's requirements documentation.

LV123-407 For HV components that are controlled by power electronics and that can feed electric energy as operationally intended into a DC HV circuit, neither overcurrent events nor overcurrent shut-offs in the DC HV circuit shall limit the specified service life (EOL), irrespective of the time elapsed until cut off occurs.

LV123-1619 For rechargeable energy storages, except an HV battery, the technical specifications regarding the characteristics pertaining to the obligation for documentation for the topic "Overcurrent protection function" shall be documented by the supplier in accordance with Section "Safety and certification-relevant scopes HV" and shall be agreed upon with the OEM.
Details on these characteristics shall be gathered from the OEM's requirements documentation.

7.5 Potential separation of HV system and LV powernet (LV123-408)

LV123-409 Note: Bibliographic references: IEC 60747, IEC 61558, IECQ

LV123-410 For testing, see Section "Test: Potential separation of HV system and LV powernet"

LV123-411 In principle, the HV system and the HV components shall be designed as galvanically separated from the LV powernet and the vehicle ground.

LV123-413 The HV potentials of an HV component shall be designed as isolated from the LV powernet and from the vehicle ground. The isolation shall conform at least to the requirements for the base insulation; see Section "Insulation coordination".

LV123-414 For the isolation resistance, the requirements in accordance with Section "Isolation resistance" shall be complied with.

LV123-415 The coupling of electric energy from HV potentials into LV circuits shall only be carried out in a galvanically separated manner.

LV123-416 The coupling of electrical signals from HV potentials into LV circuits shall only be carried out in a galvanically separated manner.

LV123-417 High-impedance connection of an HV potential, e.g. for measuring circuits or symmetrizing circuits, is only permissible to vehicle ground. The isolation resistance shall not fall below the required value. The symmetrizing circuit shall be specified by the supplier and agreed upon with the OEM.

LV123-2104 Note: Requirements for isolation-bridging parts are given in Section "Isolation-bridging parts".

LV123-2105 Parts of HV components that are used for galvanic separation and for which the requirements for an insulation (basic insulation, double or reinforced insulation) in accordance with Section "Insulation coordination" apply, shall be selected based on applicable standards.

LV123-2106 Note 1: Requirements for transformers are specified in applicable parts of the IEC 61558 series of standards.

LV123-2107 Note 2: Requirements for optocouplers are specified in IEC 60747-5-1 and in applicable parts of the series IEC 61558.

LV123-2108 Note 3: IECQ is a quality rating system for component elements in electronics and may be used for safety-relevant criteria.

7.6 Isolation resistance (LV123-418)

LV123-419 Note: Bibliographic references: ECE-R100, GB/T 18384.3, ISO 6469-1, ISO 6469-3, ISO/DIS 17409: 2013-09, SAE J1742, SAE J1766, SAE J2344, SAE J2578

LV123-420 For testing, see Section "Test: Isolation resistance"

LV123-428 The requirements for the isolation resistance shall be fulfilled by an HV component that is ready for operation, including all media required for operation, e.g. coolant.

LV123-429 If an HV component consists of several subcomponents considerably higher isolation resistances shall be achieved for the individual subcomponents, if applicable, in order to guarantee the total resistance.

LV123-430 If several HV components are assembled inside a single housing, the requirement for isolation resistance shall be met for the assembly (e.g. inverter with integrated DC/DC converter HV/LV).

LV123-431 The requirements for the isolation resistance shall be complied with until the end of the specified service life (EOL).

LV123-432 The requirements for the isolation resistance shall be complied with for the relevant worst-case ambient conditions of an HV component.

LV123-433 The worst-case ambient conditions apply to the operating conditions of the HV component during driving operation. The following are examples of influencing factors for the worst-case ambient conditions:

- Climatic ambient conditions, e.g. condensing
- Unique operating conditions, e.g. operating temperature
- Operating equipment, incl. condensing
- Contact with fluids or chemicals, e.g. salt water, depending on the installation area and the IP degree of protection.

LV123-434 The worst-case ambient conditions shall be specified by the supplier for each HV component and shall be agreed upon with the OEM.

LV123-435 The isolation resistance of the HV component at BOL shall be specified by the supplier.

LV123-421 The required isolation resistance for HV components, including HV cables, applies to HV systems with the voltage levels in accordance with Table "HV voltage ranges".

LV123-423 HV components including HV cables shall comply with the requirements for the isolation resistance in accordance with Table "Isolation resistances". In this context, the isolation resistance shall be measured in accordance with the test method in Section "Test: Isolation resistance".

LV123-427 The requirements for the isolation resistance shall be complied with in connection with the required test procedure. The isolation resistance shall be maintained as an

- isolation resistance between all connected HV contactings and vehicle ground or as a
- parallel resistance resulting from the individual resistances between HV+ and vehicle ground, as well as HV and vehicle ground.

LV123-424 Table: Isolation resistances

LV123-425

Isolation resistance	**Unit**	**HV_1, HV_2a, HV_2b**	**HV_3**
HV battery	MOhm	1,5	3,0
All HV wiring harnesses (DC and AC HV circuits) Independent HV power distribution unit DC connection box	MOhm	25	50
AC power supply wiring harness (vehicle inlet to on-board charger with galvanic separation) DC connection wiring harness	MOhm	75	150
All further HV components incl. on-board charger	MOhm	2,5	5
HV components of fuel cell systems, except FC stack	MOhm	2,5	5
The isolation resistances are minimum values that apply in connection with the described testing procedure and with the specified ambient conditions until the end of the specified service life (EOL)			

LV123-426 For an FC stack, the requirements pertaining to isolation resistance shall be gathered from the OEM's requirements documentation.

LV123-437 The technical specifications regarding the safety and certification-relevant

characteristics pertaining to the obligation for documentation for the topic "Isolation resistance" shall be documented by the supplier in accordance with Section "Safety and certification-relevant scopes HV" and shall be agreed upon with the OEM. Details on these characteristics shall be gathered from the OEM's requirements documentation.

7.7 Insulation coordination (LV123-438)

7.7.1 General (LV123-1623)

LV123-439 Note: Bibliographic references: GB/T 18384.1, GB/T 18384.3, ISO 6469-1, ISO 6469-3, ISO/DIS 17409: 2013-09, SAE J1742, SAE 2344, SAE J2578

LV123-440 For testing, see Section "Test: General, clearances and creepage distances and solid insulating materials" in Section "Test: Insulation coordination"

LV123-441 Solid insulating materials, clearances, and creepage distances shall generally be defined by the supplier for the HV components. The requirements specified in this document for insulation coordination are minimum requirements which shall be taken into account by the supplier during design.

LV123-444 An HV component shall provide an appropriate isolation for the purpose of electrical safety. For this isolation (also designated isolation paths), the requirements for the insulation coordination shall be complied with in principle between live parts of the HV circuits and

- live parts of the galvanically separated HV circuits,
- live parts of the LV powernet, including 48 V powernet, e.g. measuring electronics, EMC filter, control unit
- accessible conductive parts of the HV component including fasteners,
- vehicle ground, and
- the protective conductor (PE), where applicable.

LV123-2284 Note: Requirements for functional insulation are not covered in this document.

LV123-2285 For accessible surfaces of housings or covers including those made of insulating material containing, for example, apertures or gaps, the following measures shall be taken for rating the insulation:

- The surface shall be covered with a metal foil having contact with the surface.
- The metal foil shall be pressed into such openings using test equipment appropriate to the degree of protection specified in Section "Protection against direct contact".

LV123-1631 The requirements for the design of

- clearances and creepage distances,
- rated voltages for insulation coordination, and
- test voltages including withstand voltage test

shall be fulfilled in accordance with Section "Insulation coordination for connection to external electric power supply" or Section "Insulation coordination without connection to external electric power supply".

LV123-446 Note: IEC 60664-1 contains specifications for insulation coordination, solid insulating materials, clearances and creepage distances.

LV123-2109 **Operating and ambient conditions**

LV123-1625 The insulation of an HV component shall be designed for the operating and ambient conditions and until the end of the specified service life (EOL); see Section "Installation areas and ambient conditions".
Major ambient conditions are listed below:

- Clearances
  - Air pressure
  - Temperature, in the event of major changes
  - Mechanical loads, vibration, forces
- Creepage distances
  - Pollution
  - Relative humidity
  - Condensation
- Solid insulations
  - Temperature.

LV123-2110 **Altitude**

LV123-452 Unless otherwise specified by the OEM, an altitude of up to 4000 m above sea level applies to the design of the HV component for all operating modes including driving operation and operation with an external electric power supply. For other specifications of the altitude, see OEM's requirements documentation, if applicable.

LV123-2111 **Pollution degree**

LV123-448 When selecting the pollution degree, internal and external factors shall be taken into account:

- Internal factors: e.g. abrasion
- External factors: e.g. condensation, see IP degree of protection in accordance with Section "Installation areas and ambient conditions".

LV123-447 Note: IEC 60664-3 specifies different measures for the protection against pollution.

LV123-449 For HV components with the degree of protection IP6K9K in accordance with ISO 20653, at least pollution degree 2 in accordance with IEC 60664-1 shall be used if there are no internal factors.

LV123-450 For HV components with a degree of protection less than IP6K9K in accordance with ISO 20653, at least pollution degree 3 in accordance with IEC 60664-1 shall be used.

LV123-451 The degree of pollution shall be specified by the supplier and agreed upon with the OEM.

LV123-2112 **Electrical field**

LV123-1630 The design of the insulation coordination shall always be based on inhomogeneous fields.

LV123-2113 **Operating voltage**

LV123-442 When an operating voltage of the HV system or of the DC HV circuit is relevant for the rating of solid insulating materials, clearance and creepage distances, the maximum operating voltage shall be selected as operating voltage in accordance with Table "HV voltage ranges". The test voltages for the withstand voltage in accordance with Table "Test voltages withstand voltage - for connection to external electric power supply" or Table "Test voltages withstand voltage - without connection to external electric power supply" shall be taken into account.

LV123-1626 If different operating or rated voltages than those specified in this document are used for an HV component, such voltages shall be taken into account by the supplier in the design and reported to the OEM.

LV123-2114 **Taking account of different HV circuits and connection to an external electric power supply**

LV123-1627 If an HV component is connected to an HV circuit where the sub-circuits are galvanically connected with each other with different rated voltages, the requirements for the circuit with the more stringent requirements for insulation coordination shall be complied with. The indication of the sub-circuits which are assigned to the HV component shall be gathered from the OEM's requirements documentation.

LV123-2286 Note: Also see voltage levels in accordance with Table "HV voltage ranges".

LV123-1628 When an HV component is connected to different HV circuits which are galvanically separated within the HV component, the requirements for the relevant circuits shall be complied with for insulation coordination. The indication of the HV circuits which are assigned to the HV component shall be gathered from the OEM's requirements documentation.

LV123-1629 In the design of the insulation coordination of the HV component, the following individual use cases shall be taken into account:

- Operation of the HV system with connection to an external electric power supply
- Operation of the HV system exclusively without connection to an external electric power supply.

The use cases for operation with or without a connection to an external electric power supply shall be gathered from the OEM's requirements documentation.

LV123-2287 HV components assigned to different supply circuits for operation at an external electric power supply shall fulfill the more stringent requirements.

7.7.2 Clearances (LV123-1632)

LV123-1633 For testing, see Section "Test: General, clearances and creepage distances and solid insulating materials" in Section "Test: Insulation coordination"

LV123-1634 Calculated clearances shall be rounded up the nearest value with an accuracy of 0,1 mm.

LV123-1635 The required minimum clearances do not take into account any operating and ambient conditions. Mechanical influences such as vibrations, in particular, as well as external forces can require larger clearances and shall therefore be taken into account by the supplier.

LV123-1636 The required clearances shall be adhered to irrespective of the pollution degree.

LV123-1637 The required clearances represent minimum values for the basic insulation.

LV123-1638 Minimum clearances for a double or reinforced insulation shall be designed for twice the value of the minimum clearance required for the basic insulation.

LV123-1639 For clearances with altitudes other than 4000 m, the required minimum clearances shall be multiplied by the following factors:

- 2000 m; factor 1/1,29
- 3000 m; factor 1/1,13.

LV123-1640 Irrespective of the specified altitude, a clearance shall be at least 1,2 mm.

LV123-1641 The supplier shall indicate the design of the clearances of an HV component.

7.7.3 Creepage distances (LV123-1642)

LV123-1643 For testing, see Section "Test: General, clearances and creepage distances and solid insulating materials" in Section "Test: Insulation coordination"

LV123-1644 The required creepage distances represent minimum values for the basic insulation.

LV123-1645 Minimum creepage distances for a double or reinforced insulation shall be designed for twice the value of the minimum creepage distances required for the basic insulation.

LV123-1646 A creepage distance shall not be shorter than the corresponding clearance.

LV123-1647 If the design of the creepage distances deviates from the specifications in the following sections for specific electronics, e.g. printed circuits, the design shall comply with IEC 60664-1 or applicable parts of IEC 60664. Such a design and the applied standard shall be documented by the supplier and agreed upon with the OEM.

LV123-1648 The design of the creepage distances of an HV component shall be reported by the supplier.

7.7.4 Solid insulating materials (LV123-1649)

LV123-1650 For testing, see Section "Test: General, clearances and creepage distances and solid insulating materials" in Section "Test: Insulation coordination"

LV123-2376 The solid insulating materials used for HV components shall be sufficiently voltage-proof.

LV123-1651 If no other requirements are specified in this document, the design of the solid insulating materials shall be in accordance with IEC 60664-1.

LV123-443 Solid insulating materials shall be designed in accordance with the rated impulse voltages or rated overvoltages specified in the sections below and comply with the requirements for the withstand voltage in accordance with Table "Test voltages withstand voltage - for connection to external electric power supply" or Table "Test voltages withstand voltage - without connection to external electric power supply".

LV123-1652 Solid insulating materials shall be selected in accordance with the following insulating material groups. These insulating material groups are formed according to the CTI values of the insulating materials:

- Insulating material group I: $600 \leq CTI$
- Insulating material group II: $400 \leq CTI < 600$
- Insulating material group IIIa: $175 \leq CTI < 400$
- Insulating material group IIIb: $100 \leq CTI < 175$

LV123-2288 Note: The comparative tracking index (CTI) value is a comparative figure for tracking which is used to describe the quality of the insulating material, see IEC 60664-1.

LV123-1653 Use of insulating materials of insulating group IIIb is not recommended. If such insulating materials are used, the required minimum creepage distances shall be multiplied by a factor of 1,6.

7.7.5 Withstand voltage (LV123-455)

LV123-457 For testing, see Section "Test: Withstand voltage".

LV123-458 Every HV component shall fulfill a sufficient level of withstand voltage for the required isolation / isolation paths in accordance with Section "General" in Section "Insulation coordination".

LV123-1654 In the case of double or reinforced insulation, the test voltage shall be selected greater by a factor of 2 compared with the value for the basic insulation.

LV123-1655 For the design of the HV components, at least the required test voltages in accordance with Section "Insulation coordination for connection to external electric power supply" or Section "Insulation coordination without connection to external electric power supply" shall be used.

LV123-267 The HV components shall be designed such that they withstand the test voltages in accordance with Table "Test voltages withstand voltage - for connection to external electric power supply" or Table "Test voltages withstand voltage - without connection to external electric power supply" for all specified tests without modification of the component, e.g. by removing parts.

7.7.6 Insulation coordination for connection to an external electric power supply (LV123-1656)

7.7.6.1 General (LV123-1657)

LV123-1658 For the connection to an external electric power supply, a distinction is made between the following supply circuits, see Figure "Sample system overview BEV, PHEV - Connection to external DC power supply switched on" and Figure "Sample system overview BEV, PHEV - Connection to external DC power supply switched on":

- AC power supply circuit
- DC power supply circuit
- DC interconnection circuit, see Figure "Sample system overview BEV, PHEV - Connection to external DC power supply off".

LV123-1659 Note: The requirements pertaining to insulation coordination are different for the DC power supply circuit and the DC interconnection circuit for the following reason. When the switching equipment for DC supply is switched off, the DC power supply circuit is divided into two galvanically separated circuits, the DC interconnection circuit and the DC HV circuit. When the switching equipment for DC supply is switched on, the DC interconnection circuit forms a sub-circuit of the DC power supply circuit.

LV123-1660 The assignment of HV components to the different supply circuits shall be gathered from the OEM's requirements documentation.

LV123-1661 The requirements for the insulation coordination for connection to an external electric power supply are specified in the following sections:

- HV components assigned to AC power supply circuits, see Section "Insulation coordination for AC and DC power supply circuits"
- HV components assigned to DC power supply circuits excluding the DC interconnection circuit, see Section "Insulation coordination for AC and DC power supply circuits"
- HV components assigned to the DC interconnection circuit, see Section "Insulation coordination for DC interconnection circuit".

7.7.6.2 Insulation coordination for AC and DC power supply circuits (LV123-1662)

LV123-1663 The following requirements for insulation coordination shall be fulfilled for HV components intended for the operation of the HV system with connection to an external electric power supply.
These requirements shall be fulfilled for any type of external electric power supply such as AC or DC power supply circuits.

LV123-2289 Note: For HV components that are also assigned to the DC interconnection circuit, the requirements are specified in Section "Insulation coordination for DC interconnection circuit".

LV123-2115 **Rated voltage**

LV123-1664 For the design of the insulation coordination of an HV component, a rated impulse voltage of 2500 V shall be applied according to overvoltage category II in accordance with IEC 60664-1.

LV123-1671 In the design of the insulation coordination of an HV component connected to the AC or DC power supply circuit, the rated voltages in accordance with Table "Rated voltages insulation coordination - for connection to an external electric power supply" shall be taken into account for the basic insulation.

LV123-1672 Table: Rated voltages insulation coordination - for connection to an external electric power supply

LV123-1673

Rated voltages Insulation coordination	**Unit**	**HV_1**	**HV_2a HV_2b**	**HV_3**
Overvoltage (transient overvoltage, peak voltage) [a]	V pk	2500	2500	2500
Long-term stresses (rated insulation voltage) [b]	V pk	250	500	800
Note: The specifications apply to basic insulation				
[a] Application for the design of clearances and solid insulating materials [b] Application for the design of creepage distances				

LV123-2116 **Clearances and creepage distances - AC power supply circuit**

LV123-1665 An HV component which is assigned to the AC power supply circuit shall, for this circuit, comply with the requirements for the minimum clearances and creepage distances for basic insulation in accordance with Table "Minimum clearance and creepage distances for AC power supply circuit".

LV123-1666 Table: Minimum clearance and creepage distances for AC power supply circuit

LV123-1667

Voltage [a] rms value V a.c. (rms)	**Minimum clearances [b]** mm	**Minimum creepage distances** mm					
		Pollution degree					
		2			3		
		Insulating material group					
		I	**II**	**IIIa**	**I**	**II**	**IIIa**
250	2,0	2,0	2,0	2,5	3,2	3,6	4,0
Note 1: The specifications for the minimum values of clearances and creepage distances apply to basic insulation. Note 2: The specifications apply to rated voltages of single-phase or multiphase external electric power supplies of 250 V a.c. (rms) and 230 V a.c. (rms) / 400 V a.c. (rms).							
[a] Rated insulation voltage according to the maximum rms value of the operating voltage to earth. [b] The specifications apply to an altitude of 4000 m.							

LV123-2117

Clearances and creepage distances - DC HV circuit and DC power supply circuit

LV123-1668

An HV component which is assigned

- to the DC HV circuit, or
- to the DC power supply circuit

shall, for this circuit, comply with the requirements for the minimum clearances and creepage distances for basic insulation in accordance with Table "Minimum clearances and creepage distances for DC power supply circuit".

LV123-1669

Table: Minimum clearances and creepage distances for DC power supply circuit

LV123-1670

Voltage level [a]	Minimum clearances [b] mm	Minimum creepage distances mm					
		Pollution degree					
		2			3		
		Insulating material group					
		I	II	IIIa	I	II	IIIa
HV_1	2,0	2,0	2,0	2,5	3,2	3,6	4,0
HV_2a, HV_2b	2,0	2,5	3,6	5,0	6,3	7,1	8,0
HV_3	2,0	4,0	5,6	8,0	10,0	11,0	12,5
Note: The specifications for the minimum values of clearances and creepage distances apply to basic insulation							
[a] Voltage level according to Table "HV voltage ranges" [b] The specifications apply to an altitude of 4000 m.							

LV123-2118

Test voltages

LV123-459

The HV components connected to the AC or DC power supply circuit shall be designed for the required test voltages in accordance with Table "Test voltages withstand voltage - for connection to external electric power supply".

LV123-269

Table: Test voltages withstand voltage - for connection to external electric power supply

LV123-270

Parameter	Unit	HV_1	HV_2a HV_2b	HV_3
Test voltage for isolation resistance HV components excluding HV cables	V d.c.	500	500	1000
Test voltage for isolation resistance of pre-assembled HV cables (see SAE J1742)	V d.c.	1000	1000	1000
Test voltage for withstand voltage HV components including pre-assembled HV cables with basic insulation	V a.c. (rms) V d.c.	1500 2150	1500 2150	1500 2150
Test voltage for withstand voltage HV components including pre-assembled HV cables with reinforced/double insulation	V a.c. (rms) V d.c.	3000 4300	3000 4300	3000 4300

7.7.6.3 Insulation coordination for DC interconnection circuit (LV123-1674)

LV123-1675 The following requirements for insulation coordination shall be fulfilled for HV components that are intended for the operation of the HV system with connection to an external DC power supply and that are assigned to the DC interconnection circuit.

LV123-2119 **Rated voltage**

LV123-1676 For the design of the insulation coordination of an HV component, a rated impulse voltage of 2500 V shall be applied according to overvoltage category II in accordance with IEC 60664-1.

LV123-1680 In the design of the insulation coordination of an HV component connected to the DC interconnection circuit, the rated voltages in accordance with Table "Rated voltages insulation coordination - DC interconnection circuit" shall be taken into account for the basic insulation.

LV123-1681 Table: Rated voltages insulation coordination - DC interconnection circuit

LV123-1682

Rated voltages Insulation coordination	**Unit**	**Maximum voltage - External DC supply**	
		500 V d.c.	**1000 V d.c.**
Overvoltage (transient overvoltage, peak voltage) [a]	V pk	2500	2500
Long-term stresses (rated insulation voltage) [b]	V pk	500	1000
Note: The specifications apply to basic insulation			
[a] Application for the design of clearances and solid insulating materials [b] Application for the design of creepage distances			

LV123-2120 **Clearances and creepage distances - DC interconnection circuit**

LV123-1677 An HV component which is assigned to the DC interconnection circuit shall, for this circuit, comply with the requirements for the minimum clearances and creepage distances for basic insulation in accordance with Table "Minimum clearance and creepage distances for DC interconnection circuit".

LV123-1678 Table: Minimum clearances and creepage distances for DC interconnection circuit

LV123-1679

Maximum voltage External DC supply [a] $V_{d.c.}$	**Minimum clearances [b]** mm	**Minimum creepage distances** mm					
		Pollution degree					
		2			3		
		Insulating material group					
		I	**II**	**IIIa**	**I**	**II**	**IIIa**
500	2,0	2,5	3,6	5,0	6,3	7,1	8,0
1000	2,0	5,0	7,1	10,0	12,5	14,0	16,0
Note: The specifications for the minimum values of clearances and creepage distances apply to basic insulation.							
[a] Maximum expected continuous voltage during connection to an external DC supply [b] The specifications apply to an altitude of 4000 m.							

LV123-2121 **Test voltages**

LV123-1683 HV components connected to the DC interconnection circuit shall be designed for the required test voltages in accordance with Table "Test voltages withstand voltage - DC interconnection circuit".

LV123-1684 Table: Test voltages withstand voltage - DC interconnection circuit

LV123-1685

Parameter	Unit	Maximum voltage - External DC supply	
		500 V d.c.	1000 V d.c.
Test voltage for isolation resistance HV components including HV cables	V d.c.	1000	1000
Test voltage for withstand voltage HV components including pre-assembled HV cables with basic insulation	V a.c. (rms) V d.c.	1500 2150	1500 2150
Test voltage for withstand voltage HV components including pre-assembled HV cables with reinforced/double insulation	V a.c. (rms) V d.c.	3000 4300	3000 4300

7.7.7 Insulation coordination without connection to external electric power supply (LV123-1686)

LV123-1687 The following requirements for insulation coordination shall be fulfilled for HV components intended for the operation of the HV system without connection to an external electric power supply. These requirements shall be fulfilled for HV components operated with AC or DC operating voltages.

LV123-2290 **Rated voltage**

LV123-1691 In the design of the insulation coordination of an HV component connected to the DC HV circuit, the rated voltages in accordance with Table "Rated voltages insulation coordination - without connection to an external electric power supply" shall be taken into account for the basic insulation.

LV123-1692 Table: Rated voltages insulation coordination - without connection to an external electric power supply

LV123-1693

Rated voltages Insulation coordination	Unit	HV_1	HV_2a, HV_2b	HV_3
Overvoltage (transient over-voltage, peak voltage) [a, b]	V pk	800	800	1500
Long-term stresses (rated insulation voltage) [c]	V pk	250	500	800
Note: The specifications apply to the basic insulation				
[a] Application for the design of clearances and solid insulating materials [b] Specifications derived from maximum rated voltages of semiconductors and from the series of preferred values for overvoltages; see IEC 60664-1 [c] Application for the design of creepage distances				

LV123-2291

Clearances and creepage distances

LV123-1688

An HV component which is assigned to a DC HV circuit shall, for this circuit, comply with the requirements for the minimum clearances and creepage distances for basic insulation in accordance with Table "Minimum clearance and creepage distances for DC HV circuit".

LV123-1689

Table: Minimum clearances and creepage distances for DC HV circuit

LV123-1690

Voltage level [a]	Minimum clearances [b] mm	Minimum creepage distances mm					
		Pollution degree					
		2			3		
		Insulating material group					
		I	II	IIIa	I	II	IIIa
HV_1	1,2	1,3	1,8	2,5	3,2	3,6	4,0
HV_2a, HV_2b	1,2	2,5	3,6	5,0	6,3	7,1	8,0
HV_3	1,2	4,0	5,6	8,0	10,0	11,0	12,5
Note: The specifications for the minimum values of clearances and creepage distances apply to basic insulation.							
[a] Voltage level according to Table "HV voltage ranges" [b] The specifications apply to an altitude of 4000 m.							

LV123-2292

Test voltages

LV123-1694

The HV components connected to DC HV circuits shall be designed for the required test voltages in accordance with Table "Test voltages withstand voltage - without connection to external electric power supply".

LV123-1695

Table: Test voltages withstand voltage - without connection to external electric power supply

LV123-1696

Parameter	Unit	HV_1	HV_2a HV_2b	HV_3
Test voltage for isolation resistance HV components excluding HV cables	V d.c.	500	500	1000
Test voltage for isolation resistance of pre-assembled HV cables (see SAE J1742)	V d.c.	1000	1000	1000
Test voltage for withstand voltage HV components including pre-assembled HV cables with basic insulation	V a.c. (rms) V d.c.	1000 1450	1000 1450	1000 1450
Test voltage for withstand voltage HV components including pre-assembled HV cables with reinforced/double insulation	V a.c. (rms) V d.c.	2000 2900	2000 2900	2000 2900

7.8 Residual voltage (LV123-1697)

LV123-1699 For testing, see Section "Test: Residual voltage"

LV123-1700 When the HV system is shutoff, all controlled HV components shall switch off the load current or activate the load-free state. The signaling for the shut-off of the HV system shall be gathered from the OEM's requirements documentation.

LV123-1701 Note: After the HV system is shut off, the state "low voltage", i.e. voltages below the lower limits for voltage class B, is set by means of a discharge; see Sections "Voltage class", "Active discharge" and "Passive discharge".

LV123-1703 When the HV system is shut off, HV components shall fulfill the following requirements pertaining to residual voltage:

- A voltage shall permanently lie below a specified voltage limit. The voltage limit shall be below voltage class B. The voltage limit shall be gathered from the OEM's requirements documentation.
- An AC voltage shall not occur.

LV123-2293 HV components shall comply with the required voltage values between the following potentials:

- Between HV potentials of HV contacting points
- Between every HV potential of an HV contacting and electrical ground
- Between each HV potential and accessible conductive parts of the HV component.

LV123-2294 These requirements pertaining to a residual voltage shall also be fulfilled under the following conditions:

- The HV component is not installed in the vehicle or connected to an HV circuit
- The removed HV component is connected to the LV supply.

LV123-1613 HV sources with stored energy or stored residual energy caused by normal operation, that do not discharge operationally within < 5 s after their switch-off to a voltage below voltage class B, shall be switched off at all poles from the DC HV circuit.

7.9 Active discharge (LV123-462)

LV123-463 Note: Bibliographic references: ISO 6469-3, SAE J1766

LV123-464 For testing, see Section "Test: Active discharge"

LV123-465 A circuit for active discharge is used for the rapid discharge of the capacitors on the DC HV circuit and the lowering of the DC HV voltage in a specified time and below a specified voltage.

LV123-466 A circuit for active discharge, and the corresponding control measures, shall be provided for the HV components specified by the OEM.

LV123-467 The active discharge circuit shall be dimensioned in such a way that the specified total capacitance is discharged even at maximum operating voltage.

LV123-468 The active discharge shall lower the DC HV voltage to a voltage below 60 V d.c. in less than 5 s. If a shorter time is required for the active discharge, the time shall be gathered from the OEM's requirements documentation.

LV123-1704 In the design of the active discharge, the total capacitances of the X capacitors and the Y capacitors of the HV component and of the DC HV circuit to be discharged shall be taken into account.

LV123-472 An HV component shall discharge the total capacitance, which consists of its own capacitance plus the relevant additional capacitance of the HV system. Details on the relevant additional capacitance of the HV system shall be gathered from the OEM's requirements documentation.

LV123-1705 For the design of the active discharge, all tolerances and delay times influencing the discharge time shall be taken into account. These include, for example, part tolerances, signal propagation times, switching times. The resulting tolerance range for the duration of discharge shall be reported by the supplier.

LV123-1706 The functional capability of the active discharge function shall be monitored. In the event of a failure, a fault memory entry shall be set.

LV123-469 The active discharge process shall be in effect every time the HV system is shut off.

LV123-471 The active discharge shall be functional in the event that the LV supply of the corresponding HV components fails.

LV123-473 Further specifications regarding the activation of the active discharge shall be gathered from the OEM's requirements documentation.

LV123-474 The circuit and the control measures for the active process shall be specified by the supplier and agreed upon with the OEM.

7.10 Passive discharge (LV123-475)

LV123-477 For testing, see Section "Test: Passive discharge"

LV123-478 The circuit for passive discharge is used for the discharge of X capacitors on the DC HV circuit and the lowering of the DC HV voltage in a specified time below a defined voltage.

LV123-479 A passive discharge circuit shall be provided for every HV component that has an X capacitor with an energy content larger than 0,2 J.

LV123-480 The circuit for passive discharge shall be dimensioned in such a way that the X capacitor of the HV component is discharged even at the maximum operating voltage.

LV123-1520 The circuit for passive discharge shall be dimensioned in such a way that during discharge the voltage at the DC HV contactings drops to a voltage below 60 V d.c.

LV123-1524 The passive discharge shall be completed within a duration of 2 min. For systems with higher power or voltages above the HV_2b voltage level in accordance with Section "Voltage levels", a duration of up to 5 min for the passive discharge of an HV component may be specified; see OEM's requirements documentation.

LV123-481 The requirements for the passive discharge shall be fulfilled for an individual HV component even when the component has been removed.

LV123-482 The passive discharge shall be implemented with discharge resistors in the HV components. If other parts are intended to be used, they shall be specified by the supplier and agreed upon with the OEM.

LV123-483 Passive discharge shall always be in effect. The passive discharge shall be independent of the LV supply of the HV component.

LV123-484 In order to limit constant load during operation and prevent overloading of individual discharge circuits on the DC HV circuit, the design of the discharge circuit should be chosen in such a way that the specified passive discharge time for every HV component is complied with.

7.11 X capacitors (LV123-485)

LV123-2122 Note: Bibliographic references: IEC 60950-1

LV123-487 For testing, see Section "Test: X capacitors"

LV123-1707 Note: Capacitors or RC combinations of class X are suitable for applications with special requirements pertaining to protection against thermal overload, see IEC 60384-14.

LV123-1708 X capacitors in DC HV circuits shall fulfill the following requirements:

- The selected X capacitors shall be capacitors or RC combinations of class X in accordance with IEC 60384-14.
- X capacitors shall correspond to capacitors of class Y. These class Y capacitors shall have the same or a greater operating voltage as is required for class X capacitors.
- X capacitors shall be qualified in accordance with the applicable requirements found in IEC 60384-1.

LV123-2123 Note: Further details on the design of capacitors or RC combinations of class X are specified in IEC 60950-1.

LV123-2124 If X capacitors are built from multiple individual capacitors that are connected in series and qualified in accordance with the requirements found in IEC 60384-1, suitable measures shall be provided for to deal with the failure of one of these single capacitors due to a short or open circuit.

LV123-2125 For the design of the X capacitors, the overvoltage category or the rated voltage in accordance with Section "Insulation coordination" shall be applied.

LV123-489 For an HV component, the supplier shall carry out the design of X capacitors if these are required for the operation of the HV component.

LV123-490 The selected values for the X capacitors shall be reported by the supplier.

LV123-491 The design of the X capacitors shall be specified by the supplier and agreed upon with the OEM.

LV123-1709 If safety and certification-relevant characteristics for the topic "Discharge in the event of a crash" are relevant, the technical specifications on the characteristics pertaining to the obligation for documentation for the X capacitor shall be documented by the supplier in accordance with Section "Safety and certification-relevant scopes HV" and agreed upon with the OEM.
Details on these characteristics shall be gathered from the OEM's requirements documentation.

LV123-2295 Note: For more information on safety and certification-relevant characteristics for the topic "Discharge in the event of a crash", see Section "Behavior in the event of a crash".

7.12 Y capacitors (LV123-492)

LV123-2126 Note: Bibliographic references: IEC 60950-1, ISO 6469-3, ISO/DIS 17409: 2013-09

LV123-494 For testing, see Section "Test: Y capacitors"

LV123-1710 Note: Capacitors or RC combinations of class Y are suitable for applications with special requirements pertaining to electrical safety, see IEC 60384-14.

LV123-1711 Y capacitors in HV circuits shall fulfill the following requirements:

- The selected Y capacitors shall be capacitors or RC combinations of class Y in accordance with IEC 60384-14.
- Y capacitors shall be qualified in accordance with the applicable requirements found in IEC 60384-1.

LV123-2127 Note: Further details on the design of Y capacitors are specified in IEC 60950-1.

LV123-1716 If Y capacitors qualified in accordance with the requirements in IEC 60384-1 are used, at least two equivalent series-connected single capacitors shall be used. If a component element fails, the remaining impedance shall fulfill the requirements pertaining to the corresponding insulation in accordance with Section "Insulation coordination". For the failure of a part, a short-circuit or an open circuit, whichever is less favorable, shall be applied. Such a failure shall be taken into account for each component element.

LV123-2128 Y capacitors to IEC 60384-14 that bridge a basic insulation shall fulfill one of the following requirements:

- Y capacitors shall correspond to class Y2.
- Y capacitors shall correspond to class Y1 and have the same or higher operating voltage as is required for Y2 capacitors.

LV123-1713 Y capacitors to IEC 60384-14 that bridge a double or reinforced insulation shall fulfill one of the following requirements:

- Y capacitors shall correspond to class Y1.
- A series connection of two or more Y capacitors of class Y2 or Y4 shall be used. For such a series connection, each single capacitor shall belong to the same class and have the same rated voltage and the same nominal capacitance value.

LV123-2129 For the selection and arrangement of Y capacitors, the requirements pertaining to clearances and creepage distances and to withstand voltage in accordance with Section "Insulation coordination" shall be fulfilled.

LV123-497 Requirements pertaining to test voltages for an HV component containing Y capacitors are specified in Section "Withstand voltage".

LV123-498 The voltage for the design of the Y capacitors shall be reported by the supplier.

LV123-499 For an HV component, an upper limit shall be complied with for the capacitance of the Y capacitors on the DC HV circuit. The complete stored energy of all Y capacitors in an HV circuit shall have a value of < 0,2 J per potential of a DC HV circuit. For the determination of the capacitances of the Y capacitors, the maximum operating voltage in accordance with Table "HV voltage ranges" shall be used.
The specifications for the Y capacitors of an HV component shall be gathered from the OEM's requirements documentation.

LV123-500 The chosen capacitance for the Y capacitors of an HV component shall be specified by the supplier.

LV123-501 The design of the Y capacitors of an HV component shall be agreed upon with the OEM by the supplier.

7.13 Isolation-bridging parts (LV123-2130)

LV123-2131 Note: Bibliographic references: IEC 60950-1, IECQ

LV123-2132 For testing, see Section "Test: Isolation-bridging parts"

LV123-2133 The requirements in this section shall be fulfilled for isolation-bridging resistors and arrangements of parts that bridge an insulation.

LV123-2377 Note: Requirements pertaining to the bridging of an isolation for Y capacitors are specified in Section "Y capacitors".

LV123-2134 The requirements in this section shall in particular be fulfilled if parts for which insulation requirements are specified are to be bridged by other parts. These include, for example:

- Parts that bridge switching equipment, see also Section "Switching equipment HV battery", Section "Pre-charge function"
- Parts that bridge parts for galvanic separation (e.g. transformers), such as a DC/DC converter HV/LV or an on-board charger
- Parts that bridge an overcurrent protection device, see also Section "Overcurrent protection", Section "Overcurrent protection HV battery".

LV123-2135 The requirements in this section shall in particular be fulfilled where isolation-bridging parts are used for a function. These include, for example:

- Measuring the HV voltage, see Section "Measuring the HV voltage"
- Isolation monitoring, see Section "Isolation monitoring".

LV123-2136 Isolation-bridging parts in HV components shall be selected taking account of at least one of the following requirements:

- Selection of the parts based on an applicable standard.
- Selection of qualified parts in accordance with a quality rating system, e.g. IECQ.
- Selection of qualified parts in accordance with verifiable tests.

LV123-2138 For the selection and arrangement of such parts and the arrangement of parts, the requirements pertaining to clearances and creepage distances and to withstand voltage in accordance with Section "Insulation coordination" shall be fulfilled.

LV123-1715 Resistors bridging an isolation shall be built from at least two equivalent series-connected single resistors.

LV123-2139 Note: Details on isolation-bridging resistors are specified in IEC 60950-1.

LV123-2140 In an arrangement of parts, if a part fails, the remaining circuit shall fulfill the requirements pertaining to the corresponding insulation (basic insulation, double or reinforced insulation) in accordance with Section "Insulation coordination". For the failure of a part, a short-circuit or an open circuit, whichever is less favorable, shall be applied. Such a failure shall be taken into account for each part.

LV123-2141 The design of isolation-bridging parts and such arrangements of parts, including the current limit, shall be specified by the supplier and agreed upon with the OEM.

7.14 HV contacting and reverse polarity protection (LV123-502)

LV123-503 Note: Bibliographic references: SAE J1742

LV123-504 For testing, see Section "Test: HV contacting"

LV123-2142 This section describes requirements for HV contacting with the exception of the vehicle inlet. Requirements for the vehicle inlet are given in Section "Requirements for the vehicle inlet".

LV123-505 Pin 1 shall conduct the positive HV pole in multi-terminal DC HV contacting.

LV123-2143 Measures to protect against the mix-up of HV contactings shall be implemented for an HV component in the following cases:

- If the HV component has multiple HV contactings of the same type
- If measures to protect against the mix-up of HV contactings are required for the HV component in the OEM's requirements documentation.

LV123-507 If a measure to protect against the mix-up of HV contactings is required, one of the following measures shall be applied to HV plug connections:

- The use of coded plug connections
- Design measures in the assembly of the HV wiring harness or the HV vehicle wiring harness.

The measure to protect against mix-up shall be gathered from the OEM's requirements documentation.

LV123-2144 If a measure to protect against the mix-up of HV contactings is required, one of the following measures shall be applied to HV threaded connections:

- Appropriate design of the HV connection
- Design measures in the assembly of the HV wiring harness or the HV vehicle wiring harness
- Appropriate marking in combination with process verification.

The design of the reverse polarity protection shall be gathered from the OEM's requirements documentation.

LV123-508 Reverse polarity protection for the HV plug connections of the HV component shall be established by one of the following measures:

- Appropriate design of the HV contact
- Design measure in the assembly of the HV wiring harness or the HV vehicle wiring harness.

The design of the reverse polarity protection shall be gathered from the OEM's requirements documentation.

LV123-2145 Reverse polarity protection for HV contactings belonging to the HV component in the form of a screw terminal connection shall be established by one of the following measures:

- Appropriate design of the HV contact
- Design measure in the assembly of the HV wiring harness or the HV vehicle wiring harness
- Appropriate marking in combination with process verification.

The design of the reverse polarity protection shall be gathered from the OEM's requirements documentation.

LV123-509 The requirements regarding the degree of protection and the protection against direct contact for HV contacting shall be fulfilled in accordance with
Section "Protection against direct contact".

LV123-1717 HV plug connections shall comply with the following additional requirement when in the disconnected (unmated) state:
All housing openings not intended for contacting while the plug is mated shall comply with at least degree of protection IPXXD in accordance with ISO 20653.

LV123-511 Fasteners for HV contactings and screws on contact connections shall be designed such as to prevent unintended loosening or unscrewing caused by the mechanical impact and vibration loads that occur during operation.

7.15 HV interlock (LV123-512)

LV123-514 For testing, see Section "Test: HV interlock".

LV123-515 The HV interlock function can be used for detection of the following states in the fully assembled vehicle:

- Disconnected HV contact
- Covers intended for assembly, disassembly or service are removed from live parts if degree of protection IPXXB is no longer fulfilled following removal.

LV123-2367 Note: The HV interlock function can be used as an additional monitoring and protective measure against access to live HV parts.

LV123-524 If an HV interlock is intended for the HV system, the implementation of the HV interlock for HV components shall be designed in accordance with the OEM's requirements documentation.
In detail, the following requirements shall be taken into account:

- The specifications for the signal generator and the signal detector
- The wiring and contacting (pin assignment)
- The specified interlock responses in case of an interlock event.

LV123-516 The HV interlock contains a signal loop or individually acting signal contacts.

LV123-517 If the HV interlock is designed as a signal loop, a signal generator and one or more signal detectors shall be included.

LV123-518 If the HV interlock is designed as an arrangement of individual signal contacts, several signal generators and several signal detectors shall be included.

LV123-519 HV components with a signal generator acting on signal contacts and/or a signal detector that analyzes signal contacts are functionally active with regard to the HV interlock function.

LV123-520 HV components that are equipped with signal contacts that are only effective outwards and, if necessary, signal wires, are functionally passive with regard to the HV interlock function.

LV123-521 A discontinuity in an individual signal contact or in the signal loop shall be detected as an interlock event by HV components that are functionally active with regard to the HV interlock.

LV123-522 HV components that are functionally active with regard to the HV interlock shall trigger the specified interlock response on detecting an interlock event.

LV123-523 If there is an interlock event, the HV system shall not be started up from its shut-off state into a power-on state.

7.16 Delayed access to live parts (LV123-525)

LV123-527 For testing, see Section "Test: Delayed access to live parts".

LV123-529 Any additional protective measure intended to delay access to live parts, e.g. for covers or fasteners for HV contactings, shall fulfill the following requirements.

LV123-530 The mechanical design of the additional safety mechanism shall be such that two separate manipulation processes are required in order to obtain access to the live part.

LV123-531 The first manipulation process shall trigger an HV system shut-off.

LV123-532 The mechanical design shall ensure that the manipulation processes take as much time as is necessary for a safe HV shut-off to be performed before it is possible to access the live part. The required time shall be chosen according to the time for active discharge, see Section "Active discharge".

LV123-533 The triggering of the HV system shut-off during the first manipulation step may be effected by an adequate integration into the HV interlock; see OEM's requirements documentation.

LV123-534 The requirement for delayed access to live parts is not applicable if protection against direct contact is fulfilled through the "Complex disassembly" design feature is implemented; see Section "Protection against direct contact".

LV123-535 The design of the safety mechanism for delayed access to live parts shall be documented by the supplier and agreed upon with the OEM.

7.17 Behavior in the event of a crash (LV123-536)

LV123-537 Note: Bibliographic references: Attachment 111, CMVSS 305, ECE-R12, ECE-R94, ECE-R95, FMVSS 305, GB/T 19751, ISO/DIS 6469-4: 2013-02, KMVSS Art. 18-2, 18-3, 91, SAE J1766, TP-305-01, TRIAS 17(2) J111(2), TRIAS 17(2)-R012, TRIAS 17(2)-R094, TRIAS 17(2)-R095

LV123-538 For testing, see Section "Test: Behavior in the event of a crash".

LV123-539 The signaling of a crash event relevant to electrical safety shall be gathered from the OEM's requirements documentation.

LV123-540 If a crash event relevant to electrical safety is signaled, all controlled HV components shall prevent the feed of electric energy into the DC HV circuit. This requirement shall be fulfilled even when such feed is not intended, e.g. feed from run-on of HV components with energy stored in rotors.

LV123-541 If a crash event relevant to electrical safety is signaled, a controlled HV component shall perform one of the following measures or combination thereof:

- Activation of a no-load state, with the exception of active discharge or support of discharge
- Shut off by means of switching equipment
- Active discharging of DC HV circuits
- Active discharging of AC HV circuits if voltages of voltage class B can occur after shut-off
- Disabling of selected functions.

The assignment and specification of the individual measures for a safe state in the event of a crash to controlled HV components shall be gathered from the OEM's requirements documentation.

LV123-542 In the event of an HV system shut-off, the active discharging of the DC HV circuits shall be initiated immediately, see Section "Active discharge".

LV123-543 After signaling of a crash event that is relevant for electrical safety, the voltage of the HV circuits shall be permanently reduced below a voltage of voltage class B in accordance with Section "Voltage class" within a time of < 5 s.

LV123-545 An HV battery shall be switched off by means of its switching equipment.

LV123-546 An inverter (drive system) shall activate an active short-circuit of the electric machine and an active discharge of the DC HV circuit, if these functions are intended; see Section "Additional requirements for inverters" and Section "Active discharge".

LV123-726 A permanent active short-circuiting of the motor windings shall be possible, even at full rotational speed, without damage to parts of the inverter, the electrical machine and the associated HV wiring harness. The duration shall be gathered from the OEM's requirements documentation.

LV123-727 The activation of the function active short-circuiting of the motor windings, e.g. during an HV shut-off, shall be gathered from the OEM's requirements documentation.

LV123-547 A DC/DC converter HV/LV shall fulfill the following requirements:

- Disabling of boost operation, if such operation is provided for; see Section "Additional requirements for DC/DC converter HV/LV"
- Activate active discharge of DC HV circuit, if this function is provided for; see Section "Active discharge".

LV123-548 Further requirements regarding the control of the HV components and regarding the sequence over time shall be gathered from the OEM's requirements documentation.

LV123-1720 If safety and certification-relevant characteristics for the topic "Discharge in the event of a crash" are relevant for electrical safety, the technical information on the relevant characteristics
for the discharge in the event of a crash shall be specified by the supplier in accordance with Section "Safety and certification-relevant scopes HV" and agreed with the OEM.
Details on these characteristics shall be gathered from the OEM's requirements documentation.

7.18 Measuring the HV voltage (LV123-549)

LV123-551 For testing, see Section "Test: Measuring the HV voltage".

LV123-552 All controlled HV components shall detect the HV voltage at the interface to the DC HV circuit for cross-component system functions (e.g. HV disconnection process), unless otherwise specified by the OEM.

LV123-553 An HV component shall be able to measure the HV voltage at least within a range from 0 V d.c. up to the upper HV circuit limit voltage, in accordance with Table "HV voltage ranges".

LV123-554 A tolerance smaller than ± 1 %, based on the maximum operating voltage in accordance with Table "HV voltage ranges", shall be complied with for the voltage measurement.

LV123-555 At voltages > 60 V d.c., the output measured value shall in no case be < 60 V d.c. In the range of (60 ± 10) V d.c, the tolerance shall therefore be (- 0 % to + 5 %) of the measured value of the HV voltage.

LV123-556 The requirements regarding the voltage measurement shall be complied with taking into account the requirements regarding voltage offset in accordance with Section "Voltage offset". This applies to the measurement range and the measuring accuracy, in particular.

LV123-557 The currently measured HV voltage shall be made available on a vehicle communication bus.

LV123-558 If a diagnostic is intended for a controlled HV component, it shall be possible to read-out the currently measured voltage values via diagnostic. The requirements for the diagnostic shall be gathered from the OEM's requirements documentation.

LV123-2146 If a diagnostic is intended for a controlled HV component, it shall be possible to activate measurement of the HV voltage by diagnostic. The requirements for the diagnostic shall be gathered from the OEM's requirements documentation.

LV123-559 For all controlled HV components that can feed electric energy as intended into a DC HV circuit, an additional monitoring measure is required through which in a single fault condition

- the compliance with the voltage limits in accordance with Table "HV voltage ranges", or
- a component protection

can be provided.
The design of this additional monitoring measure shall be specified by the supplier and agreed upon with the OEM.

LV123-2296 Note: One possible monitoring measure is the plausibility check of the measured HV voltage and of the specified voltage limits.

7.19 Failure of LV supply voltage (LV123-561)

LV123-563 For testing, see Section "Test: Failure of LV supply voltage"

LV123-564 In the event of a failure of the LV power supply, a controlled HV component shall enter a safe state. This state shall be gathered from the OEM's requirements documentation.

LV123-565 The HV components shall be designed in such a way that, in the event of a partial or total failure of the LV power supply for their electronic control units, no currents or voltages exceeding the specified limits occur in the HV circuits; see Section "Voltage ranges".

LV123-566 The HV component itself shall not be damaged in the event of a LV power supply failure, and shall not damage other components inside the vehicle either.

7.20 Electrical equivalent circuit diagrams (LV123-567)

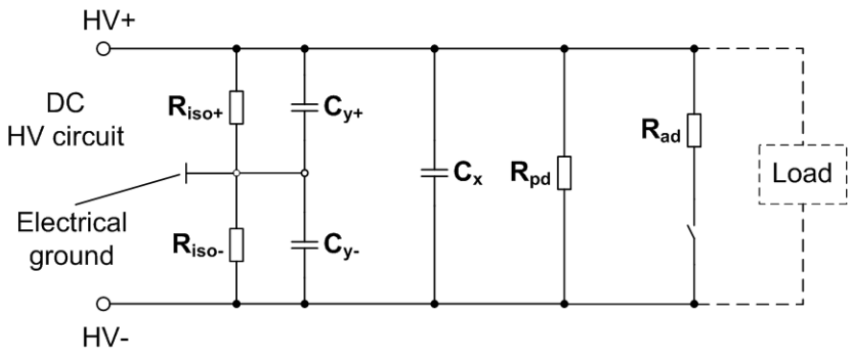
LV123-569 For testing, see Section "Test: Electrical equivalent circuit diagrams"

LV123-570 For each HV component, the supplier shall specify an equivalent electric circuit diagram containing the effective equivalent circuit diagram elements in the DC HV circuit. The values shall be specified inclusive of the tolerances.
An example is given in Figure "Equivalent circuit diagram".

LV123-1721 Appropriate equivalent circuit diagrams and values of the equivalent circuit diagram elements taking into account the cable length shall be specified for the HV cables of the HV circuits.

LV123-1722 For HV components on AC HV circuits, appropriate equivalent circuit diagrams and values shall be reported according to diagram "Equivalent circuit diagram".

LV123-1723



R_{iso+}, R_{iso-}	Resulting resistance per HV potential Resistance between HV+ or HV- and electrical ground, including proportional isolation resistance and all resistances of electronic circuitry, e.g. for HV voltage symmetrization, HV voltage measurement
R_{ad}	Resistance for active discharge
R_{pd}	Resistance for passive discharge
C_x	Capacitance of X capacitors
C_{y+}, C_{y-}	Resulting capacitance of Y capacitors, capacitance between HV+ or HV- and electrical ground

LV123-1725 Figure: Equivalent circuit diagram

7.21 Installation areas and ambient conditions (LV123-571)

LV123-572 Note: Bibliographic references: GB/T 18384.3, ISO 16750

LV123-573 For testing, see Section "Test: Installation areas and ambient conditions"

LV123-124 For HV components, the requirements for electrical safety for the specified installation areas and ambient conditions shall be fulfilled. If necessary, additional requirements for the electrical safety shall be clarified and fulfilled.

LV123-574 **Installation areas**

LV123-575 The specification of the installation areas for the HV components shall be gathered from the OEM's requirements documentation; see ISO 16750-1.

LV123-576 **Load in the event of a crash**

LV123-577 Requirements for the HV components regarding the load in the event of a crash shall be gathered from the OEM's requirements documentation.

LV123-578 One possible design-based measure for HV components to protect against damage in case of a crash is to increase the mechanical strength of the housing. HV components and HV cables may be protected by additional covers or barriers.

LV123-1726 If operation of the HV system is intended after the crash, the equipotential bonding of an HV component shall be maintained after a crash. The operation of the HV system after a crash shall be gathered from the OEM's requirements documentation.

LV123-1727 Possible design measures for the maintenance of equipotential bonding include a length compensation for conductors or suitable attachments.

LV123-579 **Protection against foreign objects and water**

LV123-580 The IP degree of protection shall be gathered from the OEM's requirements documentation; see ISO 20653.

LV123-581 **Ambient conditions**

LV123-582 The specification of the ambient conditions (e.g. mechanical loads, thermal loads, corrosion, chemical substances) and the corresponding tests shall be gathered from the OEM's requirements documentation; see also the applicable parts of the series ISO 16750.

LV123-583 **Fording ability and driving through water**

LV123-584 The fording ability and driving through water at a water level up to the specified water level heights shall be taken into account in accordance with the OEM's requirements documentation. For this purpose, the installation location of an HV component, as well as the contacting and the routing of the wiring, shall be taken into account.

LV123-2147 HV components located below fording depth shall at least fulfill the degree of protection IP67 in accordance with ISO 20653. The fording depth shall be gathered from the OEM's requirements documentation.

LV123-585 **Altitude**

LV123-586 For the design of the HV component, the altitude shall be taken into account in accordance with Section "Insulation coordination".

7.22 Pre-assembly and mounting (LV123-588)

LV123-589 For testing, see Section "Test: Pre-assembly and mounting"

LV123-590 For HV components, the requirements for electrical safety for pre-assembly and mounting of an HV component shall be fulfilled. If necessary, additional requirements for the electrical safety shall be clarified and fulfilled. These include, e.g.:

- Installation location in regard to accessibility
- Condition upon delivery
- Storage life
- Pre-assembly, mounting, including sequence of process steps
- Testing after mounting.

For details, see OEM's requirements documentation.

7.23 Disassembly and disposal (LV123-1728)

LV123-1729 For testing, see Section "Test: Disassembly and disposal"

LV123-1730 For HV components, the requirements for electrical safety for disassembly and disposal of an HV component shall be fulfilled. If necessary, additional requirements for the electrical safety shall be clarified and fulfilled. These include, e.g.:

- Disassembly, including sequence of process steps
- Recycling
- Disposal.

For details, see OEM's requirements documentation.

7.24 EMC (LV123-591)

LV123-593 Note: The EMC requirements for HV components are specified in the corresponding OEM's requirements documentation.

7.25 Underload factors for HV parts (LV123-596)

LV123-597 For testing, see Section "Test: Underload factors for HV parts"

LV123-598 For HV components, underload factors shall be taken into account for parts that are operative on HV circuits, see also Section "Electrical equivalent circuit diagrams".

LV123-599 The underload factors shall be specified by the supplier and agreed upon with the OEM.

7.26 Documentation (LV123-600)

7.26.1 General (LV123-2297)

LV123-603 Note: Bibliographic references: Attachment 111, CMVSS 305, CNCA-02C-023, ECE-R12, ECE-R94, ECE-R95, ECE-R100, FMVSS 305, GB/T 18487.1, GB/T 18487.2, GB/T 18487.3, GB/T 19751, KMVSS Art. 18-2, 18-3, 91, QC/T 743, TRIAS 17(2) J111(2), TRIAS 17(2)-R012, TRIAS 17(2)-R094, TRIAS 17(2)-R095, TRIAS 17(2)-R100

LV123-601 For testing, see Section "Test: Documentation"

7.26.2 Safety and certification-relevant scopes HV (LV123-602)

LV123-604 The requirements of the applicable legal regulations of the relevant regions or markets are decisive in the approval of road vehicles with an HV system.

LV123-605 This document specifies, among other requirements, requirements for HV components regarding electrical safety, taking into account legal regulations; see Section "Annex A Bibliographic references".

LV123-606 It is hereby expressly stated that the requirements regarding electrical safety do not comprise the full scope of all requirements that are necessary for approval.

LV123-607 For HV components, the obligatory documentation requirement applies on the drawing level and in the documentation systems with respect to:

- Identification and documentation of safety relevance, here designated "DS", and
- Identification and documentation of certification relevance, including emissions relevance, here designated "DZ".

LV123-610 Parts or systems are safety relevant when their failure can cause an immediate risk of injury or death for road users.

LV123-611 Certification-relevant components or systems are those whose data, information, evidence or type approvals are used in certificates or country-specific registration documents or which are examined during type approval.

LV123-612 Table "Safety and certification-relevant scopes HV" contains an exemplary overview regarding scopes that are subject to obligatory documentation and their assignment to HV components.

LV123-613 Table: Safety and certification-relevant scopes HV

LV123-614

Topic	Documentation with DS, DZ	HV component	Reference
Marking	DZ	All HV components, incl. HV wiring harness	Section "Marking", Section "Test: Marking"
Overcurrent protection device Switching equipment	DZ	HV battery	Section "Overcurrent protection HV battery", Section "Test: Overcurrent protection HV battery"
Overcurrent protection function	DZ	Rechargeable energy storage	Section "Overcurrent protection", Section "Test: Overcurrent protection"
Protection against direct contact - Degree of protection	DZ	All HV components, incl. HV wiring harness	Section "Protection against direct contact", Section "Test: Protection against direct contact"
Equipotential bonding	DS, DZ	All HV components, except HV wiring harness	Section " Equipotential bonding", Section "Test: Equipotential bonding"
Isolation resistance	DS, DZ	All HV components, incl. HV wiring harness	Section "Isolation resistance", Section "Test: Isolation resistance"
Discharge in the event of a crash, incl. X capacitors	DZ	HV components as per OEM's requirements documentation	Section "Behavior in the event of a crash", Section "Test: Behavior in the event of a crash", Section "X capacitors", Section "Test: X capacitors"

LV123-615 The scopes in Table "Safety and certification-relevant scopes HV" include a partial scope of the requirements regarding electrical safety in accordance with Section "Requirements for electrical characteristics and HV safety" and the tests in accordance with Section "Testing for electrical characteristics and HV safety".

LV123-616 Table "Safety and certification-relevant scopes HV" does not claim to be complete. The binding requirements for the safety and certification-relevant characteristics of an HV component and documentation with DS, DZ shall be gathered from the OEM's requirements documentation.

7.26.3 Description of HV components for certification (LV123-617)

LV123-1513 The details for the description of an HV component, which are relevant for certification, shall be documented by the supplier for all countries or markets in which the use of the HV component is planned and delivered to the OEM.

LV123-619 The characteristics for the description of an HV component shall be gathered for the regulations or legal regulations of the relevant countries or markets.

LV123-1514 Note: For characteristics for the description of an HV component for certification in Europe, see list of "Essential characteristics of road vehicles or systems" in the Annex of ECE-R100.

LV123-1515 The relevant countries or markets for the planned use of an HV component shall be gathered from the OEM's requirements documentation.

8 Additional requirements for individual HV components
(LV123-620)

8.1 Isolation monitoring (LV123-621)

LV123-622 Note: Bibliographic references: ECE-R100, GB/T 18384.3, ISO 6469-3, ISO/DIS 17409: 2013-09

LV123-623 For testing, see Section "Test: Isolation monitoring"

LV123-624 The isolation monitoring of the HV system shall include the following partial functions:

- Functions for the determination and output of the isolation resistance (unit for the determination of the isolation resistance), and
- Functions for the evaluation of the output isolation resistance.

The implementation of these partial functions, including functional partitioning and interfaces, shall be specified by the supplier and agreed upon with the OEM.

LV123-628 The assignment of isolation monitoring functions to HV components or control units shall be gathered from the OEM's requirements documentation.

LV123-625 If several units are used for the determination of the isolation resistance, one of the following requirements shall be fulfilled:

- Only one unit for the determination of the isolation resistance shall be operated at the same time
- The units for the determination of the isolation resistance shall not interfere with each other.

LV123-627 The units for the determination of the isolation resistance shall be designed as measuring equipment.

LV123-629 The isolation monitoring function (display, response, vehicle system behavior) shall be designed in accordance with the OEM's specifications. This also includes the functional availability of isolation monitoring when the switching equipment of the HV battery or of other HV components that can feed electric energy into DC HV circuits is switched off.

LV123-630 The unit for the determination of the isolation resistance shall be matched to the Y capacitors in the HV system. For details regarding the Y capacitors of the HV system, see the OEM's requirements documentation.

LV123-631 The unit for the determination of the isolation resistance shall be capable of detecting insulation faults in all galvanically connected DC HV circuits and AC HV circuits of an HV system.

LV123-1731 If different operating voltages or HV voltage levels are used in galvanically connected HV circuits, the unit for the determination of the isolation resistance shall be capable of detecting isolation faults in the complete HV circuit. Details regarding HV voltage levels shall be gathered from the OEM's requirements documentation; see also Table "HV voltage ranges".

LV123-632 The unit for the determination of the isolation resistance shall be capable of detecting symmetrical and asymmetrical insulation faults.

LV123-633 The supplier shall indicate whether the unit for the determination of the isolation resistance

- determines the isolation resistance values separately between each HV pole of the DC HV circuit and vehicle ground, or
- determines the resulting parallel resistance for both HV poles of the DC HV circuit.

If the isolation resistance values are determined separately for each HV pole, the smallest value shall be used as output value.

LV123-634 It shall be possible to output the isolation resistances measured by the unit for the determination of the isolation resistance via a communication bus and to read them via out diagnostics.

LV123-635 A measuring tolerance of + 0 % to - 25 % shall be maintained within the range of 100 Ohm/V to 500 Ohm/V, i.e., the unit for the determination of the isolation resistance shall never output values larger than those actually occurring in the system.

LV123-636 Within the range of 500 Ohm/V to 750 Ohm/V, and for higher isolation resistances, the measurement tolerances shall be agreed upon with the OEM by the supplier.

LV123-637 As an output value, the unit for the determination of the isolation resistance shall use the measured value of the isolation resistance for the complete measured electrical system, i.e. exclusive of internal measuring resistances of the unit for the determination of the isolation resistance.

LV123-1732 Internal measurement resistors of the unit for the determination of the isolation resistance shall be specified by the supplier and agreed upon with the OEM.

LV123-1733 The unit for the determination of the isolation resistance shall be designed such that its internal measuring resistances are not detected during a measurement of the isolation resistance of the HV system using external measuring instruments. This requirement can be fulfilled, for example, by switching off the measurement resistors.

LV123-638 The upper HV circuit limit voltage of the HV system shall be selected as reference voltage for the calculation of the isolation resistance; see Table "HV voltage ranges".

LV123-639 The time until the output of a valid isolation resistance shall be shorter than 30 s provided that no other requirement is specified in the OEM's requirements documentation.

LV123-1734 The time until the output of a valid isolation resistance as a function of the capacitance of the Y capacitors in the range 0 µF to 2 µF for each DC HV potential shall be specified by the supplier.

LV123-1735 If an additional fast isolation monitoring function is required, the following requirements shall be fulfilled unless other requirements are specified in the OEM's requirements documentation:

- The time until the output of a valid isolation resistance shall be shorter than 5 s.
- The measuring tolerance of + 0 % to - 50 % shall be maintained in the range from 100 Ohm/V to 500 Ohm/V.

Requirements for an additional fast isolation monitoring function shall be gathered from the OEM's requirements documentation.

LV123-640 The current flowing through the unit for the determination of the isolation resistance shall always fall below the limit of 1 mA.

LV123-641 It shall be possible to switch off the unit for the determination of the isolation resistance by means of an appropriate circuit.

LV123-642 A self-test of the isolation monitoring system is required. In the event of a malfunction, a fault memory entry shall be set, and fault values shall be output as isolation resistance values.

LV123-2148 It shall be possible to activate the unit for the determination of the isolation resistance by diagnostic.

LV123-643 The functions of the isolation monitoring shall be specified by the supplier and agreed upon with the OEM (switch on, measuring interval, measuring frequency, switch off).

LV123-644 The sub-functions of the isolation monitoring shall fulfill the full scope of functionality under all operating conditions of the HV system in accordance with Section "Voltage ranges". The requirement pertaining to the functional availability of isolation monitoring in the undervoltage range shall be gathered from the OEM's requirements documentation.

8.2 Service disconnect function (LV123-652)

LV123-653 For testing, see Section "Test: Service disconnect function"

LV123-1521 The service disconnect function is a measure for the shutdown of the HV system within the framework of the HV disconnection process, e.g. in case of service.

LV123-1736 The service disconnect function can also be used for the following purposes:

- Assembly of the HV system
- Rework process in production
- Rescue disconnect (deactivation of HV system).

LV123-655 The service disconnect function shall be designed such that on actuation or activation the shut-off of the complete HV system is effected.

LV123-654 When the HV system is switched off using the service disconnect function, all HV components that can feed electric energy into DC HV circuits under operationally conditions shall be switched off in all HV circuits, e.g. on-board charger, DC/DC converter HV/LV, HV battery, HV generator.

LV123-656 The service disconnect function should be designed such that an HV system shut-off is carried out under no-load conditions.

LV123-657 The service disconnect function shall be designed such that after it is actuated or activated for an HV system shut-off, it is possible to secure against restarting (power-on) by interlocking.

LV123-1737 The interlocking shall be designed such as to prevent powering on of the entire HV system or of individual HV components that can feed electric energy into a DC HV circuit under operational condition.

LV123-658 The service disconnect function shall be designed such that interlocking is rendered impossible if no actuation or activation for an HV system shut-off is present.

LV123-659 The design of the service disconnect function and all related functions shall be gathered from the OEM's requirements documentation.

8.3 Pre-charge (LV123-660)

LV123-661 For testing, see Section "Test: Pre-charge"

LV123-662 A pre-charge circuit shall be provided for starting up the HV system.

LV123-663 The assignment of the pre-charge function shall be gathered from the OEM's requirements documentation.

LV123-664 The X capacitors of the HV components on the DC HV circuits shall be charged up to a pre-charge voltage with the pre-charge function.

LV123-665 The pre-charge voltage shall be gathered from the OEM's requirements documentation.

LV123-666 The pre-charge current shall be limited. The current limit shall be agreed upon with the OEM by the supplier.

LV123-667 The pre-charging shall be completed within a specified time. The specifications shall be gathered from the OEM's requirements documentation.

LV123-668 The HV system shall not be powered-on completely until the conditions for the end of the pre-charging function have been fulfilled.

LV123-1738 If the switching equipment of the HV battery is used for pre-charging, the switching device or switching device arrangement for the other DC HV potential shall not be switched on until the pre-charging is completed.

LV123-669 The pre-charging shall be designed such that deviations from a specified voltage curve over time are detected as faults.

LV123-670 If a fault is detected during pre-charging, the pre-charging shall be terminated.

LV123-671 All X capacitors in the entire HV system shall be taken into account when designing the pre-charge function. Details regarding the X capacitors of the HV system shall be gathered from the OEM's requirements documentation.

LV123-672 The design of the pre-charge function, a pre-charge circuit and the switching devices employed shall be specified by the supplier and agreed upon with the OEM.

LV123-673 Further requirements regarding the pre-charging and its control shall be gathered from the OEM's requirements documentation.

8.4 Detection of open HV cables (LV123-674)

LV123-675 For testing, see Section "Test: Detection of open HV cables"

LV123-677 A measure for the detection of open HV cables shall be provided if live parts of disconnected HV contactings in HV circuits (non-contact state) can be touched during servicing (e.g. screwed HV contactings), see also Section "Protection against direct contact".

LV123-681 For the detection of open HV cables, one of the following measures shall be provided:

- Technical measure
- Organizational or procedural measure.

The details on the relevant measure shall be gathered from the OEM's requirements documentation.

LV123-1739 A technical measure for the detection of open HV cables shall be designed such that it is capable to detect disconnected HV contactings (unmated state).

LV123-679 The assignment of a technical measure for the detection of open HV cables for

- DC HV circuits, and
- AC HV circuits

to an HV component shall be gathered from the OEM's requirements documentation.

LV123-1740 A technical measure for the detection of open HV cables shall comply with one of the following requirements:

- Used voltages shall be below voltages of voltage class B
- Used currents shall be < 10 mA d.c. or < 2 mA a.c.
- The cut-off time after detection of an open cable shall be selected such that the requirements in accordance with the time/current diagrams in IEC/TS 60479-1 are fulfilled.

LV123-678 If a technical measure for the detection of open HV cables is required, a circuit suitable for a DC HV circuit or AC HV circuit shall be specified by the supplier and agreed upon with the OEM.

LV123-680 The activation for the detection of open HV cables shall be effected before or during the power-on procedure (e.g. pre-charge of the DC HV circuits) or immediately following switching on the HV system.

LV123-682 If open HV cables are detected as a result of a technical measure, the power-on procedure shall be interrupted, or the HV system shall be shut off.

LV123-1741 Further requirements for the detection of open HV cables and related control functions shall be gathered from the OEM's requirements documentation.

LV123-1742 For an organizational or procedural measure, the individual measures of the OEM, for example, the training of service personnel or the selection of qualified workshops, shall apply.

8.5 Additional requirements for HV battery (LV123-690)

8.5.1 General requirements (LV123-693)

LV123-694 If more than one HV battery is used in a single vehicle, the requirements apply to each individual HV battery.

LV123-1743 HV plug connections within the HV battery that are operated during servicing shall comply with the following additional requirement when in the disconnected (non-contact) state:
All housing openings not intended for contacting when plug is inserted shall comply with at least degree of protection IPXXD in accordance with ISO 20653.

8.5.2 Switching equipment HV battery (LV123-701)

LV123-691 Note: Bibliographic references: ECE-R100, ISO 6469-1, ISO 12405-1, ISO 12405-2, ISO/FDIS 12405-3: 2014-01, SAE J2578

LV123-692 For testing, see Section "Test: Switching equipment HV battery" in Section "Test: Additional requirements for HV battery"

LV123-695 The HV battery shall be separated on all poles from the DC HV circuits when the HV system is shut off. Details on the shut-off of the HV system shall be gathered from the OEM's requirements documentation.

LV123-696 Switching equipment shall be used for switching the HV battery on and off.

LV123-1522 Switching on of the switching equipment shall be disabled unless it is enabled. The requirements for the release shall be gathered from the OEM's requirements documentation.

LV123-1744 The switching equipment shall be designed such that at least one pole of the DC HV circuit is switched off by means of a contactor.

LV123-1745 One of the following devices shall be used as switching equipment:

- One contactor for each pole of the DC HV circuit
- Combination of a contactor for one pole and a semiconductor switch for the other pole of the DC HV circuit.

The details on the switching equipment shall be gathered from the OEM's requirements documentation.

LV123-1746 A contactor shall be designed such that between the active parts of the contacts in open state at least the requirements for the basic insulation in accordance with Section "Insulation coordination" are fulfilled.

LV123-1747 If the switching equipment of the HV battery is used for pre-charging, the following requirement shall be fulfilled:

- If the switching equipment in the pre-charge path is designed as semiconductor switch, a contactor shall be used as switching equipment for the other DC HV pole.

LV123-702 For contactors, the supplier shall indicate the maximum ampacity over the time of the current load during which no jamming of the contacts occurs.

LV123-703 In the event of an overcurrent in the contactors' robustness range, neither the switching off of the switching equipment nor the operation after the subsequent operationally intended switching on shall result in jamming of the contactor, a failure of a semiconductor switch or damage to the switching equipment that is not covered by the specification of the switching equipment; see Figure "Overview of overcurrent protection tripping thresholds".

LV123-1748 Semiconductor switches of switching equipment shall be designed such that they interrupt a current flow in both directions in their switched off state.

LV123-1749 On canceling of the activation or cut off of power supply, the switches of the switching equipment shall assume the switched off state.

LV123-705 Contactors shall be able to cut off charging and load currents within the robustness range of the contactors with a number of cut-offs in accordance with the OEM's requirements documentation; see Figure "Overview of overcurrent protection tripping thresholds".

LV123-706 It shall be detected when a switching device can no longer be switched off (jammed contactor or breakdown of semiconductor switch).

LV123-707 When a switching device can no longer be switched off due to a jammed contactor or a semiconductor switch breakdown, for example, a fault memory entry shall be set.

LV123-708 It shall be possible to read out the fault memory entry for a switching device that can no longer be switched off by diagnostic.

LV123-709 For contactors, the number of switching operations shall be monitored taking into account the load current.

LV123-710 For contactors, it shall be possible to read out the number of switching operations via diagnostics.

LV123-711 When an upper limit for the permissible number of switching operations under load current is reached, the switching equipment shall be prevented from switching on.

LV123-712 Further requirements and reaction behavior in the event of jammed contactors, broken-down semiconductor switches or fault conditions shall be gathered from the OEM's requirements documentation.

8.5.3 Overcurrent protection HV battery (LV123-386)

LV123-387 Note: Bibliographic references: ECE-R100, GB/T 18384.1, GB/T 19751, ISO 6469-1, ISO 8820, ISO 12405-1, ISO 12405-2, ISO/FDIS 12405-3: 2014-01, KMVSS Art. 18-2, 18-3, 91, QC/T 743, SAE 2344, SAE J2578, SAE J2929

LV123-388 For testing, see Section "Test: Overcurrent protection HV battery" in Section "Additional requirements for HV battery"

LV123-400 The technical specifications regarding the safety and certification-relevant characteristics relating to the obligation for documentation for the topic "Overcurrent protection device, switching equipment" shall be documented by the supplier in accordance with Section "Safety and certification-relevant scopes HV" and shall be agreed upon with the OEM.
Details on these characteristics shall be gathered from the OEM's requirements documentation.

LV123-697 **Overcurrent protection device**

LV123-698 In addition to the switching equipment, the HV battery shall be equipped with an overcurrent protection device.

LV123-699 The overcurrent protection device shall be capable of interrupting overcurrents in the galvanically connected DC HV circuit which can be present as overload currents or short-circuit currents.

LV123-1750 The overcurrent protection device shall fulfill the following requirements:

- After a triggering of the overcurrent protection device and with the maximum operating voltage in accordance with Table "HV voltage ranges" applied, the leakage current that can flow through the overcurrent protection device shall be restricted to a specified current limit.
- After the overcurrent protection device is triggered, the resistance between the contacts of the overcurrent protection device shall comply with a specified minimum value.
- The breaking capacity of the overcurrent protection device for interrupting overcurrents shall be reported by the supplier.

The individual requirements for the overcurrent protection device shall be gathered from the OEM's requirements documentation.

LV123-1751 One of the following devices shall be used as an overcurrent protection device:

- Fuse
- Protection device which fulfills the overcurrent protection requirements in a comparable way to a fuse.

The overcurrent protection device shall be gathered from the OEM's requirements documentation.

LV123-2149 If a fuse is used as the overcurrent protection device, it shall be designed in accordance with the OEM's requirements documentation or with applicable standards.

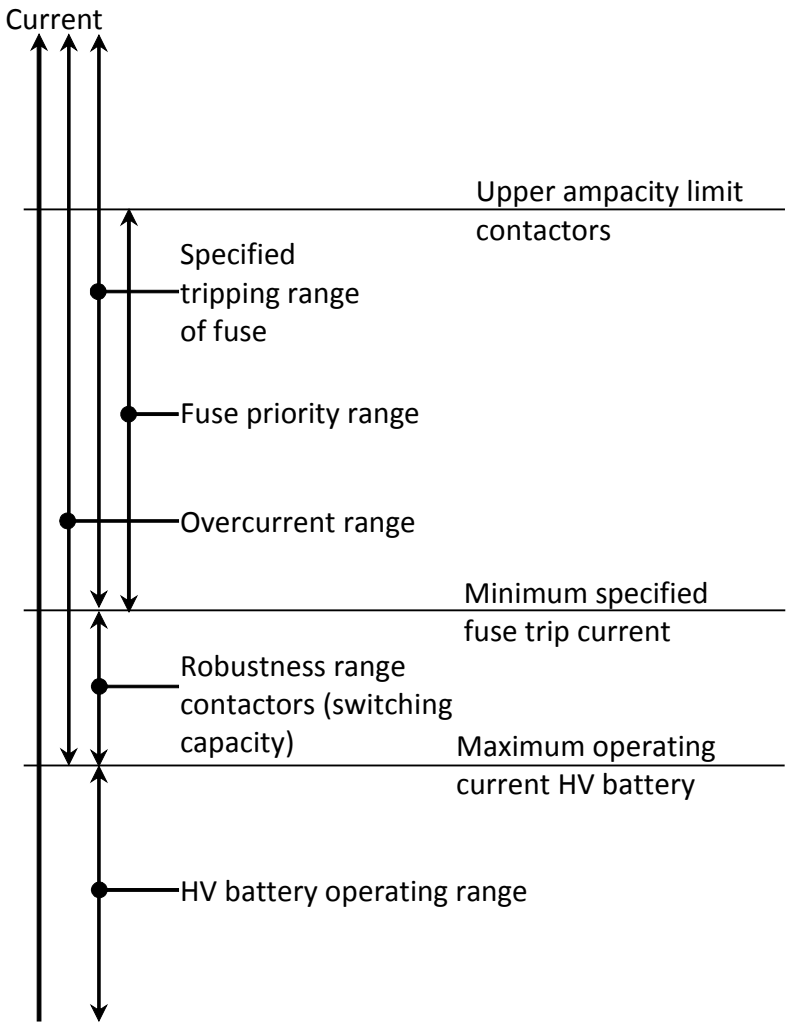
LV123-2150 Note: Fuse requirements are specified in the series ISO 8820.

LV123-700 The design of the overcurrent protection device shall be specified by the supplier and agreed upon with the OEM. This includes, for example, details on the triggering time and current for triggering.

LV123-1752 **Combination of switching equipment and overcurrent protection device**

LV123-390 Current limits, tripping thresholds and triggering ranges above the maximum operating current are shown in Figure "Overview of overcurrent protection tripping thresholds". The maximum short-circuit current is a characteristic of the HV battery; see Figure "Overview of overcurrent protection tripping thresholds".

LV123-391



LV123-392 Figure: Overview of overcurrent protection tripping thresholds

LV123-389 The HV battery shall be able to detect an overcurrent in the contactor robustness range; see Figure "Overview of overcurrent protection tripping thresholds".

LV123-393 The interconnection of switching equipment and overcurrent protection device shall be capable of switching off overcurrents which can occur as overload or short-circuit currents irrespective of their current direction or current level.

LV123-394 The switching off of an overcurrent by the switching equipment or the overcurrent protection device shall not cause any mechanical or thermal damage outside the HV battery. No mechanical damage shall occur to the housing of the HV battery.

LV123-1753 For overcurrents in the fuse priority range in accordance with Figure "Overview of overcurrent protection tripping thresholds", the fuse shall always trigger early enough to ensure that no jamming of the contactors or conductive failure of a semiconductor switch occurs.

LV123-396 For the contactors of the switching equipment, the ampacity in the event overcurrent shall be coordinated with the tripping characteristic of the overcurrent protection device; see Figure "Overview of overcurrent protection tripping thresholds". Tolerances and ambient conditions shall be taken into account. The values shall be specified by the supplier and agreed with the OEM.

LV123-1754 The supplier shall indicate the upper limit of the ampacity for contactors of the switching equipment. The following parameters shall be specified for the upper limit of the current carrying capacity:

- Ampacity limit as a function of the time of the current load, inclusive of short-term loads taking into account a time/current characteristic
- Levitation limit.

LV123-2298 Note: The levitation limit is the upper limit of the ampacity at which no undesired opening of the contactor contacts occurs due to current-dependent magnetic forces.

8.6 Additional requirements for DC/DC converter HV/LV (LV123-716)

LV123-717 For testing, see Section "Test: Additional requirements for DC/DC converter HV/LV"

LV123-718 The electrical connection between DC/DC converter HV/LV and the negative pole of the LV powernet shall meet the equipotential bonding requirements if the contacting of this plug and the housing are connected in a conductive manner; see Section "Equipotential bonding".

LV123-719 In this case, the DC/DC converter HV/LV shall fulfill one of the following requirements in order to prevent an unintended current feedback via different LV powernet paths, e.g. ground shieldings, signal lines:

- An additional means of equipotential bonding shall be provided which fulfills the requirements for equipotential bonding in accordance with Section "Equipotential bonding" and the ampacity for the connection to the LV powernet. The requirements pertaining to connection technology and routing to achieve redundancy shall be gathered from the OEM's requirements.
- The missing of an electric connection between the DC/DC converter HV/LV and the negative pole of the LV powernet (battery) shall be detected. In the case of a detected missing connection, the response of the DC/DC converter HV/LV shall avoid potential consequential damage.

The implementation of the measure for equipotential bonding shall be gathered from the OEM's requirements documentation.

LV123-720 If a detection and response in the case of a missing connection between the DC/DC converter HV/LV and the negative pole of the LV powernet is provided, these shall be agreed upon with the OEM by the supplier.

LV123-721 If the electrical connection between the DC/DC converter HV/LV and the negative pole of the LV powernet (battery) is also used as an equipotential bonding means, and an electrical conductor or a ground strap with protective sheath is used for this purpose, the following requirement shall be fulfilled:

- For the insulation or the protective sheath the color selected shall be the color used for equipotential bonding in the vehicle.

For this electrical connection the color brown shall be generally used for road vehicles with 12 V powernet. In other cases the specification regarding the color shall be gathered from the OEM's requirements documentation.

LV123-722 If a boost mode is provided, it shall be disabled under the following conditions:

- The boost mode is not enabled; see OEM's requirements documentation.
- The voltage on the DC HV circuit falls outside the operating voltage ranges, in accordance with Table "HV voltage ranges".
- The HV system is in shut-off state.
- A crash has been detected; see Section "Behavior in the event of a crash"
- The service disconnect function has been actuated or is activated, see Section "Service disconnect function".

8.7 Additional requirements for inverters (LV123-724)

LV123-725 For testing, see Section "Test: Additional requirements for inverters"

LV123-728 The generation of a DC HV voltage ≥ 60 V d.c. shall be blocked under the following conditions:

- Generator operation is not enabled, see OEM's requirements documentation.
- Idle operation is not enabled, see OEM's requirements documentation.
- The HV system is in shut-off state.
- A crash has been detected; see Section "Behavior in the event of a crash"
- The service disconnect function has been actuated or is activated, see Section "Service disconnect function".

8.8 Additional requirements for HV wiring harness (LV123-729)

LV123-730 Note: Bibliographic references: GB/T 25087, ISO 6722, ISO 14572, SAE J1654, SAE J1673, SAE J2501, SAE J2578

LV123-731 For testing, see Section "Test: Additional requirements for HV wiring harness"

LV123-733 For HV cables or HV wiring harnesses with integrated EMC shielding, the applicable requirements for the electrical safety for the insulation between live parts and the EMC shield shall be fulfilled in accordance with Section "Requirements for electrical characteristics and HV safety".

LV123-734 If an HV cable or an HV wiring harness comprises an integrated EMC shielding, the requirements for the outer sheathing such as protection against external loads shall be gathered from the OEM's requirements documentation.

LV123-1756 HV cables shall comply with the requirements for the ampacity for a short-circuit current through a equipotential bonding path according to the requirements for a equipotential bonding means in accordance with Section "Equipotential bonding".

9 Additional requirements for connection to an external electric power supply (LV123-1757)

9.1 General (LV123-1759)

LV123-1758 Note: Bibliographic references: GB/T 20234.1, GB/T 20234.3, IEC 61851-1, IEC 61851-22, IEC/FDIS 61851-23: 2013-11, IEC/TS 62763, ISO 6469-3, ISO 15118-1, ISO/DIS 17409: 2013-09,SAE J1772, UL 2231, UL 2251, UL 2594

LV123-1760 The requirements described in this section apply to the connection and supply of the vehicle from an external electric power supply or a low-voltage network, e.g. for charging the HV battery or for the supply of HV components for various functions. The connections to an external AC and DC power supply are covered.

9.2 General requirements for conductive connection to an external electric power supply (LV123-1761)

9.2.1 Protective conductor (PE) (LV123-1762)

LV123-2151 Note: Bibliographic references: DIN 72551-7, IEC 60445, IEC 61851-1, IEC/TS 62763, ISO/DIS 17409: 2013-09, SAE J1772

LV123-1763 Vehicles that have a conductive connection to an external electric power supply shall be provided with a contact in the vehicle inlet that connects the vehicle ground with the protective conductor (PE) of the external electric power supply.

LV123-2152 Note: The protective conductor contact in the vehicle inlet is the protective conductor contact or connection of the vehicle.

LV123-2153 The protective conductor contact in the vehicle inlet shall be marked in accordance with the applicable standard. The following marks may be used, see IEC 60445:

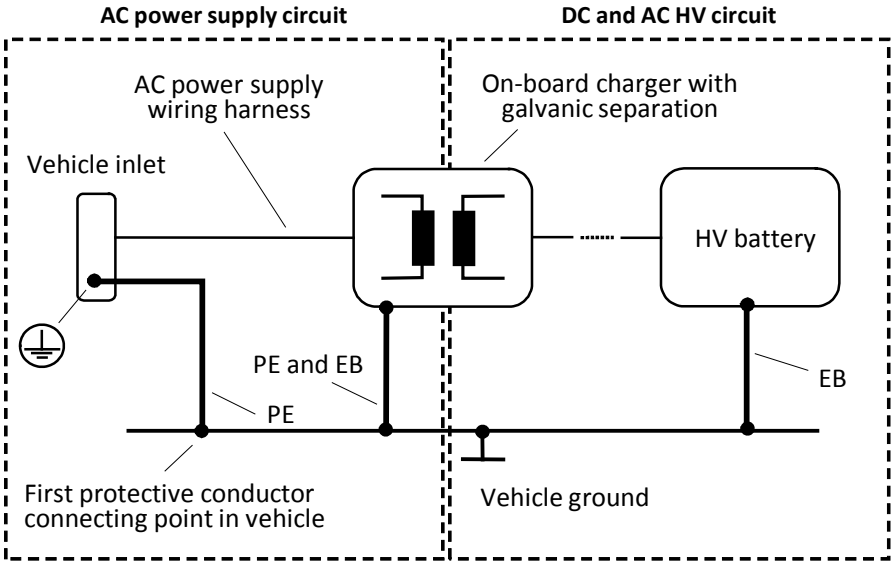
- Alphanumeric identifier PE
- A graphic symbol, e.g. 

LV123-2154 For the protective conductor connection inside the vehicle, 2 types of cases shall be distinguished:

- The first protective conductor connecting point is the vehicle ground, see Figure "Example of protective conductor connection - first connecting point on vehicle ground"
- The first protective conductor connecting point in the vehicle is on an HV component in an electric power supply circuit, see Figure "Example of protective conductor connection - first connecting point on HV component".

The first protective conductor connecting point in the vehicle and the associated vehicle ground shall be gathered from the OEM's requirements documentation.

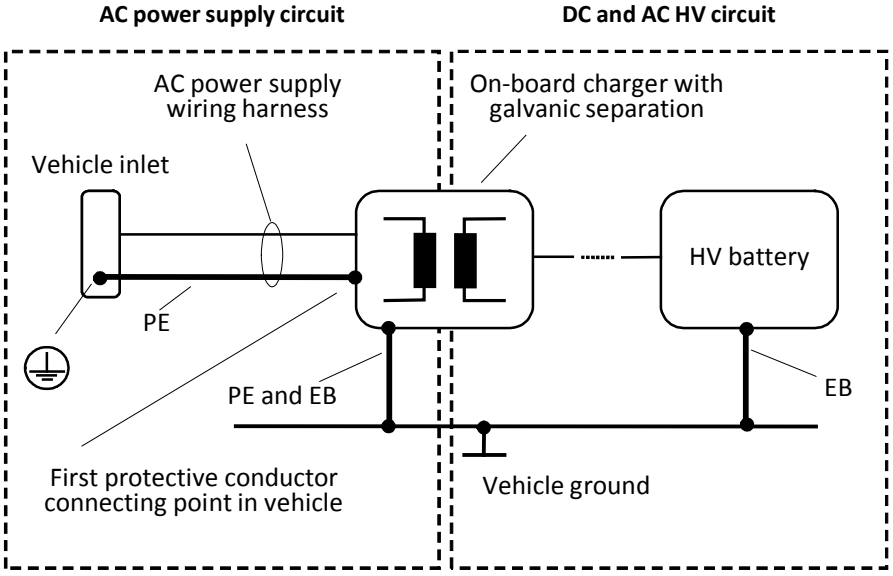
LV123-2155



PE: Protective conductor
EB: Equipotential bonding conductor

LV123-2156 Figure: Example of protective conductor connection - first connecting point on vehicle ground

LV123-2157



PE: Protective conductor
EB: Equipotential bonding conductor

LV123-2158 Figure: Example of protective conductor connection - first connecting point on HV component

LV123-2159 The HV components of an electric power supply circuit as well as their exposed conductive parts shall be connected with the vehicle ground such as to fulfill the requirements for a protective conductor connection.

LV123-2160 If the first protective conductor connecting point in the vehicle is provided on an HV component, this shall be connected to the protective conductor contact of the vehicle inlet such that the requirements pertaining to a protective conductor connection are fulfilled.

LV123-1776 If the first protective conductor connecting point in the vehicle is provided on an HV component, the protective conductor shall be installed in the power supply wiring harness of this HV component.

LV123-1774 If the first protective conductor connecting point in the vehicle is provided on an HV component, this shall fulfill one of the following requirements:

- The protective conductor shall be led in by the plug into the HV component and connected inside the HV component to the component's housing.
- The protective conductor shall be spliced out from the power supply wiring harness near the HV component and connected to the housing of the HV component.

LV123-1772 The resistance value of the protective conductor connection between the PE contact in the vehicle inlet and the first protective conductor connecting point in the vehicle shall be < 40 mOhm until the end of the specified service life (EOL). This requirement shall be fulfilled for every arrangement of this connecting point, see Figure "Resistance of protective conductor connection - example 1" and Figure "Resistance of protective conductor connection - example 2".

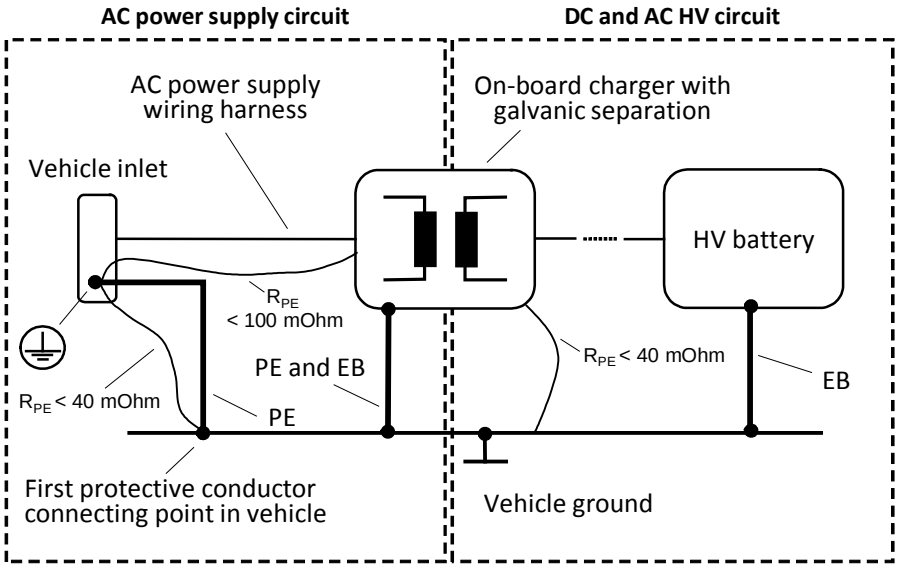
LV123-1771 For an HV component that belongs to an electric power supply circuit, the total electrical resistance of the protective conductor connection between the PE contact in the vehicle inlet and the housing of an HV component shall be less than 100 mOhm until the end of the specified service life (EOL). The installation location of the HV component (e.g. distance to vehicle inlet) and the arrangement of the complete path of the protective conductor connection shall be taken into account, see Figure "Resistance of protective conductor connection - example 1" and Figure "Resistance of protective conductor connection - example 3".

LV123-1773 For an HV component that belongs to an electric power supply circuit, one of the following requirements shall be fulfilled:

- The electrical resistance of the protective conductor connection between the housing of the HV component and the vehicle ground shall be < 40 mOhm until the end of the specified service life (EOL), see Figure "Resistance of protective conductor connection - example 1", Figure "Resistance of protective conductor connection - example 2" and Figure "Resistance of protective conductor connection - example 3".
- For another configuration of the protective conductor connection, the requirement for total resistance of the protective conductor connection between the PE contact of the vehicle inlet and the housing of the HV component shall be complied with. The configuration of the protective conductor connection and the partitioning of individual resistances shall be gathered from the OEM's requirements documentation.

LV123-2161 Note: The requirements result in a resistance of a protective conductor connection between the vehicle ground and the PE contact of the vehicle inlet that is always < 100 mOhm.

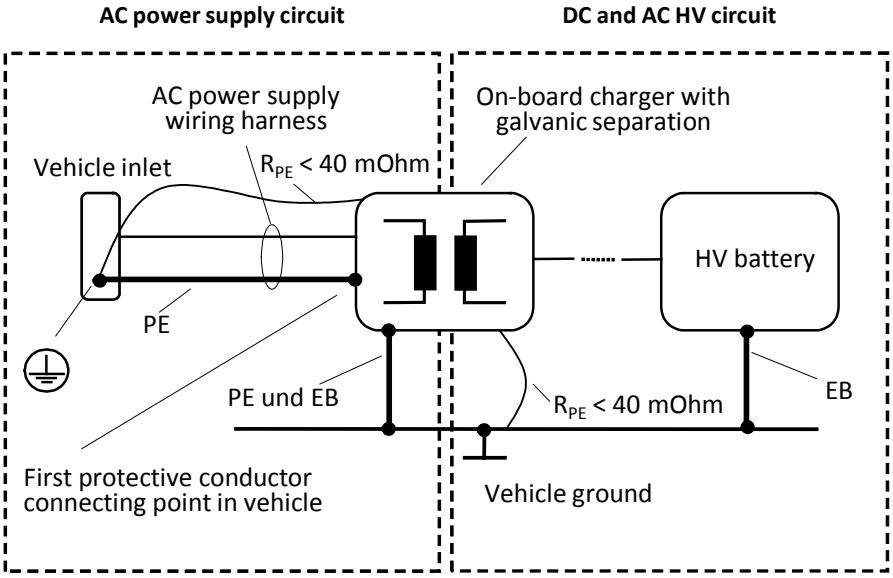
LV123-2162



PE: Protective conductor
EB: Equipotential bonding conductor

LV123-2163 Figure: Resistance of protective conductor connection - example 1

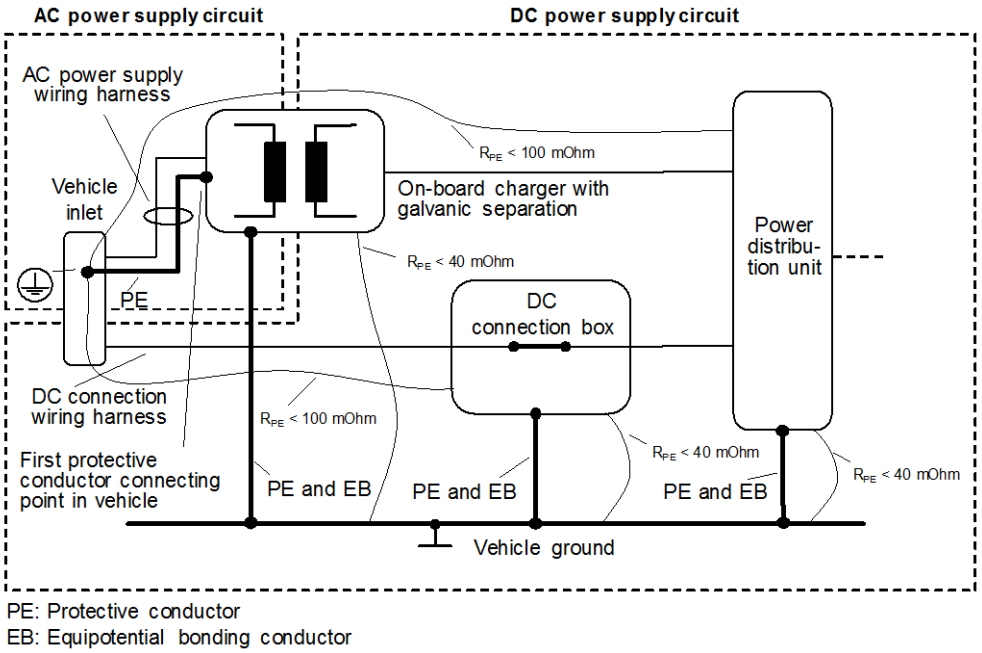
LV123-2164



PE: Protective conductor
EB: Equipotential bonding conductor

LV123-2165 Figure: Resistance of protective conductor connection - example 2

LV123-2166



LV123-2167 Figure: Resistance of protective conductor connection - example 3

LV123-2168 If the cover or the housing of an HV component consists of several individual parts, the electrical requirements for the protective conductor connection shall be fulfilled in every position on the surface of the cover or housing. The resistance of an electrical connection from a conductive part to the protective conductor connection on the HV component shall be < 10 mOhm until the end of the specified service life (EOL).

LV123-1769 A permissible means for equipotential bonding in accordance with Section "Equipotential bonding" shall be used as means for the protective conductor (PE). The means for the equipotential bonding and the indication as to whether or not these means are an integral part of the HV component shall be gathered from the OEM's requirements documentation.

LV123-1765 Protective conductors between the vehicle inlet and the vehicle ground or the housing of an HV component shall not be interrupted by switching equipment, measuring devices or other equipment or be reduced in their ampacity.

LV123-1764 The cross-sectional area of a protective conductor shall be designed to meet the requirements of IEC 60364-5-54 and shall be at least 2,5 mm².

LV123-1768 If for an HV component a common conductor is used for the protective conductor (PE) and for equipotential bonding, this shall be designed such that the requirements for the cross-sectional area of a protective conductor in accordance with IEC 60364-5-54 and the requirements for equipotential bonding in accordance with Section "Equipotential bonding" are fulfilled.

LV123-2169 Fasteners used for the protective conductor connection (PE) shall fulfill the requirements in accordance with Sub-Section "Mounting of the equipotential bonding solution" in Section "Equipotential bonding".

LV123-1770 The following protective conductor connecting points shall have no more than 2 protective conductor connections:

- The first protective conductor connecting point in the vehicle.
- The protective conductor connection from the HV component, for which the first protective conductor connecting point in the vehicle is provided, to the vehicle ground (e.g. vehicle body).

LV123-1766 The protective conductor between the vehicle inlet and the first protective conductor connecting point in the vehicle shall be marked according to the following requirements:

- Two-color combination green-yellow, see IEC 60445
- Basic color: yellow, similar to RAL 1021, see DIN 72551-7
- Identification color for longitudinal color stripes: green, similar to RAL 6018, see DIN 72551-7
- With reference to a length of 15 mm, one of these colors shall cover a minimum of 30 % and a maximum of 70 % of the surface. The other color shall cover the rest of the surface.

LV123-1778 The protective conductor connection between equipment for the external electric power supply and the protective conductor contact of the vehicle inlet shall be monitored in the vehicle by means of the control pilot function in accordance with applicable standards. The applicable standards and the assignment of the control pilot function to a control unit for the selected connection to an external electric power supply shall be gathered from the OEM's requirements documentation, see also Section "General requirements" in Section "Special requirements for an AC power supply".

9.2.2 Overcurrent protection (LV123-2170)

LV123-2171 For protection in case of overload current, one of the following requirements shall be fulfilled:

- The cross-sectional areas of the AC or DC power supply wiring harnesses and the nominal current for the vehicle inlet shall be designed according to the maximum load current for the electric power supply circuit.
- An overcurrent protection device shall be provided for the wiring harnesses or for the vehicle inlet.

The requirements pertaining to protection in case of overload current shall be gathered from the OEM's requirements.

LV123-2172 For short-circuit protection, one of the following requirements shall be fulfilled:

- The cross-sectional areas of the AC or DC power supply wiring harnesses and the nominal current for the vehicle inlet shall be designed according to the characteristics of the overcurrent protection device of the external electric power supply. The I^2t value of this overcurrent protection device shall be taken into account. This I^2t value is specified according to the maximum I^2t value for an applicable vehicle connector and the I^2t value of a charging cable.
- An overcurrent protection device shall be provided for the wiring harness of the power supply circuit. The cross-sectional areas of the power supply circuit wiring harnesses that are protected by this overcurrent protection device shall be selected based on the characteristics of this overcurrent protection device.

The requirements pertaining to overcurrent protection, including the required I^2t value, shall be gathered from the OEM's requirements.

LV123-2173 For the connection to an external DC power supply, the I^2t value of the overcurrent protection device for the DC power supply circuit shall be limited to a maximum value. The maximum I^2t value shall be gathered from the OEM's requirements documentation.

9.2.3 Requirements for the vehicle inlet (LV123-1779)

LV123-2299 Note: Bibliographic references: GB/T 20234.1, GB/T 20234.2, GB/T 20234.3, IEC 62196-1, IEC 62196-2, IEC/CDV 62196-3: 2013-01, ISO 2575, ISO 7000, ISO/DIS 17409: 2013-09, SAE J1772, UL 2251

LV123-1780 For the protection against direct contact, the vehicle inlet shall fulfill at least the degree of protection IPXXD in accordance with ISO 20653 when the vehicle connector is mated.

LV123-1781 The vehicle inlet shall fulfill the following requirement when it is in the unmated state (vehicle connector not mated) and it is connected with the vehicle-side power supply wiring harness:
All housing openings not intended for contacting while mating shall comply with at least degree of protection IPXXD in accordance with ISO 20653.

LV123-1782 In the unmated state of the vehicle inlet at least degree of protection IPXXB in accordance with ISO 20653 shall be fulfilled for its HV terminals.

LV123-1783 For the protection against moisture, the vehicle inlet, with the vehicle connector mated, shall fulfill at least degree of protection IP44K in accordance with ISO 20653.

LV123-1784 For the vehicle inlet, the requirements with regard to insulation, protection against direct contact and prevention of thermal overload shall be fulfilled over the complete operating range and for the specified service life (EOL).

LV123-1785 The vehicle inlet shall fulfill the requirements for the electric power supply connection according to the connection used for an external AC and/or DC power supply and shall comply with the associated standards for the vehicle inlet.
The applicable standards for the vehicle inlet and the connections used for an external electric power supply shall be gathered from the OEM's requirements documentation.

LV123-1786 Note: Marking with the operator's manual symbol based on ISO 7000 (see also Section "Marking") in the direct vicinity of the vehicle inlet can be used for referencing the operator's manual.

LV123-1787 If the marking of the connection to an external electric power supply is intended, the use of the symbols in accordance with ISO 2575 is recommended.

LV123-1788 Marking with an HV symbol according to Section "Marking" is not permissible at the vehicle inlet.

9.3 Special requirements for connection to an AC power supply (LV123-1789)

9.3.1 General requirements (LV123-1790)

LV123-2378 Note: Bibliographic references: GB/T 20234.1, GB/T 20234.3, IEC 61851-1, IEC 61851-22, IEC/TS 62763, ISO 6469-3, ISO 15118-1, ISO/DIS 17409: 2013-09, SAE J1772, UL 2231, UL 2594

LV123-2300 For the connection to an external AC power supply, a control pilot function in accordance with the applicable standards shall be provided. The assignment of the control pilot function to a component in the vehicle and the applicable standards, e.g. ISO/DIS 17409: 2013-09, IEC 61851-1, IEC/TS 62763, SAE J1772 shall be gathered from the OEM's requirements documentation.

LV123-2301 The control pilot function shall fulfill the following requirements pertaining to the detection of the control pilot signal:

- The frequency of the signal shall be detected.
- The duty cycle of the signal shall be detected.
- The voltage (amplitude) of the signal shall also be detected if this is demanded by the OEM.

LV123-1791 When the control pilot function detects a discontinuity of the protective conductor connection between the external electric power supply and the vehicle inlet, the AC supply circuit including on-board charger shall be switched off.
Details on switching-off of the AC power supply circuit including on-board charger shall be gathered from the OEM's requirements documentation.

LV123-2302 The activation on the control pilot shall be canceled if a corresponding signaling is present. The relevant signalings shall be gathered from the OEM's requirements documentation.

LV123-2303 The control pilot function shall detect the maximum supply current transmitted from the external AC power supply.

LV123-2174 In the following sections, the use of a vehicle inlet to connect to an external electric power supply is assumed.

LV123-2175 If a charging cable with a plug, that is permanently attached to the vehicle, is used for connection to an external AC power supply, the requirements shall be agreed upon with the OEM or gathered from the OEM's requirements documentation.

9.3.2 Protective conductor current and touch current (LV123-1792)

LV123-2304 Note: Bibliographic references: GB/T 18487.2, IEC 61851-21, ISO/DIS 17409:2013-09

LV123-1793 For testing, see Section "Test: Protective conductor current and touch current"

LV123-1794 The protective conductor current of the on-board charger shall not exceed 3,5 mA. In this context, the protective conductor current shall be measured in accordance with the testing procedure in Section "Test: Protective conductor current and touch current".

LV123-2176 Note: The maximum permitted protective conductor current for the vehicle is 5 mA.

LV123-1795 The touch current of the on-board charger shall not exceed 2,5 mA. For this purpose, the currents shall be measured in accordance with the testing procedure in Section "Test: Protective conductor current and touch current".

LV123-1796 If several on-board chargers are used, the requirements for the touch and leakage current shall be fulfilled by the complete arrangement. The requirements for each individual on-board charger shall be reduced accordingly. Details on the arrangement of the on-board chargers or their number shall be gathered from the OEM's requirements documentation.

LV123-1797 The on-board charger itself shall have a sufficient margin to the permissible protective conductor current and touch current limits for the vehicle. To achieve a sufficient margin between the limits for the on-board charger and the vehicle system, the parasitic or installed couplings in the on-board charger shall be taken into account.

LV123-2177 Note 1: Protective conductor, leakage and touch currents can be generated by a coupling between the AC power supply circuit and the DC HV circuit in the on-board charger and ripples from the HV system.

LV123-2178 Note 2: The maximum permitted touch current for the vehicle is 3,5 mA.

LV123-1798 The coupling between AC power supply circuit and DC HV circuit in the on-board charger shall be taken into account and minimized during an early stage during development.

LV123-1799 The parasitic or installed coupling capacitances in the on-board charger should be smaller than 1 nF.

LV123-1800 The coupling capacitances shall be determined in accordance with Section "Protective conductor and touch current". These shall be specified by the supplier and agreed upon with the OEM.

9.3.3 Additional requirements for the on-board charger (LV123-1801)

LV123-1802 For the connection of the vehicle inlet to the DC HV circuits, the on-board charger shall fulfill one of the following requirements:

- The on-board charger shall galvanically separate the AC power supply circuit from the DC HV circuit, see Figure "Sample system overview BEV, PHEV - Connection to external DC power supply on". This galvanic separation shall at least fulfill the requirements for a simple separation (basic insulation).
- If no galvanic separation from the DC HV circuit is intended, the requirements shall be agreed upon with the OEM by the supplier.

LV123-1803 The on-board charger shall measure the input voltage of the external electric power supply.

LV123-1804 If the input voltage of the external electric power supply is outside the specified limit values, the on-board charger shall cancel the activation on the control pilot and switch off the charging operation. The limit values shall be gathered from the OEM's requirements documentation.

LV123-1805 The AC power supply circuit with connected on-board charger shall within a period of < 5 s after unmating of the vehicle connector have voltages of < 30 V a.c. and < 60 V d.c. at the vehicle inlet.

LV123-2179 An on-board charger shall limit inrush currents that occur when the external AC power supply is switched on:

- Peak value and duration of the transient inrush current that can occur when filter capacitors are charged
- rms value and duration of the momentary inrush current that can occur when capacitors in other internal circuits are charged.

The current limits and durations shall be gathered from the OEM's requirements documentation.

LV123-2305 The on-board charger shall limit the current to the level of the maximum supply current transmitted from the external AC power supply.

LV123-2306 In limiting the current, the on-board charger shall take account of the following limits:

- Current limit transmitted via the control pilot function, see Section "General requirements" in Section "Special requirements for an AC power supply"
- Current limit transmitted via digital communication, if such communication is provided for (see also ISO 15118-1 and applicable parts of the series ISO 15118).

LV123-2180 For the design of X capacitors in the AC power supply circuit and DC HV circuit, the requirements given in Section "X capacitors" shall be taken into account.

LV123-2181 For the design of Y capacitors in the AC power supply circuit and DC HV circuit, the requirements given in Section "Y capacitors" and Section "Isolation-bridging parts" shall be observed.

9.3.4 Additional requirements for the AC power supply wiring harness (LV123-1806)

LV123-1809 The HV cables of the AC power supply wiring harness between the vehicle inlet and the connecting point in the vehicle shall fulfill the requirements for double

9.4 Special requirements for connection to a DC power supply (LV123-1810)

9.4.1 General requirements (LV123-1811)

LV123-2307 Note: Bibliographic references: GB/T 20234.1, GB/T 20234.3, IEC 61851-1, IEC/FDIS 61851-23: 2013-11, IEC 62196-1, IEC/CDV 62196-3: 2013-01, IEC/TS 62763, ISO/DIS 17409: 2013-09, SAE J1772, UL 2202

LV123-2182 Examples of applicable systems for the external DC power supply include:

- CCS, System C, see IEC/FDIS 61851-23: 2013-11
- CHAdeMO, System A, see IEC/FDIS 61851-23: 2013-11.

The system used shall be gathered from the OEM's requirements documentation.

LV123-1812 When a discontinuity of the protective conductor connection is detected by the control pilot function, the DC power supply circuit shall be switched off.

LV123-1813 For the DC supply circuit, switching equipment shall be provided that is able to switch off currents between the external DC power supply and the DC supply circuit, see Figure "Sample system overview BEV, PHEV - Connection to external DC power supply on" and Figure "Sample system overview BEV, PHEV - Connection to external DC power supply off".
The assignment of the switching equipment to an HV component (e.g. DC connection box, HV battery) shall be gathered from the OEM's requirements documentation.

LV123-1814 The switching equipment shall switch off all poles of the DC power supply circuit using contactors.

LV123-2183 The switching equipment shall fulfill the following requirements according to the requirements of the system used for external DC power supply:

- The switching equipment shall be capable of switching off load currents corresponding to the maximum rated current of the vehicle inlet and the vehicle connector.
- The switching equipment shall withstand inrush currents
- The switching equipment shall be designed according to the specified voltage difference between the two sides of the switching equipment (voltage difference between the vehicle inlet or DC interconnection circuit and the DC HV circuit when the DC power supply circuit is switched off).

LV123-2184 The switching equipment of the DC power supply circuit shall be controlled according to the control pilot functions of the intended external DC power supply. The assignment of this control function to a control unit shall be gathered from the OEM's requirements documentation.

LV123-2185 The voltages upstream and downstream of the switching equipment in the DC power supply circuit shall be measured and monitored. The assignment of this measurement function to a control unit shall be gathered from the OEM's requirements documentation.

LV123-2186 Note: Monitoring of the voltage measurement can be performed by plausibility checks of different voltages measured during operation.

LV123-2187 According to the requirements of the external DC power supply, temporary overvoltages, caused when voltage rises due to an abrupt shut off of, for example the HV battery, while the DC power supply is switched on, shall be taken into account for the selection and design of relevant parts in the DC power supply circuit.
The system used for the external DC power supply shall be gathered from the OEM's requirements documentation.

9.4.2 Additional requirements for the DC power supply wiring harness (LV123-1815)

LV123-1817 Details on DC wiring harnesses between the vehicle inlet and the HV battery which carry current on connection to an external DC power supply shall be gathered from the OEM's requirements documentation.

LV123-1818 The HV cables of the wiring harness for the DC interconnection circuit between the vehicle inlet and the connecting point in the vehicle or the DC connection box shall fulfill the requirements for double or reinforced insulation.

9.4.3 Locking of the DC vehicle connector (LV123-1819)

LV123-1820 The requirements for the locking of the DC vehicle connector shall be fulfilled according to the requirements of the external DC power supply used. The system used shall be gathered from the OEM's requirements documentation.

LV123-1821 **Requirements for System CCS**

LV123-1822 The vehicle inlet shall provide a means for the locking of a completely mated vehicle connector.

LV123-1823 The vehicle inlet shall be designed such that only a completely mated vehicle connector can be detected and locked.

LV123-1824 The locking of the vehicle inlet shall be designed such that complete mating of the vehicle connector is prevented when this lock is actuated.

LV123-1827 The vehicle connector shall be locked as soon as the vehicle connector is detected as fully mated.

LV123-2188 The locking of the vehicle connector shall be monitored through detection of the end position of the locking means.

LV123-1825 The locking of the vehicle connector shall not be unlocked until the voltage at the vehicle inlet is below the voltages of voltage class B.

LV123-1826 The locking of the vehicle connector, the vehicle inlet and the vehicle connector shall, with the vehicle connector mated and in locked condition, withstand withdrawal forces of up to 700 N applied in the plugging direction without damage.

LV123-2189 The locking of the vehicle connector shall in normal operation not be permitted to unlock until the following requirements are fulfilled:

- The voltage at the vehicle inlet shall be below a voltage of voltage class B
- The load current shall be < 1 A.

LV123-1828 The assignment of the DC vehicle connector locking function to a control unit shall be gathered from the OEM's requirements documentation.

10 Tests (LV123-735)

10.1 Overview (LV123-736)

LV123-737 This Section describes tests for HV components. The tests apply to the operation of the HV components in HV circuits and to electrical safety for vehicles with HV systems. The following tests are covered:

- Tests regarding the voltage ranges of the HV system
- Tests regarding electrical characteristics and HV safety
- Tests regarding additional requirements for HV components.

LV123-738 Note: Adequate training of testing personnel is required for the performance of the HV tests. The supplier is responsible for the selection of personnel and for carrying out training measures.

LV123-740 The device under test is the HV component.

LV123-741 A test type is specified for each test. The following are intended as test types:

- Product validation and
- 100% standard production testing.

Product validation is required for acceptance and/or approval and shall be performed during the development process.
100% standard production testing shall be performed for each product manufactured.

LV123-742 Adequate test methods are specified for each test. Test methods are, for example:

- Measurement
- Expert consultation
- Production process quality test.

LV123-743 **Test plan**

LV123-744 For performing the tests, the supplier shall prepare a test plan and agree upon it with the OEM. The test plan, performing of the tests, and test results shall be documented by the supplier.

LV123-745 For the creation of a test sequence plan, the requirements regarding individual tests as set forth in the respective sections in this document, as well as their arrangement in a test sequence in accordance with Section "Test sequence plan", shall be taken into account.

LV123-746 **Tests for sample versions**

LV123-747 The required tests for 100% standard production testing shall also be performed and documented for early sample versions. Additionally the required protection against direct contact and the required equipotential bonding shall be tested.

LV123-1504 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

LV123-750 **HV system voltage ranges**

LV123-751 The tests are based on the requirements for HV components with regard to their electric behavior in DC HV circuits; see Section "Electrical operating ranges of the HV system".

LV123-752 An overview of the tests is provided in Table "Tests regarding the voltage ranges of the HV system". These tests shall be performed for the HV components in accordance with Section "Testing for voltage ranges". The testing scopes for product validation, marked Xp, and the testing scopes for the 100% standard production test, marked Xs, may differ.

LV123-753 Table: Tests regarding the voltage ranges of the HV system

LV123-754

Test	Product validation	100% standard production test
Range of unlimited operating capability	Xp	N/A
Range of upper limited operating capability	Xp	N/A
Range of lower limited operating capability	Xp	N/A
Range of highly limited operating capability	Xp	N/A
Voltage dynamics	Xp	N/A
Voltage ripple	Xp	N/A
Overvoltage	Xp	N/A
Undervoltage	Xp	N/A
Load dump and voltage limiting	Xp	Xs
Voltage offset	Xp	N/A
Interactions between LV and HV system	Xp	N/A
Xp: Test scope for product validation Xs: Test scope for 100% standard production test		

LV123-755 **Electrical characteristics and HV safety**

LV123-756 The tests are based on the requirements regarding electrical characteristics and electrical safety for HV components in accordance with Section "Requirements for electrical characteristics and HV safety".

LV123-757 An overview of the tests is provided in Table "Tests regarding electrical characteristics and HV safety". These tests shall be performed for the HV components in accordance with Section "Testing for electrical characteristics and HV safety". The testing scopes for product validation, marked Xp, and the testing scopes for the 100% standard production test, marked Xs, may differ.

LV123-758 Table: Tests regarding electrical characteristics and HV safety for HV components

LV123-759

Test	Product validation	100% standard production test
Marking	Xp	Xs
Protection against direct contact	Xp	Xs
Equipotential bonding	Xp	Xs
Overcurrent protection	Xp	Xs
Potential separation of HV system and LV powernet	Xp	N/A
Isolation resistance	Xp	Xs
Insulation coordination		
• General, clearances and creepage distances, and solid insulating materials	Xp	N/A
• Withstand voltage	Xp	Xs
Residual voltage	Xp	Xs
Active discharge	Xp	Xs
Passive discharge	Xp	Xs
X capacitors	Xp	Xs
Y capacitors	Xp	Xs
Isolation-bridging parts	Xp	Xs
HV contacting	Xp	Xs
HV interlock	Xp	Xs
Delayed access to live parts	Xp	Xs
Behavior in the event of a crash	Xp	Xs
Measuring the HV voltage	Xp	Xs
Failure of LV supply voltage	Xp	N/A
Electrical equivalent circuit diagrams	Xp	N/A
Installation areas and ambient conditions	Xp	N/A
Pre-assembly and mounting	Xp	N/A
Disassembly and disposal	Xp	N/A
Underload factors for HV parts	Xp	N/A
Documentation	Xp	N/A
Xp: Test scope for product validation Xs: Test scope for 100% standard production test		

LV123-760 **Additional requirements for individual HV components**

LV123-761 The tests are based on the additional requirements for HV components in accordance with Section "Additional requirements for individual HV components".

LV123-762 An overview of the tests which shall be performed in addition to the tests indicated in the other tables of Section "Overview" is provided in Table "Tests regarding additional requirements for HV components". These tests shall be performed for the HV components in accordance with Section "Testing for additional requirements for individual HV components".
The testing scopes for product validation, marked Xp, and the testing scopes for the 100% standard production test, marked Xs, may differ.

LV123-763 Table: Tests regarding additional requirements for HV components

LV123-764

Test	Product validation	100% standard production test
Isolation monitoring	Xp	Xs
Service Disconnect function	Xp	Xs
Pre-charge	Xp	Xs
Detection of open HV cables	Xp	Xs
Requirements for HV battery		
• Switching equipment	Xp	Xs
• Overcurrent protection device	Xp	Xs
Requirements for DC/DC converter HV/LV	Xp	Xs
Requirements for inverters	Xp	Xs
Requirements for HV wiring harness	Xp	N/A
Xp: Test scope for product validation Xs: Test scope for 100% standard production test		

LV123-1829 Additional requirements for connection to an external electric power supply

LV123-1830 The tests are based on the additional requirements for HV components in accordance with Section "Additional requirements for the connection to an external electric power supply".

LV123-1831 An overview of the tests which shall be performed in addition to the tests indicated in the other tables of Section "Overview" is provided in Table "Tests regarding additional requirements for the connection to an external electric power supply". These tests shall be performed for the HV components in accordance with Section "Testing for additional requirements for the connection to an external electric power supply".
The testing scopes for product validation, marked Xp, and the testing scopes for the 100% standard production test, marked Xs, may differ.

LV123-1832 Table: Tests regarding additional requirements for connection to an external electric power supply

LV123-1833

Test	Product validation	100% standard production test
Protective conductor current and touch current	Xp	N/A
Xp: Test scope for product validation Xs: Test scope for 100% standard production test		

10.2 Test parameters and general test requirements (LV123-1834)

10.2.1 Temperatures (LV123-1835)

LV123-1836 Table : Abbreviations for temperatures

LV123-1837

Test parameter	Value
T_{min}	Minimum operating temperature (depending on temperature classification)
T_{max}	Maximum operating temperature (depending on temperature classification)
T_{test}	Test temperature
T_{cool}	Coolant temperature

The DUT shall have the test temperatures specified in the relevant table.

10.2.2 Times/durations (LV123-1838)

LV123-1839 Table : Abbreviations for times/durations

LV123-1840

Test parameter	Value
t_r	Rise time (e.g. of a voltage profile)
t_f	Fall time (e.g. of a voltage profile)
t_h	Hold time (e.g. of a voltage profile)
t_{test}	Test duration

10.2.3 Standard tolerances (LV123-1841)

LV123-1842 Unless otherwise specified, the tolerances in accordance with Table "Standard tolerances" apply. Tolerances of envelopes must always be considered unilaterally as otherwise the requirement is mitigated.
Tolerances refer to the required setting value.

LV123-1843 Table : Standard tolerances

LV123-1844

Test parameter	Value
Frequencies	± 1 %
Temperatures	± 2 °C
Humidity	± 5 %
Times/durations	- 0 % to + 5 %
Voltages	± 1 %
Currents	± 2 %

10.2.4 Standard values (LV123-1845)

LV123-1846 Unless otherwise specified, the values in accordance with Table "Standard values" shall be selected.

LV123-1847 Table : Standard values

LV123-1848

Test parameter	Value
Room temperature	T_{RT} = 23 °C ± 5 °C
Humidity	F_{rel} = 25 % to 75 % RH
Ambient test temperature	T_{RT}
Internal resistance HV voltage source (R_i)	$R_i \leq$ 100 mOhm
LV voltage for test	14 V / 28 V

10.2.5 Sampling rates and measured value resolutions (LV123-1852)

LV123-1853 The sampling rate and bandwidth of the measuring system shall be adapted for the respective test. All measured values with all maximum values (peaks) shall be recorded.

LV123-1854 The resolution of the measured values shall be adapted to the respective test. Care shall be taken to ensure that occurring voltage peaks do not lead to an overflow or cannot be measured in the case of insufficient resolution.

10.2.6 Parameter test (LV123-1855)

LV123-1856 All parameters to be monitored separately shall be defined in the Component Requirement Specifications for the relevant tests with their value ranges.

10.2.7 Continuous parameter monitoring with drift analysis (LV123-1857)

LV123-1858 During the complete test, the parameters to be monitored shall be recorded.

LV123-1859 For components with fault memory, the fault memory shall be monitored continuously and the entries shall be documented.

LV123-1860 The data resulting from the continuous parameter monitoring shall be examined for trends and drifting to detect abnormalities, aging or malfunctions of the component.

10.2.8 Interface description (LV123-1861)

LV123-1862 The states and electrical properties of all interfaces (measuring arrangement and component) shall be described completely. This description is intended as a basis for the evaluation of the test results and shall therefore be available in detail.

10.3 Testing of HV components following repair (LV123-748)

LV123-1505 Appropriate tests with regard to performed repairs shall be defined for HV component testing after the repair.

LV123-1506 Appropriate tests shall be selected and adapted, if necessary, in accordance with the testing scope of the 100% standard production test for HV component testing after the repair.

LV123-1507 An appropriate test procedure, including the required tests after repairs and the selected tests of the 100% standard production tests, shall be specified by the supplier and agreed upon with the OEM.

10.4 Tests regarding voltage ranges (LV123-765)

10.4.1 Test: Range of unlimited operating capability (LV123-766)

LV123-767 Requirement: see Section "Range of unlimited operating capability"

LV123-768 Test type: Product validation

LV123-769 Test method: Measurement

LV123-770 **Product validation**

LV123-771 The behavior in the range of unlimited operating capability shall be verified for each HV component. The specifications of Table "HV voltage levels" shall be used.

LV123-772 Operation with the maximum intended performance shall be verified in the range of unlimited operating capability.

LV123-773 Compliance with the HV operating status B1 shall be verified.

LV123-1863 The test shall be performed under operational ambient conditions.

LV123-775 Test criteria:

- Unlimited operating capability
- Maximum intended performance in accordance with the HV operating status B1
- No fault memory entry.

LV123-1864 **Testing of HV battery**

LV123-1865 The test for the behavior in the range of unlimited operating capability shall be performed according to the test parameters and test pulse specified below with the switching equipment switched off.

LV123-1866 In addition, evidence of the behavior in its individual range of unlimited operating capability shall be provided for the HV battery by means of an appropriate measurement with the switching equipment switched on. This measurement can be carried out within the framework of performance tests of the HV battery (e.g. charging, discharging, capacitance).

LV123-1867 **Testing of HV components**

LV123-1868 For the test, the test parameters in accordance with Table "Test parameters range of unlimited operating capability" shall be selected.

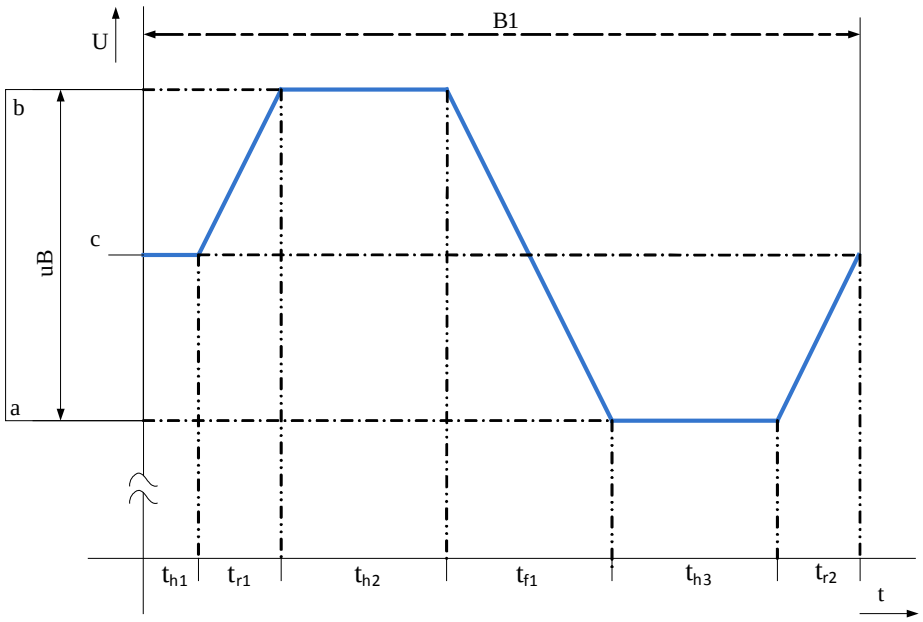
LV123-1869 Table: Test parameters range of unlimited operating capability

LV123-1870

Test parameter	Value
Test procedure with HV operating status	B1 (continuous output)
a	Minimum value of the unlimited operating capability in the relevant voltage level
b	Maximum value of the unlimited operating capability of the relevant voltage level
c	Calculated value of the unlimited operating capability of the relevant voltage level $c = a + \frac{b-a}{2}$
uB	Unlimited operating capability of the relevant voltage level
t_{h1}	Until thermal equilibrium has been attained, but at least 5 minutes
t_{r1}	To be calculated from the relevant parameters / Table Dynamic parameters / Present voltage dynamics
t_{h2}	Until thermal equilibrium has been attained, but at least 5 minutes
t_{f1}	To be calculated from the relevant parameters / Table Dynamic parameters / Present voltage dynamics
t_{h3}	Until thermal equilibrium has been attained, but at least 5 minutes
t_{r2}	To be determined from the relevant parameters / Table Dynamic parameters / Present voltage dynamics
T_{test}	T_{RT}
T_{cool}	$T_{coolmax}$ and minimum flow rate
Number of cycles	3
Number of DUTs	3

LV123-1871 For the test, the test pulse in accordance with Figure "Test pulse range of unlimited operating capability" shall be selected.

LV123-1872



LV123-1873 Figure: Test pulse range of unlimited operating capability

10.4.2 Test: Range of upper limited operating capability (LV123-777)

LV123-778 Requirement: see Section "Range of upper limited operating capability"

LV123-779 Test type: Product validation

LV123-780 Test method: Measurement

LV123-781 **Product validation**

LV123-782 The behavior in the range of upper limited operating capability shall be verified for each controlled HV component by means of an appropriate measurement. The specifications of Table "HV voltage levels" shall be used.

LV123-783 Operation with the maximum intended performance within the permissible deviations for the HV operating status B2 shall be verified in the range of upper limited operating capability.

LV123-784 Compliance with the HV operating status B2 shall be verified.

LV123-785 The operating behavior of the HV component shall be documented and verified.

LV123-786 The test shall be used to verify that the maximum intended performance or the HV operating status B1 is complied with again when the DC HV voltage falls within the range of unlimited operating capability again after a deviating characteristic.

LV123-787 The test shall be performed under operational ambient conditions.

LV123-788 Test criteria:

- Maximum intended performance in accordance with the HV operating status B2; performance within permissible deviations
- No fault memory entry
- Automatic reestablishment of maximum intended performance and of the HV operating status B1 in the event of a return to the range of unlimited operating capability.

LV123-1874 **Testing of HV battery**

LV123-1875 The test for the behavior in the range of upper limited operating capability shall be performed according to the test parameters and test pulse specified below with the switching equipment switched off.

LV123-1876 In addition, evidence of the behavior in its individual range of upper limited operating capability shall be provided for the HV battery by means of an appropriate measurement with the switching equipment switched on. This measurement can be carried out within the framework of performance tests of the HV battery (e.g. charging, discharging, capacitance).

LV123-1877 **Testing of HV components**

LV123-1878 For the test, the test parameters in accordance with Table "Test parameters range of upper limited operating capability" shall be selected.

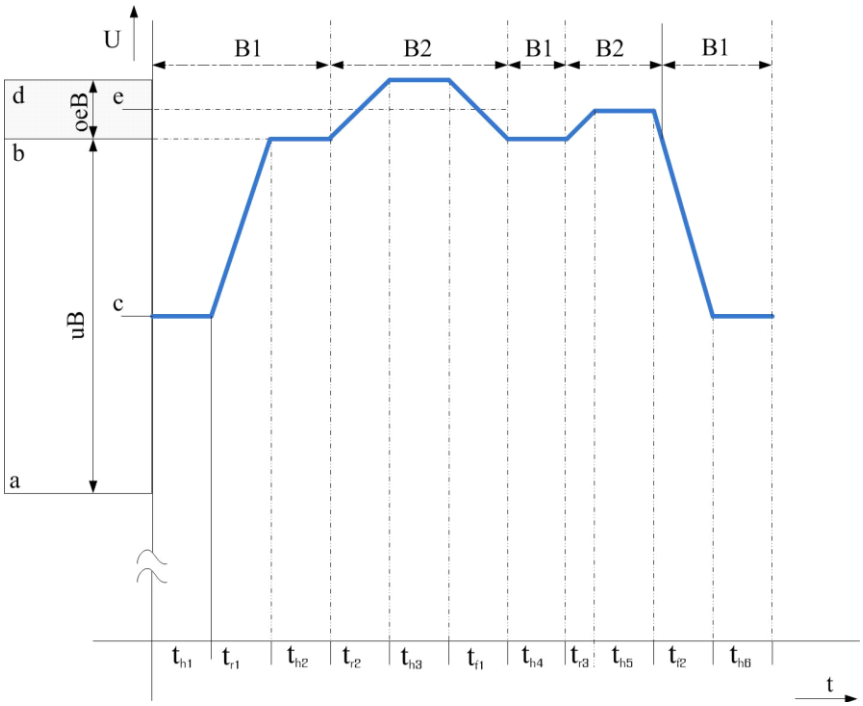
LV123-1879 Table: Test parameters range of upper limited operating capability

LV123-1880

Test parameter	Value
Test procedure with HV operating status	B1 and B2 (specified continuous outputs)
a	Minimum value of the unlimited operating capability of the relevant voltage level
b	Maximum value of the unlimited operating capability of the relevant voltage level
c	Calculated value of the unlimited operating capability of the relevant voltage level $c = a + \frac{b-a}{2}$
d	Maximum value of the upper limited operating capability of the relevant voltage level
e	Calculated value of the upper limited operating capability of the relevant voltage level $e = b + \frac{d-b}{2}$
uB	Unlimited operating capability of the relevant voltage level
oeB	Upper limited operating capability of the relevant voltage level
t_{h1}	1 min
t_{r1}	To be calculated from the relevant parameters in accordance with the indication of present voltage dynamics in Table "Dynamic parameters"
t_{h2}	1 min
t_{r2}	1 min
t_{h3}	1 min
t_{f1}	1 min
t_{h4}	1 min
t_{r3}	To be calculated from the relevant parameters in accordance with the indication of present voltage dynamics in Table "Dynamic parameters"
t_{h5}	1 min
t_{f2}	To be calculated from the relevant parameters in accordance with the indication of present voltage dynamics in Table "Dynamic parameters"
t_{h6}	1 min
T_{test}	T_{RT}
T_{cool}	$T_{coolmin}$ and maximum flow rate
Number of cycles	3
Number of DUTs	3

LV123-1881 For the test, the test pulse in accordance with Figure "Test pulse range of upper limited operating capability" shall be selected.

LV123-1882



LV123-1883 Figure: Test pulse range of upper limited operating capability

10.4.3 Test: Range of lower limited operating capability (LV123-790)

LV123-791 Requirement: see Section "Range of lower limited operating capability"

LV123-792 Test type: Product validation

LV123-793 Test method: Measurement

LV123-794 **Product validation**

LV123-795 The behavior in the range of lower limited operating capability shall be verified for each controlled HV component. The specification of Table "HV voltage levels" shall be used.

LV123-796 Operation with the maximum intended performance within the permissible deviations for the HV operating status B2 shall be verified in the range of lower limited operating capability.

LV123-797 Compliance with the HV operating status B2 shall be verified.

LV123-798 The operating behavior of the HV component shall be documented and verified.

LV123-799 The test shall be used to verify that the maximum intended performance or the HV operating status B1 is complied with again when the DC HV voltage falls within the range of unlimited operating capability again after a deviating characteristic.

LV123-800 The test shall be performed under operational ambient conditions.

LV123-801 Test criteria:

- Maximum intended performance in accordance with the HV operating status B2; performance within permissible deviations
- No fault memory entry
- Automatic reestablishment of maximum intended performance and of the HV operating status B1 in the event of a return to the range of unlimited operating capability.

LV123-1884 **Testing of HV battery**

LV123-1885 The test for the behavior in the range of lower limited operating capability shall be performed according to the test parameters and test pulse specified below with the switching equipment switched off.

LV123-1886 In addition, evidence of the behavior in its individual range of lower limited operating capability shall be provided for the HV battery by means of an appropriate measurement with the switching equipment switched on. This measurement can be carried out within the framework of performance tests of the HV battery (e.g. charging, discharging, capacitance).

LV123-1887 **Testing of HV components**

LV123-1888 For the test, the test parameters in accordance with Table "Test parameters range of lower limited operating capability" shall be selected.

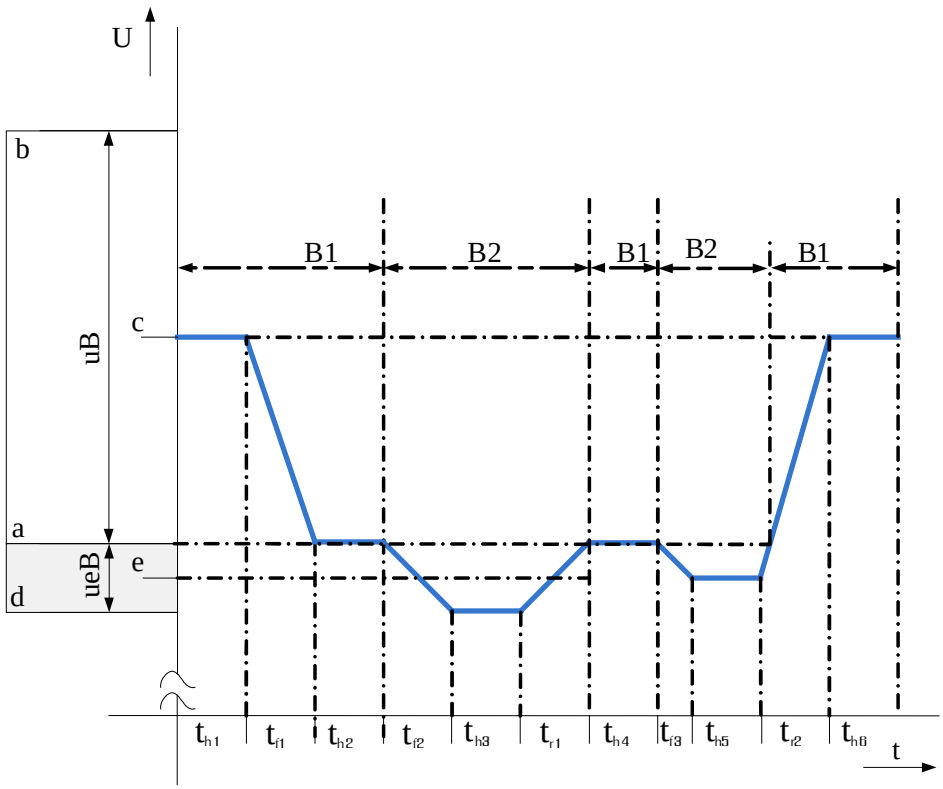
LV123-1889 Table: Test of lower limited operating capability

LV123-1890

Test parameter	Value
Test procedure with HV operating status	B1 and B2 (specified continuous outputs)
a	Minimum value of the unlimited operating capability of the relevant voltage level
b	Maximum value of the unlimited operating capability of the relevant voltage level
c	Calculated value of the unlimited operating capability of the relevant voltage level $c = a + \frac{b-a}{2}$
d	Minimum value of the lower limited operating capability of the relevant voltage level
e	Calculated value of the lower limited operating capability of the relevant voltage level $e = a - \frac{a-d}{2}$
uB	Unlimited operating capability of the relevant voltage level
ueB	Lower limited operating capability of the relevant voltage level
t_{h1}	1 min
t_{f1}	To be calculated from the relevant parameters in accordance with the indication of present voltage dynamics in Table "Dynamic parameters"
t_{h2}	1 min
t_{f2}	1 min
t_{h3}	1 min
t_{r1}	1 min
t_{h4}	1 min
t_{f3}	To be calculated from the relevant parameters in accordance with the indication of present voltage dynamics in Table "Dynamic parameters"
t_{h5}	1 min
t_{r2}	To be calculated from the relevant parameters in accordance with the indication of present voltage dynamics in Table "Dynamic parameters"
t_{h6}	1 min
T_{cool}	$T_{coolmax}$ and minimum flow rate
T_{test}	T_{RT}
Number of cycles	3
Number of DUTs	3

LV123-1891 For the test, the test pulse in accordance with Figure "Test pulse range of lower limited operating capability" shall be selected.

LV123-1892



LV123-1893 Figure: Test pulse lower limited operating capability

10.4.4 Test: Range of highly limited operating capability (LV123-803)

LV123-804 Requirement: See Section "Range of highly limited operating capability"

LV123-805 Test type: Product validation

LV123-806 Test method: Measurement

LV123-807 **Product validation**

LV123-808 The behavior in the range of highly limited operating capability shall be verified for each controlled HV component. The specifications of Table "HV voltage levels" shall be used.

LV123-809 The operating behavior of the HV component shall be documented and verified.

LV123-810 The test shall be performed under operational ambient conditions.

LV123-1894 **Testing of HV battery**

LV123-1895 The test for the behavior in the range of highly limited operating capability shall be performed according to the test parameters and test pulse specified below with the switching equipment switched off.

LV123-1896 In addition, evidence of the behavior in its individual range of highly limited operating capability shall be provided for the HV battery by means of an appropriate measurement with the switching equipment switched on. This measurement can be carried out within the framework of performance tests of the HV battery (e.g. charging, discharging, capacity).

LV123-1897 **Testing of HV components**

LV123-1898 For the test, the test parameters in accordance with Table "Test parameters highly limited operating capability" shall be selected.

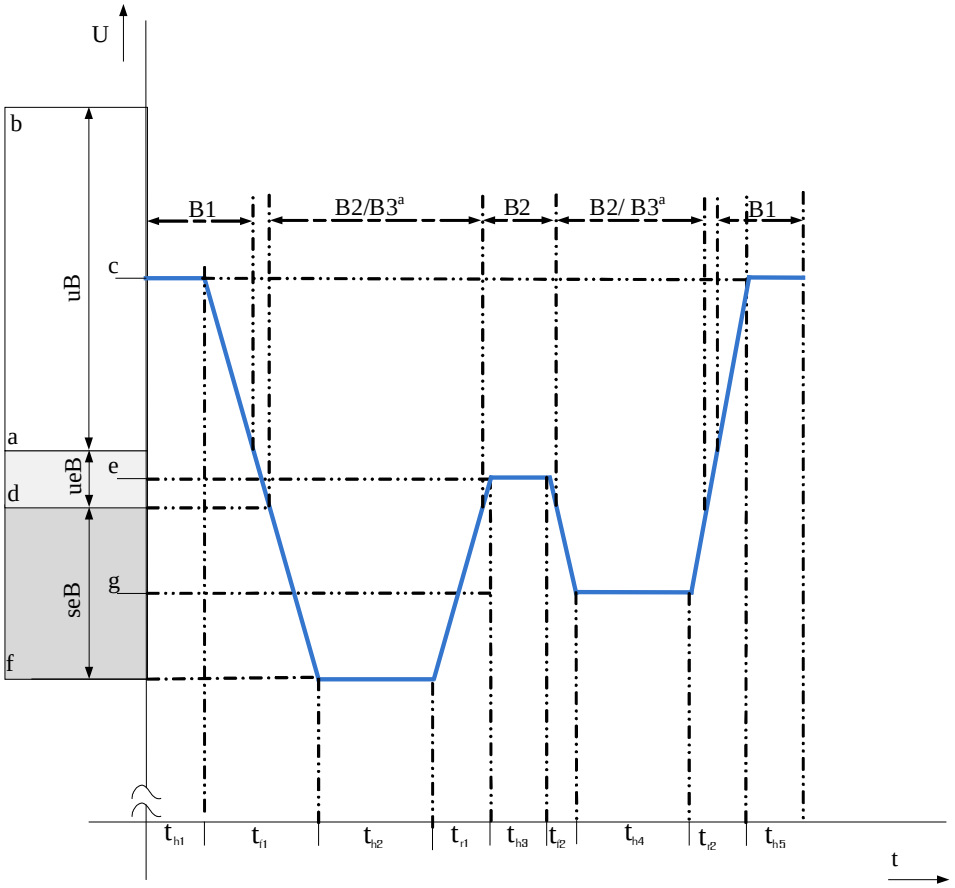
LV123-1899 Table: Test parameters highly limited operating capability

LV123-1900

Test parameter	Value
Test procedure with HV operating status	B1, B2 and B3 (specified continuous outputs)
a	Minimum value of the unlimited operating capability of the relevant voltage level
b	Maximum value of the unlimited operating capability of the relevant voltage level
c	Calculated value of the unlimited operating capability of the relevant voltage level $c = a + \frac{b-a}{2}$
d	Minimum value of the lower limited operating capability of the relevant voltage level
e	Calculated value of the lower limited operating capability of the relevant voltage level $e = a - \frac{a-d}{2}$
f	Minimum value of the highly limited operating capability of the relevant voltage level
g	Calculated value of the highly limited operating capability of the relevant voltage level $g = d - \frac{d-f}{2}$
uB	Unlimited operating capability of the relevant voltage level
ueB	Lower limited operating capability of the relevant voltage level
seB	Highly limited operating capability of the relevant voltage level
t_{h1}	1 min
t_{f1}	To be calculated from the relevant parameters in accordance with the indication of present voltage dynamics in Table "Dynamic parameters"
t_{h2}	1 min
t_{r1}	1 min
t_{h3}	1 min
t_{f2}	1 min
t_{h4}	1 min
t_{r2}	To be calculated from the relevant parameters in accordance with the indication of present voltage dynamics in Table "Dynamic parameters"
t_{h5}	1 min
T_{cool}	$T_{coolmax}$ and minimum flow rate
T_{test}	T_{RT}
Number of cycles	3
Number of DUTs	3

LV123-1901 For the test, the test pulse in accordance with Figure "Test pulse range of highly limited operating capability" shall be selected.

LV123-1902



[a] The status B2/B3 depends on the following conditions:
B2: For components which are relevant for establishing readiness-for-driving
B3: For components which are not relevant for establishing readiness-for-driving

LV123-1903 Figure: Test pulse heavily limited operating capability

LV123-812 **The following applies for HV components relevant for establishing readiness-for-driving:**

LV123-813
- Operation with the maximum intended performance within the permissible deviations for the HV operating status B2 shall be verified.

LV123-814
- Compliance with the HV operating status B2 shall be verified.

LV123-815
- The test shall be used to verify that the maximum intended performance or the HV operating status B1 is complied with again when the DC HV voltage returns to the range of unlimited operating capability after a deviating characteristic.

LV123-816 Test criteria for HV operating status B2:
- Maximum intended performance in accordance with the HV operating status B2; performance within permissible deviations
- No fault memory entry
- Automatic reestablishment of maximum intended performance and of the HV operating status B1 in the event of a return to the range of unlimited operating capability.

LV123-817 **The following applies for HV components not relevant for establishing readiness-for-driving:**

LV123-818
- Operation with reduced performance in accordance with the HV operating status B3 shall be verified.

LV123-819
- Compliance with the HV operating status B3 shall be verified.

LV123-820
- The test shall be used to verify that the maximum intended performance or the HV operating status B1 is complied with again when the DC HV voltage returns to the range of unlimited operating capability after a deviating characteristic.

LV123-821
- The test shall be used to verify that the maximum intended performance or the operating status B2 is complied with again when the DC HV voltage returns to the range of limited operating capability after a deviating characteristic.

LV123-822 Test criteria for the HV operating status B3:
- Operational, specified state, no malfunctions of other HV components, self-protection provided by means of performance reduction in accordance with the HV operating status B3
- Automatic reestablishment of intended performance in accordance with the HV operating status B1 or B2 in the event of a return to the corresponding voltage range
- No fault memory entry
- Automatic reestablishment of maximum intended performance and of the HV operating status B1 in the event of a return to the range of unlimited operating capability
- Automatic reestablishment of maximum intended performance and of the HV operating status B2 in the event of a return to the range of limited operating capability.

10.4.5 Test: Voltage dynamics (LV123-823)

LV123-824 Requirement: See Section "Voltage dynamics"

LV123-825 Test type: Product validation

LV123-826 Test method: Measurement

LV123-827 **Product validation**

LV123-1904 For the voltage dynamics test, the operating modes in accordance with Table "Operating modes test voltage dynamics" shall be taken into consideration. Compliance with the maximum generated/present voltage dynamics (slope) shall be verified for all operating modes.

LV123-1905 Table: Operating modes test voltage dynamics

LV123-1906

HV component	Operating mode
DC/DC converter HV/LV	Boost mode
DC/DC converter HV/LV	Buck mode
Drive system power electronics	Engine mode
Drive system power electronics	Generator mode
On-board charger	HV system power supply (charging operation)
Other HV components, HV battery, HV source	Load mode

LV123-828 **Generated voltage dynamics**

LV123-1907 Test set-up generated voltage dynamics:
The HV powernet conditions, e.g. in the form of an applicable equivalent circuit diagram, shall be agreed upon with the OEM by the supplier. The test set-up shall be documented in detail, including cable inductances, cable capacitances, powernet equivalent capacitances and cable resistances.

LV123-1908 **Testing of HV battery**

LV123-1909 Test "Generated voltage dynamics" is waived for the HV battery.

LV123-1910 **Testing of HV components**

LV123-1911 For the test, the test parameters in accordance with Table "Test parameters generated voltage dynamics" shall be selected.

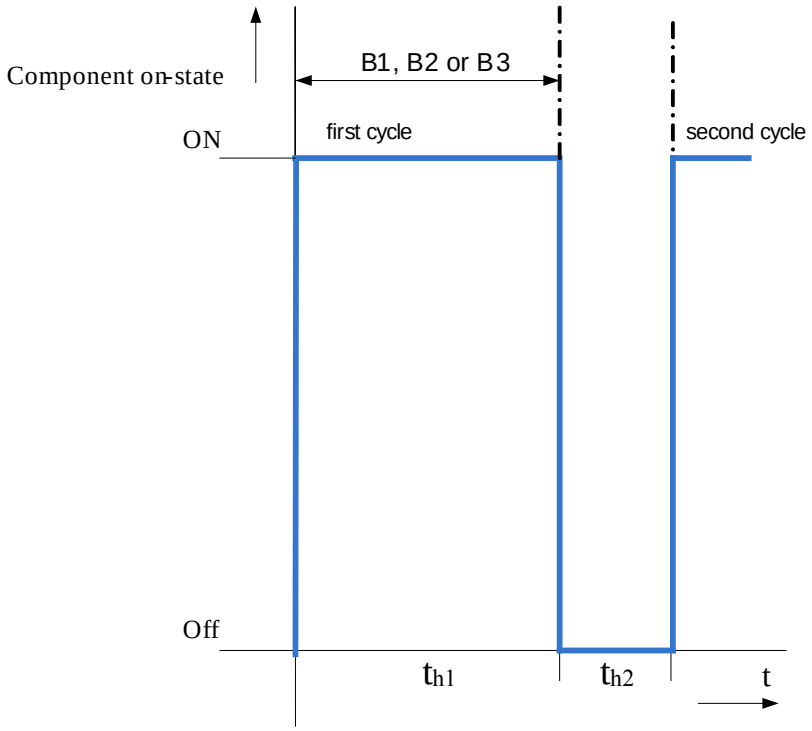
LV123-1912 Table: Test parameters generated voltage dynamics

LV123-1913

Test parameter	**Value**
Test procedure with HV operating status	B1, B2 and B3 (specified continuous outputs)
t_{h1}	1 min
t_{h2}	10 s
T_{test}	T_{RT}
T_{cool}	$T_{coolmax}$ and minimum flow rate
Number of cycles	10
Number of DUTs	3

LV123-1914 For the test, the test pulse in accordance with Figure "Test pulse generated voltage dynamics" shall be selected.

LV123-1915



LV123-1916 Figure: Test pulse generated voltage dynamics

LV123-829 Compliance with the maximum generated voltage dynamics (slope) shall be verified for all HV components controlled by power electronics by measuring the DC HV voltage over time. The test pulse in accordance with Figure "Test pulse generated voltage dynamics" and the specifications for voltage dynamics in Table "Dynamic parameters" shall be used.

LV123-830 It shall be verified that the HV operating status of the HV component in the respective operating voltage range does not change due to generated voltage dynamics (slope).

LV123-831 **Present voltage dynamics**

LV123-832 Robustness with regard to the maximum present voltage dynamics (slope) shall be verified for all HV components by means of appropriate measurements. The specifications for the voltage dynamics in Table "Dynamic parameters" shall be used.

LV123-833 It shall be verified that the HV operating status of the HV component in the respective operating voltage range does not change due to present voltage dynamics (slope).

LV123-1917 **Testing of HV battery**

LV123-1918 The test for the present voltage dynamics shall be performed according to the following requirements for test parameters and test pulse with the switching equipment switched off.

LV123-1919 In addition, evidence of the behavior for a load corresponding to a present voltage dynamics in accordance with Table "Dynamic parameters" shall be provided for the HV battery within the individual voltage ranges by means of an appropriate measurement with the switching equipment switched on. This measurement can be carried out within the framework of performance tests of the HV battery (e.g. charging, discharging, capacity).

LV123-1920 **Testing of HV components**

LV123-1921 For the test, the test parameters in accordance with Table "Test parameters present voltage dynamics" shall be selected.

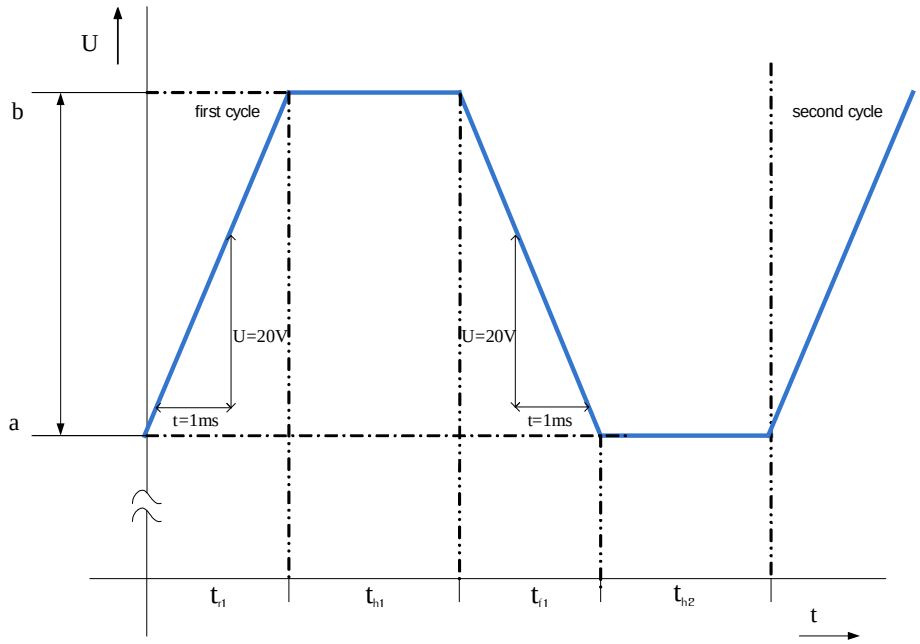
LV123-1922 Table: Test parameters present voltage dynamics

LV123-1923

Test parameter	**Value**
Test procedure with HV operating status	B1, B2 and B3
a	Minimum value of voltage of corresponding voltage range
b	Maximum value of voltage of corresponding voltage range
t_{r1}	To be determined from the relevant parameters
t_{h1}	2 s
t_{f1}	To be determined from the relevant parameters
t_{h2}	2 s
T_{test}	T_{RT}
t_{Test}	10 min
T_{cool}	$T_{coolmax}$ and minimum flow rate
Number of DUTs	3

LV123-1924 For the test, the test pulse in accordance with Figure "Test pulse present voltage dynamics" shall be selected.

LV123-1925



LV123-1926 Figure: Test pulse present voltage dynamics

LV123-834 **General**

LV123-835 The evidence shall be provided in the form of test records for all operating voltage ranges in accordance with Table "HV voltage ranges".

LV123-836 The operating behavior of the HV component shall be documented and verified by means of test records.

LV123-837 The test shall be performed under operational ambient conditions.

10.4.6 Test: Voltage ripple (LV123-839)

LV123-840 Requirement: See Section "Voltage ripple"

LV123-841 Test type: Product validation

LV123-842 Test method: Measurement

LV123-843 **Product validation**

LV123-1927 For the voltage ripple test, the operating modes in accordance with Table "Operating modes test voltage ripple" shall be taken into consideration. Compliance with the maximum generated/present voltage ripple shall be documented.

LV123-1928 Table: Operating modes test voltage ripple

LV123-1929

HV component	Operating mode
DC/DC converter HV/LV	Boost mode
DC/DC converter HV/LV	Buck mode
Drive system power electronics	Engine mode
Drive system power electronics	Generator mode
On-board charger	Power supply for HV system from external electric power supply
Other HV component, HV battery	Load mode

LV123-844 **Generated voltage ripple**

LV123-1930 Test set-up generated voltage ripple:
The HV powernet conditions shall be agreed upon with the departments responsible. The test set-up shall be documented in detail, including line inductances, line capacitances, on-board electrical system equivalent capacitances and line resistances.

LV123-845 For every HV component controlled by power electronics, evidence shall be provided that the generated voltage ripple in HV system operation with HV battery (switching equipment HV battery switched on) in accordance with Table "Dynamic parameters" is fulfilled.

LV123-846 For every HV component controlled by power electronics, evidence shall be provided that the generated voltage ripple in HV system operation without HV battery (switching equipment HV battery switched off) in accordance with Table "Dynamic parameters" is fulfilled."

LV123-847 Evidence shall be provided that the HV operating status of the HV component in the respective operating voltage range does not change due to the superimposition of the specified voltage ripple.

LV123-1931 **Testing of HV battery**

LV123-1932 Test "Generated voltage ripple" is waived for the HV battery and FC stack.

LV123-1933 **Testing of HV components**

LV123-1934 For the test, the test parameters in accordance with Table "Test parameters generated voltage ripple" shall be selected.

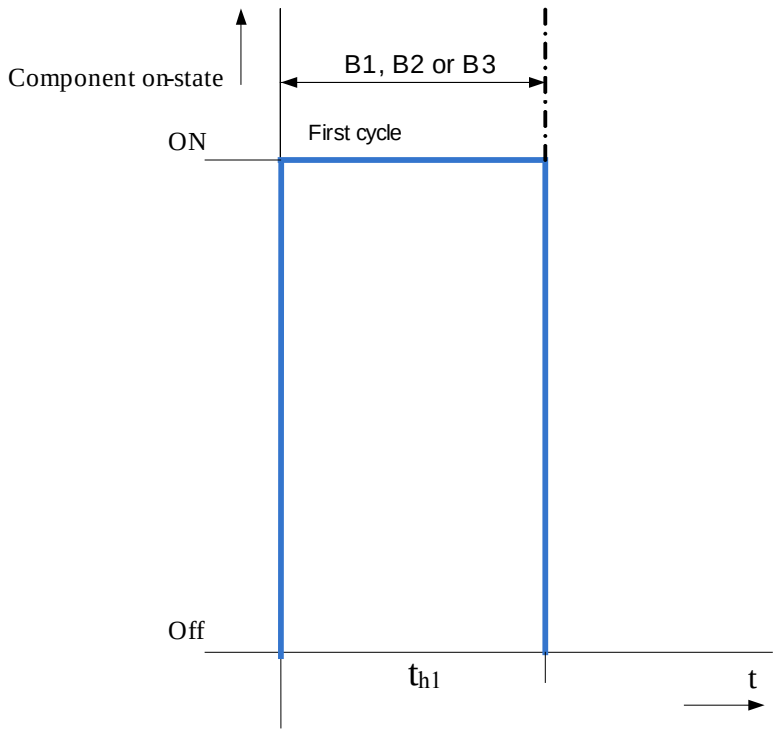
LV123-1935 Table: Test parameters generated voltage ripple

LV123-1936

Test parameter	Value
Test procedure with HV operating status	B1, B2 and B3 (specified continuous outputs)
t_{h1}	10 min
T_{test}	T_{RT}
T_{cool}	$T_{coolmax}$ and minimum flow rate
Number of cycles	1
Number of DUTs	3

LV123-1937 For the test, the test pulse in accordance with Figure "Test pulse generated voltage ripple" shall be selected.

LV123-1938



LV123-1939 Figure: Test pulse generated voltage ripple

LV123-848 **Present voltage ripple**

LV123-849 For every HV component, robustness and stable operation shall be verified when there is a voltage ripple present during the operation of the HV system with an HV battery (switching equipment HV battery switched on) in accordance with Table "Dynamic parameters".

LV123-850 For every HV component, robustness and stable operation shall be verified when there is a voltage ripple present during the operation of the HV system without an HV battery (switching equipment HV battery switched off) in accordance with Table "Dynamic parameters".

LV123-851 Evidence shall be provided that the HV operating status of the HV component in the respective operating voltage range does not change due to the superimposition of the specified voltage ripple.

LV123-1940 For the test, the test parameters in accordance with Table "Test parameters present voltage ripple" shall be selected.

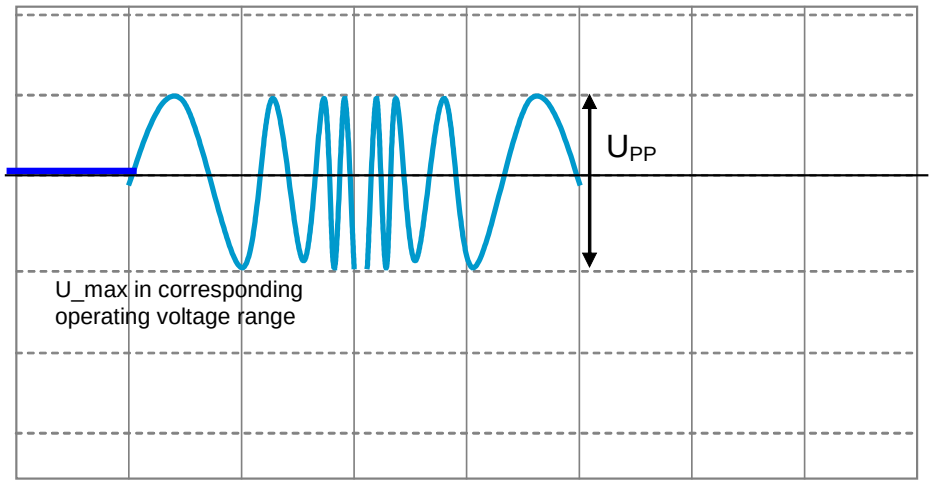
LV123-1941 Table: Test parameters present voltage ripple

LV123-1942

Test parameter	Value
Test procedure in HV operating mode	B1, B2 and B3 (specified continuous output)
Present HV voltage U without ripple	Relevant upper limit of each HV voltage range
Test duration	30 min
Frequency range	15 Hz – 20 kHz[a]
Wobble period[a]	2 min
Wobble type[a]	triangular, logarithmic
t_{Test}	30 min
T_{test}	T_{RT}
Number of DUTs	3
T_{cool}	$T_{coolmax}$
[a]	If possible. Deviations shall be coordinated with the OEM by the supplier
Upp	See Table "Dynamic parameters"

LV123-1943 For the test, the test pulse in accordance with Figure "Test pulse present voltage ripple" shall be selected.

LV123-1944



LV123-1945 Figure: Test pulse present voltage ripple

LV123-852 **General**

LV123-853 The operating behavior of the HV component shall be specified and verified by means of test records.

LV123-854 The test shall be performed under operational ambient conditions.

10.4.7 Test: Overvoltage (LV123-856)

LV123-857 Requirement: See Section "Overvoltage"

LV123-858 Test type: Product validation

LV123-859 Test method: Measurement

LV123-860 **Product validation**

LV123-861 Based on the draft and the design of the HV components, as well as on measurements, the operating capability at the maximum required operating voltage of the HV system, as well as the strength at the upper HV circuit limit voltage, shall be verified. The specifications regarding the maximum operating voltage and the upper HV circuit limit voltage included in Table "Voltage ranges" shall be used.

LV123-862 Compliance with the HV operating status B3 or B4 in the event of overvoltage shall be verified; see Table "HV operating status".

LV123-863 The operating behavior of the HV component shall be documented and verified.

LV123-864 It shall be verified that the required HV operating status for the range of unlimited operating capability is reestablished if the DC HV voltage exceeds the maximum operating voltage and then falls again below the maximum operating voltage.

LV123-1946 The voltage increase and decrease for the test pulse overvoltage shall be effected in accordance with Table "Maximum voltage dynamics", with the exception of the HV battery.

LV123-1947 For the HV battery the voltage increase for the test pulse overvoltage shall be effected with the maximum slope in accordance with Table "Dynamic parameters" up to the time when the switching equipment switches off. Then, i.e. with the switching equipment switched on, the voltage increase and decrease shall be performed with the maximum voltage dynamics in accordance with Table "Maximum voltage dynamics".

LV123-865 Test criteria for the HV operating status B3:

- Operational, specified state
- Automatic reestablishment of intended performance in the event of a return to the HV operating status B1 or B2
- Fault memory entry.

LV123-866 Test criteria for the HV operating status B4:

- Operational, specified state
- Reestablishment of intended performance following a reset or simple intervention (e.g. ignition state transition, vehicle restart)
- Fault memory entry.

LV123-867 The test shall be performed under operational ambient conditions.

LV123-1948 After the test, the tested HV component shall be checked visually and electrically by means of an ICT.

LV123-1949 For the test, the test parameters in accordance with Table "Test parameters overvoltage" shall be selected.

LV123-1950

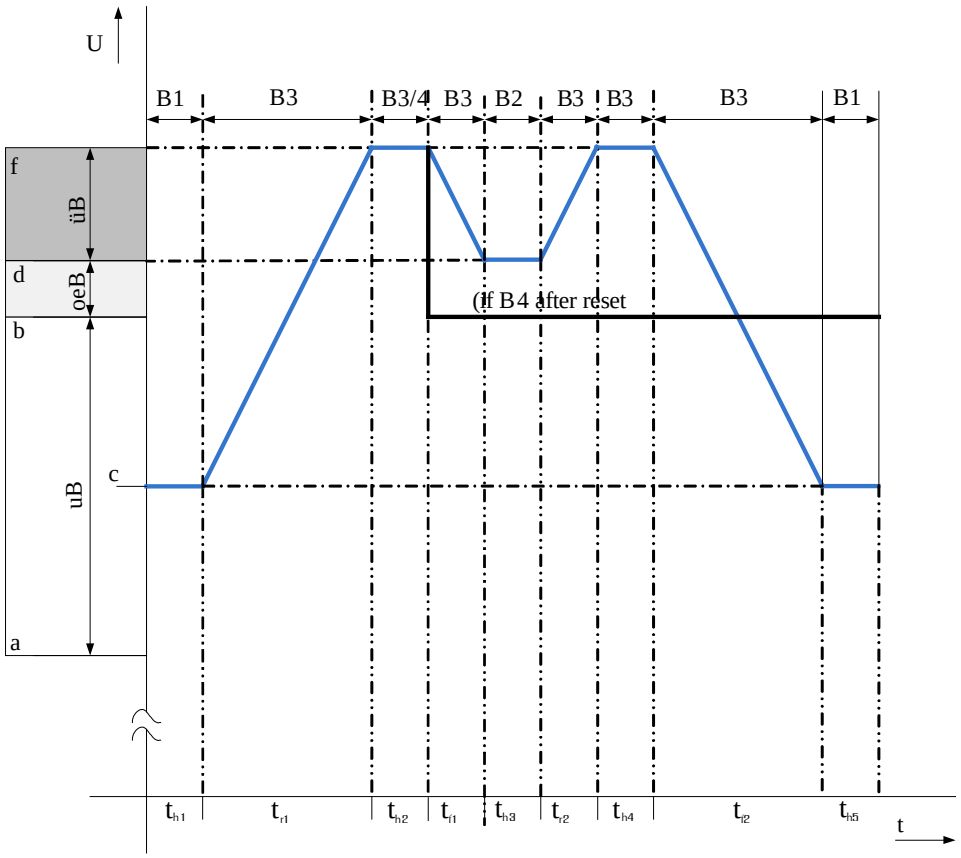
Table: Test parameters overvoltage

LV123-1951

Test parameter	**Value**
Test procedure with HV operating status	B1, B2 and B3 / B4 (specified continuous output)
A	Minimum value of the unlimited operating capability of the relevant voltage level
B	Maximum value of the unlimited operating capability of the relevant voltage level
C	Calculated value of the unlimited operating capability of the relevant voltage level $c = a + \frac{b-a}{2}$
D	Maximum value of the upper limited operating capability of the relevant voltage level
F	Upper HV circuit limit voltage of the relevant voltage level
uB	Unlimited operating capability of the relevant voltage level
oeB	Upper limited operating capability of the relevant voltage level
üB	Overvoltage range
t_{h1}	1 min
t_{r1}	To be determined from the relevant parameters
t_{h2}	10 s
t_{f1}	To be determined from the relevant parameters
t_{h3}	1 min
t_{r2}	To be determined from the relevant parameters
t_{h4}	10 s
t_{f2}	To be determined from the relevant parameters
t_{h5}	1 min
T_{test}	T_{RT}
T_{cool}	$T_{coolmax}$
Number of cycles	To be determined from the specified number of overvoltage events
Number of DUTs	3

LV123-1952 For the test, the test pulse in accordance with Figure "Test pulse overvoltage" shall be selected.

LV123-1953



LV123-1954 Figure: Test pulse overvoltage

10.4.8 Test: Undervoltage (LV123-896)

LV123-897 Requirement: See Section "Undervoltage"

LV123-898 Test type: Product validation

LV123-899 Test method: Measurement

LV123-900 **Product validation**

LV123-901 The behavior in the event of undervoltage shall be verified for each controlled HV component. The specifications of Table "HV voltage levels" shall be used.

LV123-902 In the event of undervoltage, operation with the performance specified for the HV operating status B3 shall be verified.

LV123-903 Compliance with the HV operating status B3 shall be verified.

LV123-904 The operating behavior of the HV component shall be documented and verified.

LV123-905 The test shall be used to verify that the maximum intended performance or the HV operating status B1 is complied with again when the DC HV voltage falls within the range of unlimited operating capability again after a deviating characteristic.

LV123-906 The test shall be used to verify that the maximum intended performance or the HV operating status B2 is complied with again when the DC HV voltage falls within the range of limited operating capability again after a deviating characteristic.

LV123-907 The test shall be performed under operational ambient conditions.

LV123-908 Test criteria for the HV operating status B3:

- Operational, specified state
- No fault memory entry if no power demand is present
- Fault memory entry if there is a power demand
- Automatic reestablishment of maximum intended performance and of the HV operating status B1 in the event of a return to the range of unlimited operating capability
- Automatic reestablishment of maximum intended performance and of the HV operating status B2 in the event of a return to the range of limited operating capability.

LV123-1955 For the test, the test parameters in accordance with Table "Test parameters undervoltage" shall be selected.

LV123-1956

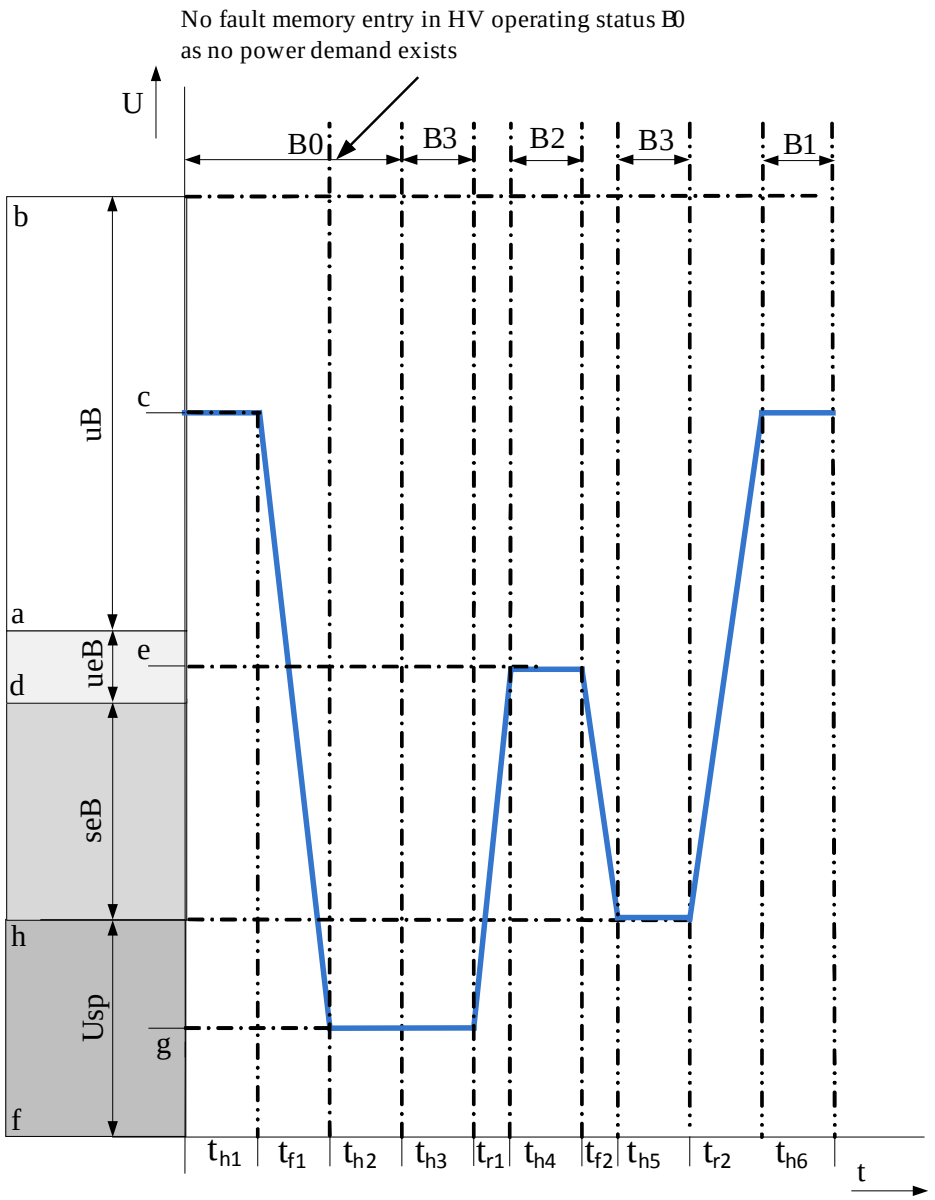
Table: Test parameters undervoltage

LV123-1957

Test parameter	Value
Test procedure with HV operating status	B1, B2 and B3 / B4 (specified continuous output)
a	Minimum value of the unlimited operating capability of the relevant voltage level
b	Maximum value of the unlimited operating capability of the relevant voltage level
c	Calculated value of the unlimited operating capability of the relevant voltage level $c = a + \frac{b-a}{2}$
d	Minimum value of the lower limited operating capability of the relevant voltage level
e	Calculated value of the lower limited operating capability of the relevant voltage level $e = a - \frac{a-d}{2}$
f	0 V
h	Maximum defined value of the undervoltage of the relevant voltage level
g	Calculated value of the undervoltage $g = \frac{h}{2}$
uB	Unlimited operating capability of the relevant voltage level
ueB	Lower limited operating capability of the relevant voltage level
seB	Highly limited operating capability of the relevant voltage level
Usp	Undervoltage range of the relevant voltage level
t_{h1}	2 min
t_{f1}	To be calculated from the relevant parameters in accordance with the indication of present voltage dynamics in Table "Dynamic parameters"
t_{h2}	2 min
t_{h3}	10 s
t_{r1}	To be calculated from the relevant parameters in accordance with the indication of present voltage dynamics in Table "Dynamic parameters"
t_{h4}	2 min
t_{f2}	To be calculated from the relevant parameters in accordance with the indication of present voltage dynamics in Table "Dynamic parameters"
t_{r2}	To be calculated from the relevant parameters in accordance with the indication of present voltage dynamics in Table "Dynamic parameters"
t_{h6}	1 min
T_{test}	T_{RT}
T_{cool}	$T_{coolmax}$
Number of cycles	2
Number of DUTs	3

LV123-1958 For the test, the test pulse in accordance with Figure "Test pulse undervoltage" shall be selected.

LV123-1959



LV123-1960 Figure: Test pulse undervoltage

10.4.9 Test: Load dump and voltage limiting (LV123-910)

LV123-911 Requirement: See Section "Load dump and voltage limiting"

LV123-1405 Test type: Product validation and 100% standard production testing

LV123-1406 Test method: Measurement

LV123-1407 **Product validation**

LV123-1961 The test for the required behavior of an HV component during present overvoltage during load dump is covered by the "Overvoltage" test. No separate test is required.

LV123-1408 The test for control measures for voltage limitation during load dump shall be carried out for the HV components specified by the OEM.

LV123-1409 The effectiveness of the voltage limiting function shall be verified for operation at maximum load and subsequent load dump.

LV123-1411 An appropriate test procedure shall be documented by the supplier and agreed upon with the OEM.

LV123-1412 **100% standard production test**

LV123-1413 The control measures for voltage limiting during load dump shall be verified within the scope of the functional tests.

LV123-1414 This test may be performed within the scope of the agreed functional test.

LV123-1415 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

10.4.10 Test: Voltage offset (LV123-933)

LV123-934 Requirement: See Section "Voltage offset"

LV123-935 Test type: Product validation

LV123-936 Test method: Measurement

LV123-937 **Product validation**

LV123-938 The following operation shall be verified for all HV components comprising electronic parts or integral parts of electronic circuits that are placed between HV potentials and vehicle ground:

1. Operation at the upper voltage of the unlimited operating capability (operating status B1), and
2. Operation at the upper HV circuit limit voltage (operating status B3 or B4)

LV123-939 The tests shall be performed for each DC HV potential and for the selected voltage range in a separate test step.

LV123-940 A test setup in accordance with Figure "Test setup for voltage offset, test step 1" and Figure "Test setup for voltage offset, test step 2" shall be provided for the measurement.

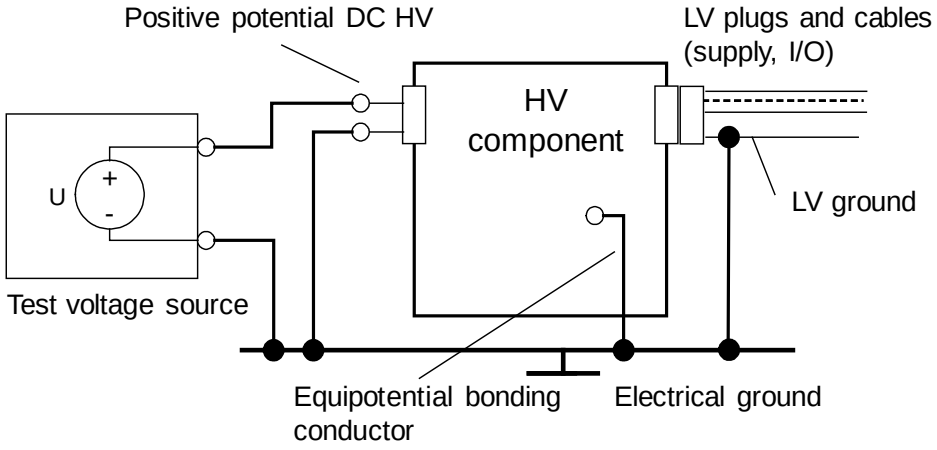
LV123-1962 Test step 1a:
A test voltage U with the value of the upper voltage of the unlimited operating capability shall be applied between the positive DC HV potential of the HV component and the electrical ground of the test setup for a period of at least 600 s.
The negative DC HV potential of the HV component shall be connected with the electrical ground of the test setup.

LV123-1963 Test step 1b:
A test voltage U with the value of the upper HV circuit limit voltage shall be applied between the positive DC HV potential of the HV component and the electrical ground of the test setup for a period of at least 10 s or a period agreed between the supplier and the OEM.
The negative DC HV potential of the HV component shall be connected with the electrical ground of the test setup.

LV123-942 All electrical grounds shall be connected with each other, in accordance with Figure "Test setup for voltage offset, test step 1", for the measurements:

- LV ground, HV component
- Conductive housings, equipotential bonding
- Negative potential of test voltage
- Negative DC HV potential of the HV component.

LV123-943



LV123-944 Figure: Test setup for voltage offset, test step 1

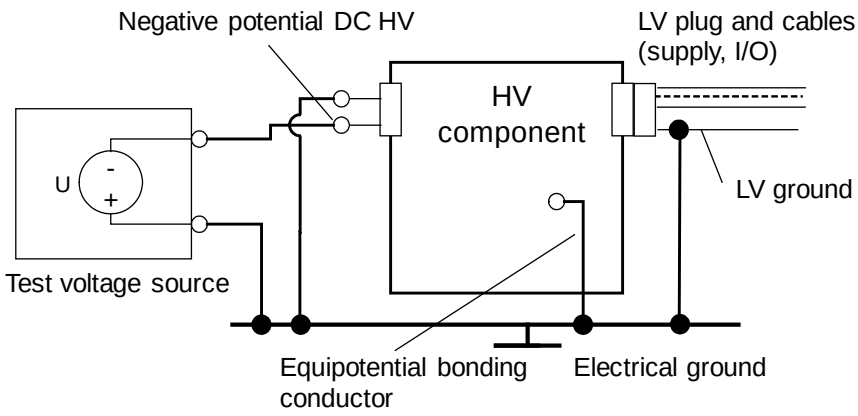
LV123-1964 Test step 2a:
A test voltage U with the value of the upper voltage of the unlimited operating capability shall be applied between the negative DC HV potential of the HV component and the electrical ground of the test setup for a period of at least 600 s.
The positive DC HV potential of the HV component shall be connected with the electrical ground of the test setup.

LV123-1965 Test step 2b:
A test voltage U with the value of the upper HV circuit limit voltage shall be applied between the negative DC HV potential of the HV component and the electrical ground of the test setup for a period of at least 10 s or a period agreed between the supplier and the OEM.
The positive DC HV potential of the HV component shall be connected with the electrical ground of the test setup.

LV123-946 All electrical grounds shall be connected with each other, in accordance with Figure "Test setup for voltage offset, test step 2", for the measurements:

- LV ground, HV component
- Conductive housings, equipotential bonding
- Positive potential of test voltage
- Positive DC HV potential of the HV component.

LV123-947



LV123-948 Figure: Test setup for voltage offset, test step 2

LV123-949 Evidence shall be provided that all parts can withstand the upper HV circuit voltage permanently.

LV123-950 Evidence shall be provided that the HV component complies with the required HV operating statuses and that the relevant HV operating status does not change under a load in accordance with Figure "Test setup for voltage offset, test step 1".

LV123-951 Evidence shall be provided that the HV component complies with the required HV operating statuses and that the relevant HV operating status does not change under a load in accordance with Figure "Test setup for voltage offset, test step 2".

LV123-952 The test shall be performed under operational ambient conditions.

LV123-1966 **Testing of HV battery:**

LV123-1967 For the test set-up of the HV battery, the test voltage source in test steps 1a and 2a is omitted. The voltage shall be selected within the individual range of the unlimited operational capability of the HV battery.

LV123-1968 The test of the HV battery under test steps 1b and 2b shall be carried out with the switching equipment switched off. The upper HV circuit limit voltage shall be applied as test voltage.

10.4.11 Test: Interactions between LV and HV system (LV123-954)

LV123-955 Requirement: See Section "Interactions between LV and HV system"

LV123-956 Test type: Product validation

LV123-957 Test method: Measurement

LV123-958 **Product validation**

LV123-959 Tests in accordance with the current OEM standards for LV supply voltage shall be performed for all HV components. Evidence of the appropriate operating behavior of the HV component in HV circuits shall be provided as part of these tests.

LV123-960 For the test, the HV component shall be operated on a typical HV voltage according to the voltage ranges in accordance with Table "HV voltage ranges", as well as with the corresponding HV operating statuses.

LV123-961 For all HV components, evidence shall be provided, within the scope of the tests in accordance with the current OEM standards for the LV supply voltage, that the requirements for the LV powernet are also fulfilled during the operation of the HV components in HV circuits. The entire operating range of the HV voltage shall be taken into account.

LV123-962 The test shall be performed under operational ambient conditions.

LV123-963 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

10.5 Testing for electrical characteristics and HV safety (LV123-964)

10.5.1 Test: Marking (LV123-965)

LV123-966 Requirement: See Section "Marking"

LV123-967 Test type: Product validation and 100% standard production test

LV123-968 Test method: Expert consultation, if necessary measurement, visual inspection

LV123-969 **Product validation**

LV123-970 The appropriate implementation of the HV marking shall be verified.

LV123-971 Strength against abrasion and resistance to all vehicle-typical chemical substances shall be verified for the HV marking. See also Section "Test: Installation areas and ambient conditions".

LV123-972 Evidence of the correct placement of the specified HV marking at the intended locations of the HV component and at all points subject to obligatory marking shall be provided within the scope of an expert consultation.

LV123-973 For HV cables, compliance with the required coloring shall be verified.

LV123-974 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

LV123-975 **100% standard production test**

LV123-976 The correct placement of the specified HV marking at the intended locations of the HV component shall be checked by means of a visual inspection or the AOI method.

LV123-977 For HV cables, compliance with the required coloring shall be checked.

LV123-978 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

10.5.2 Test: Protection against direct contact (LV123-979)

LV123-980 Note: Bibliographic references: ECE-R100, GB/T 18384.3, GB/T 19751, GB/T 24549, ISO 6469-3, ISO/DIS 17409: 2013-09, TRIAS 17(2)-R100

LV123-981 Requirement: See Section "Protection against direct contact"

LV123-982 Test type: Product validation and 100% standard production test

LV123-983 Test method: Measurement, visual inspection

LV123-984 **Product validation**

LV123-985 The effectiveness of the measures designed to protect persons against direct contact with live parts shall be verified for HV components by means of the tests described below.

LV123-986 The degree of protection specified for the protection against direct contact shall be verified. The requirements regarding the IP degree of protection in accordance with Section "Protection against direct contact" and the corresponding requirements documentation of the OEM shall be fulfilled.

LV123-987 The test shall be carried out in accordance with ISO 20653, and shall be performed with test probes according to a defined testing procedure.

LV123-2190 Prior to testing, all manually removable parts (not requiring tools) of the HV components and all flexible connection lines for media shall be removed.

LV123-988 For the testing of the HV components, a current source (with a no-load voltage not less than 40 V and not more than 50 V) shall be connected in series with an appropriate lamp between the probe and the live parts inside the housing (signal-current procedure).

LV123-990 The test probe shall not be permitted to contact live parts. If the distance is tested with a signal-current circuit between the probe and live parts in order to make sure that it is sufficient, the lamp shall not light up.

LV123-1516 If protection against direct contact is provided by solid insulating materials, the use of appropriate materials and an appropriate design shall be verified.

LV123-991 If protection against direct contact is established by the "Complex disassembly" design feature, the supplier shall verify the procedures and specialized skills required for this purpose in coordination with the OEM.

LV123-992 It shall be verified, that covers for live parts can only be removed with tools.

LV123-993 It shall be verified, that the fastening of covers for live parts does not come loose during operation.

LV123-994 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

LV123-995 **100% standard production test**

LV123-996 For plug-in connections, the required degree of protection for the protection against direct contact in unplugged condition shall be verified with an appropriate test, e.g. AOI.

LV123-997 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

10.5.3 Test: Equipotential bonding (LV123-998)

LV123-999 Note: Bibliographic references: ECE-R100, GB/T 18384.3, ISO 6469-3, TRIAS 17(2)-R100

LV123-1000 Requirement: See Section "Equipotential bonding"

LV123-1001 Test type: Product validation and 100% standard production test

LV123-1002 Test method: Expert consultation, measurement, procedural test

LV123-1003 **Product validation**

LV123-1969 In an expert consultation, the supplier shall provide evidence on the basis of the design documentation and the fully developed HV component that the design measures for equipotential bonding fulfill all relevant requirements for equipotential bonding.

LV123-1004 For each HV component, evidence of the required electrical resistances for equipotential bonding shall be provided through measurements. The following measurements shall be performed:

- Electrical resistance between different most unfavorable measuring points on the surface of the cover or the housing of an HV component and the connecting point of the means for equipotential bonding.
- Electrical resistance between the most unfavorable measuring point on the surface of the cover or the housing of an HV component, and
  - the electrical ground, or
  - an adjacent conductive part in accordance with the arrangement specified by the OEM.
  - The details shall be gathered from the OEM's requirements documentation.

LV123-1007 For HV component testing, the means intended for equipotential bonding, e.g. a cable, shall be connected with a suitable ground in the test arrangement.

LV123-1011 The test shall be carried out such that the means intended for equipotential bonding constitutes the only conductive connection between the measuring points.

LV123-1012 The following conditions shall be complied with during the test:

- The LV connector shall be unplugged.
- The influence of EMC shielding, e.g. for HV contacting, shall be excluded.
- The influence of metallic brackets not specified for equipotential bonding shall be excluded.

LV123-1005 For the measurement, a test current of at least 0,2 A shall be impressed on the required measuring path. The test duration shall be selected such that a stable resistance value can be determined.

LV123-2191 Note: A test current of 0,2 A to 1 A is sufficient in the relevant measuring range for resistances up to 100 mOhm.

LV123-1006 The test current shall be fed and the voltage shall be measured via separate cables and test contacts (four-wire measurement).

LV123-1970 For testing, an appropriate current source with a known test current shall be used. The resistance determined shall not depend on an electrical output provided by the test source for the measuring path. A voltage source shall not be used as test source. This rule is intended to prevent a dependency of the determined contact resistance on test-related thermal influences.

LV123-1008 The electric resistance of the equipotential bonding shall be determined from the test current and the measured voltage drop.

LV123-1009 The resistance determined shall fulfill the required resistance values for each of the required individual measurements.

LV123-1010 The test of the electric resistance of the equipotential bonding shall be performed for the brand-new component and for the condition that corresponds to the condition at the end of the specified service life (EOL).

LV123-1971 A suitable test shall be used to verify that fasteners of the HV component which are intended for the equipotential bonding path do not work loose. Evidence shall be provided for the following fasteners / attachments:

- Fasteners of covers and housings of an HV component
- Fasteners for the connection of the means for equipotential bonding to the HV component.

The test shall be performed in the condition at the end of the specified service life (EOL) and after the endurance tests specified for this purpose.

LV123-1972 Before the required test in the condition at the end of specified service life (EOL), the following endurance tests shall be performed as a minimum; see also Section "Test sequence plan":

- Vibration test
- Corrosion test.

Further endurance tests, if required, and details on endurance tests shall be gathered from the OEM's requirements documentation.

LV123-1013 The required ampacity of the means for equipotential bonding shall be verified.

LV123-1973 The required ampacity shall be verified for the conductive covers and housings of an HV component.

LV123-1974 If the HV component is part of a linked equipotential bonding path, evidence of the relevant required ampacity shall be provided. The details shall be gathered from the OEM's requirements documentation.

LV123-1014 The test sequence for measurements shall be implemented in accordance with Section "Test sequence plan".

LV123-1015 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

LV123-1016 **100% standard production test**

LV123-1017 An appropriate test shall be performed.

LV123-1508 The test can be performed as an electrical test of the resistance or as a procedural test of the selected joining technique.

LV123-1509 If the test is carried out as an electrical test of the resistance, an appropriate current source shall be used with a current of at least 0,2 A. The current shall be selected in such a way that a sufficient accuracy of the resistance test is achieved.

LV123-1510 The procedural test of the joining technique selected can be carried out by means of torque and angle of rotation monitoring at the connection points if, for example, screwed connections are used for direct mounting of the HV component or equipotential bonding conductors.

LV123-1018 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

10.5.4 Test: Overcurrent protection (LV123-1975)

LV123-1976 Note: Bibliographic references: ECE-R100, ISO/DIS 17409: 2013-09, TRIAS 17(2)-R100

LV123-1977 Requirement: See Section "Overcurrent protection"

LV123-1978 Test type: Product validation and 100% standard production test

LV123-1979 Test method: Expert test, if necessary measurement

LV123-1980 **Product validation**

LV123-1981 For HV batteries, the test requirements are specified in Section "Overcurrent protection HV battery".

LV123-1982 Evidence shall be provided that the switching devices and the overcurrent protection device are suitable for interrupting the DC HV circuit in the event of overcurrents up to the magnitude of the short-circuit current of the corresponding HV component with overcurrent protection requirements.

LV123-1983 The supplier shall deliver to the OEM details from a suitable testing laboratory that verifies the adequate dimensioning of the switching devices and the elements of the overcurrent protection device.

LV123-1984 The selection of appropriate and approved subcomponents or parts shall be verified within the scope of expert testing.

LV123-1985 For contactors, the tripping behavior at the upper limit of the specified tripping range shall be verified with a device qualification procedure.

LV123-1986 For the fuse or the overcurrent protection part, the tripping behavior in the

- specified overcurrent range and
- at the lower limit of the tripping range

shall be verified by means of a part qualification procedure.

LV123-1987 If the overcurrent protection of an HV source is designed with switching equipment, the following evidence shall be provided by means of measurements:

- The switching equipment shall not switch off when the maximum operating current has been reached during operation.
- The HV source shall be short-circuited during operation. In the case of active current detection, the switching equipment shall switch off when the specified current limit above the maximum operating current is reached. Evidence of the compliance with the specified switch-off time after the occurrence of a short-circuit shall be provided. A resistor with (20 + 0 /- 10) mOhm shall be used for the short-circuit.

LV123-1988 For controlled HV components, an appropriate test shall be used to verify that overload current can be detected, limited and switched off.

LV123-1043 For HV components that are controlled by power electronics and that can feed electric energy as operationally intended into a DC HV circuit, the following evidence shall be provided:

- A measurement shall be used to verify that the HV component can be switched off during operation with maximum load current (generation-based operation) and a short-circuit on the HV circuit.
- Evidence shall be provided that the HV component will not be mechanically or electrically damaged in the event of this short-circuit taking place.
- Evidence shall be provided that the HV component will be fully functional after the short-circuit is removed.

An appropriate test procedure, as well as the corresponding operating behavior, shall be specified by the supplier and agreed upon with the OEM.

LV123-1989 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

LV123-1990 **100% standard production test**

LV123-1991 Evidence of the functional capability of the overcurrent detection shall be provided.

LV123-1992 If contactors are used, evidence of the functional capability of the switch off function shall be provided.

LV123-1993 The test shall be performed such that premature damage of the HV component is excluded.

LV123-1994 This test may be performed within the scope of the agreed functional test.

LV123-1995 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

10.5.5 Test: Potential separation of HV system and LV powernet (LV123-1047)

LV123-2192 Note: Bibliographic references: IEC 60747, IEC 61558, IECQ

LV123-1048 Requirement: See Section "Potential separation of HV system and LV powernet"

LV123-1049 Test type: Product validation

LV123-1050 Test method: Expert consultation, HV component inspection

LV123-1051 **Product validation**

LV123-1052 The test is required for each HV component.

LV123-1053 In an expert consultation, the supplier shall provide evidence on the basis of the design documentation and the finally developed HV component that the galvanic separation between the LV powernet and the HV circuits has been taken into account for all subcomponents.

LV123-1996 The supplier shall indicate parts used for galvanic separation between HV potentials and LV powernet and between HV potentials of circuits that are isolated from one another.

LV123-2193 The qualification of parts for galvanic separation that are subject to the requirements for insulation (basic insulation, double or reinforced insulation) in accordance with Section "Insulation coordination", shall be verified and documented by means of suitable part tests, selection of parts according to an applicable standard and/or by another proof of qualification (e.g. selection in accordance with IECQ).

LV123-1054 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

10.5.6 Test: Isolation resistance (LV123-1055)

LV123-1056 Note: Bibliographic references: ECE-R100, GB/T 18384.1, GB/T 18384.3, ISO 6469-1, ISO 6469-3, ISO/DIS 17409: 2013-09, SAE J1766,TRIAS 17(2)-R100

LV123-1057 Requirement: See Section "Isolation resistance"

LV123-1058 Test type: Product validation and 100% standard production test

LV123-1059 Test method: Measurement

LV123-1060 **Product validation**

LV123-1061 The test shall be performed on a completely assembled HV component. This includes, among other parts, all corresponding main parts, additional parts, and add-on parts in accordance with Section "HV components".

LV123-1062 For HV component testing, the part intended for equipotential bonding, e.g. a cable, shall be connected with an adequate ground belonging to the test setup. Protective covers (e.g. housing, partition walls) shall be taken into account during the test.

LV123-1063 The HV component shall be commissioned before the test and shall be supplied with the media intended for operation, e.g. coolant.

LV123-1064 The test shall be performed in two test steps for the following conditions:

LV123-1065 Test step 1:
BOL and standard ambient conditions, following commissioning;
without conditioning according to ambient conditions

LV123-1066 Test step 2:
EOL and worst-case ambient conditions, end-of-service-life and environmental testing; with conditioning according to worst-case ambient conditions, at least climatic condition with condensation.

LV123-1067 The isolation resistance shall be documented for each test step.

LV123-1068 As a test criterion for test step 2, evidence shall be provided that at least the required isolation resistance in accordance with Section "Isolation resistance" is complied with.

LV123-1069 If the minimum requirement for climatic conditioning is valid for test step 2 and the worst-case ambient conditions, the isolation resistance of the HV component shall be measured after the
HV component has been conditioned under the following ambient conditions:

LV123-1070 Preconditioning:

- Eight hours at a temperature of: (5 ± 2) °C.

LV123-1071 Conditioning, eight hours at:

- A temperature of: (23 ± 5) °C
- A relative humidity of: (93 + 5 / - 2) %
- An atmospheric pressure of: 86 kPa to 106 kPa.

LV123-1072 During the conditioning phase, the measurement of the isolation resistance shall be carried out in such a way that the lowest occurring isolation resistance is recorded.

LV123-1073 It is recommended that the isolation resistance measurements be carried out at appropriate intervals during the conditioning phase.

LV123-1997 The measurements shall be carried out using appropriate isolation resistance measuring instruments which are able to provide the required test voltage.

LV123-1075 An external DC voltage shall be applied as a test voltage. It shall be applied for a duration that ensures a constant measured value. If testing equipment with internal test voltage generation is used, the specified test voltage value shall be set.

LV123-1076 The test voltage shall be selected according to specifications in Table "Test voltages withstand voltage - for connection to external electric power supply" or Table "Test voltages withstand voltage - without connection to external electric power supply".

LV123-1077 The isolation resistance of an HV component shall be measured such that all DC HV circuits and AC HV circuits associated with this HV component are included. This requirement shall be fulfilled, for example, for the following types of HV components:

- HV components with integrated inverter and electric motor that do not comprise AC HV contacting that is accessible from outside
- HV components with integrated mechanical switching devices in HV circuits.

LV123-1998 If an HV component contains mechanical switching devices in HV circuits, these switching devices shall be switched on for performing the measurement, i.e. the switching devices of the switching equipment shall be closed.

LV123-1999 For HV components with an internal galvanic separation between HV circuits, which is effective in switch-on state, the measurement of the isolation resistance shall be carried out for each partial HV circuit.

LV123-1078 For the HV battery, the special requirements for the test set-up and the execution of the test described below shall be complied with.

LV123-1079 The following procedure shall be applied for HV cables and HV components, excluding the electric energy storage (typically an HV battery):

LV123-1080 In principle, for an HV component:

- all LV signal contacts,
- the LV supply,
- the LV ground contact,
- the conductive parts of the housing, and
- the part for electrical equipotential bonding

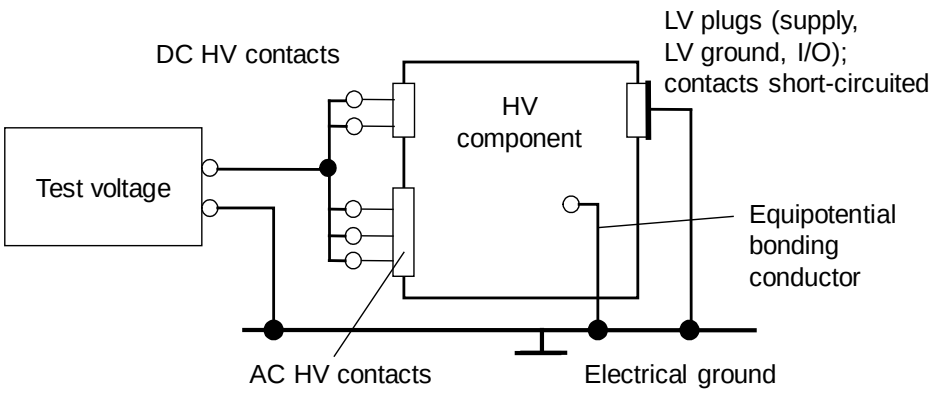
shall be electrically connected with each other and with the electrical ground of the test setup.

LV123-1081 All AC HV contactings and all DC HV contactings shall be connected with each other electrically at the interface of the HV component to HV circuits.
This requirement shall also be fulfilled for HV components with a permanent internal galvanic separation of HV circuits, e.g. on-board charger with transformer.

LV123-1082 The test voltage shall be applied between the connected HV contactings and the electrical ground of the test setup.

LV123-1083 A test setup in accordance with Figure "Test setup for HV component isolation resistance" shall be provided, in principle, for measuring the isolation resistance of an HV component.

LV123-1084



LV123-1085 Figure: Test setup for HV component isolation resistance

LV123-2000 If an HV component contains mechanical switching devices in HV circuits, the test set-up shall be adjusted so that these switching devices can be switched on.

LV123-1086 For components having a non-conductive housing, the following requirements shall be fulfilled for the test:

- The surface shall be covered with a metal foil that makes contact with the surface.
- If the housing or cover has apertures or gaps, the metal foil shall be pressed into such openings using test equipment appropriate to the degree of protection specified in Section "Protection against direct contact".
- The metal foil shall be connected with the electrical ground.

LV123-1087 An appropriate test for HV cables or an HV wiring harness shall be specified. The installation conditions inside the vehicle shall be taken into account.

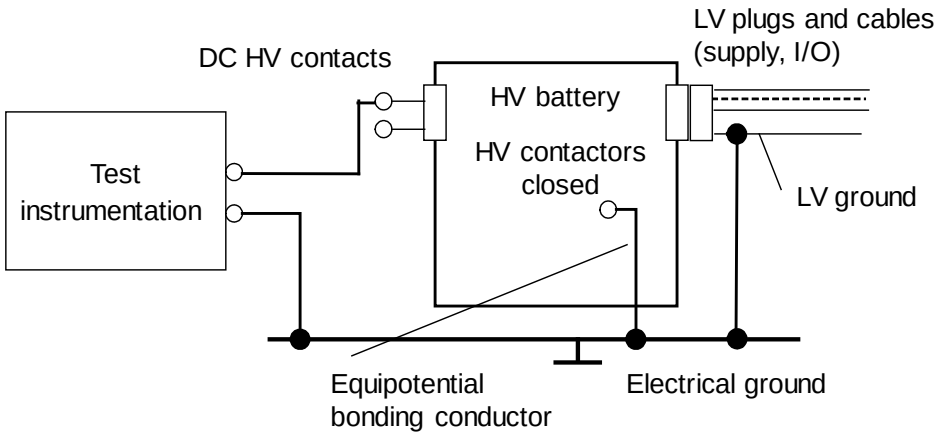
LV123-1088 If an HV cable or an HV wiring harness does not comprise an integrated EMC shielding, an adequate closed and conductive cover shall be placed around the HV cable or the HV wiring harness for testing purposes. This cover shall be connected to the electrical ground.

LV123-1089 If an HV cable or an HV wiring harness comprises an integrated EMC shielding, the test voltage shall be applied between the connected HV contactings and the EMC shielding.

LV123-1090 **Procedure for measuring the isolation resistance for an HV battery**

LV123-1091 A test setup in accordance with Figure "Test setup for HV component isolation resistance" shall be provided, in principle, for measuring the isolation resistance of an HV battery.

LV123-1092



LV123-1093 Figure: Test setup for HV battery isolation resistance

LV123-1095 The HV battery shall be switched on for carrying out the measurement, i.e. the switching devices of the switching equipment shall be closed.

LV123-1096 The voltage of the HV battery shall correspond to the operating voltage at maximum SOC that is intended for operation.

LV123-1097 The test procedure specified below shall be used for measuring the HV battery's isolation resistance, similar to ECE-R100.
Another test procedure can be used, if its suitability and a comparable accuracy are proved by the supplier. The test voltage shall be selected according to specifications in Table "Test voltages withstand voltage - for connection to external electric power supply" or Table "Test voltages withstand voltage - without connection to external electric power supply".

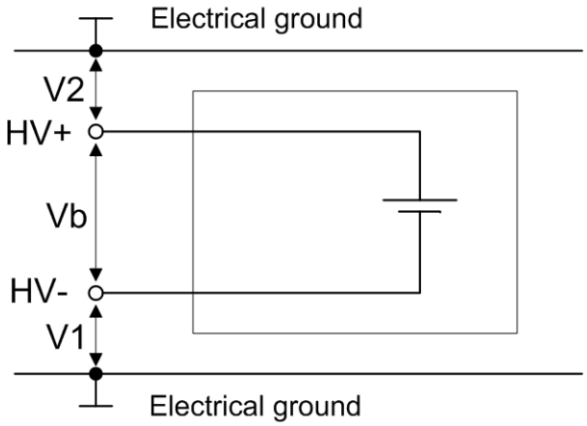
LV123-1523 A voltmeter and a known resistor Ro shall be used for the test instrumentation in accordance with Figure "Test setup for HV battery isolation resistance".

LV123-1074 The measurements shall be carried out between the active parts of the electric circuit and the ground of the test set-up using appropriate measuring equipment (e.g. voltmeter with high internal resistance, at least 10 MOhm).

LV123-1094 During the measurement, the voltage of the HV battery shall be used as a measuring voltage. The measurement shall be carried out in two stages.

LV123-1098 **Stage 1:** In separate steps, voltages Vb (between the potentials HV+ and HV-), V1 (between the potentials HV- and ground) and V2 (between the potentials HV+ and ground) shall be measured in sequence; see Figure "Isolation resistance measurement, stage 1".

LV123-1099

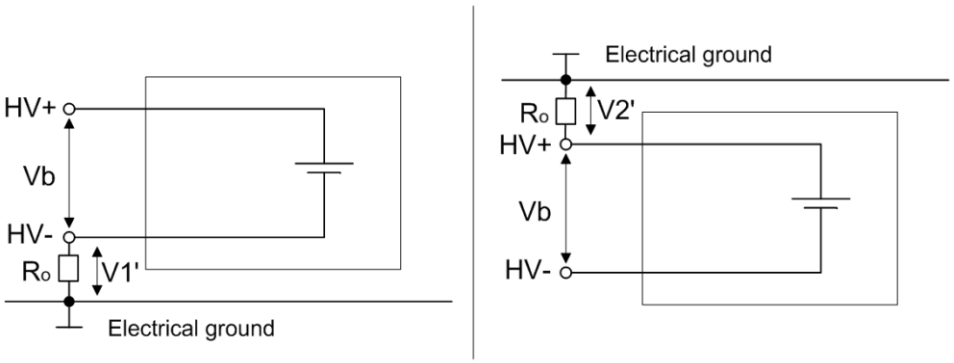


LV123-1100 Figure: Isolation resistance measurement, stage 1

LV123-1101 Note: It is assumed that the total of the absolute values of V1 and V2 will approximately equal the absolute value of the battery voltage Vb (between the potentials HV+ and HV-). If the summation of voltages V1 and V2 is significantly lower than the battery voltage, this is an indication of the fact that the isolation resistance is approximately equal to the internal resistance of the measuring equipment (at least 10 MOhm). In this case, there are almost ideal insulation conditions.

LV123-1102 **Stage 2:** For the measurement in stage 2, a distinction shall be made between 2 cases, see Figure "Isolation resistance measurement, stage 2".

LV123-1103



a) if V1 ≥ V2 b) if V2 > V1

LV123-1104 Figure: Isolation resistance measurement, stage 2

LV123-1105 If V1 ≥ V2, a known resistor Ro shall be placed between HV- and electrical ground. Voltage V1' between HV- and ground shall be measured. The isolation resistance shall be calculated with the following formula:

$$R_{iso} = R_O \bullet \left(\frac{Vb}{V1'} - \frac{Vb}{V1} \right)$$

LV123-1106 If V2 > V1, a known resistor Ro shall be placed between HV+ and electrical ground. Voltage V2' between HV+ and ground shall be measured. The isolation resistance shall be calculated with the following formula:

$$R_{iso} = R_O \bullet \left(\frac{Vb}{V2'} - \frac{Vb}{V2} \right)$$

LV123-1107 Ro shall be a resistor with a value that approximately equals that of the required isolation resistance.

LV123-1108 **Testing procedure**

LV123-1109 During product validation, evidence shall be provided that the isolation resistance of an HV component does not change due to the withstand voltage test under the conditions of the 100% standard production test; see Section "Test: Withstand voltage".

LV123-1110 The following sequence is recommended for performing the tests intended for product validation:

LV123-1111 - Isolation resistance test, test step 1

LV123-1112 - Withstand voltage test with test conditions in accordance with "100% standard production test"; see Section "Test: Withstand voltage"

LV123-1113 - Additional isolation resistance check measurement

LV123-1114 - Isolation resistance test, test step 2

LV123-1115 - The sequence shall be performed in accordance with Section "Test sequence plan".

LV123-1116 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

LV123-1117 **100% standard production test**

LV123-1118 The test shall be carried out for every HV component.

LV123-2002 In principle, the 100% standard production test shall be carried out according to the requirements for the product validation test. The following modified test conditions shall be taken into account:

LV123-1119 Deviating from the requirements for the product validation test, the conditioning according to the test step 1 for product validation shall be used for all HV components including the HV battery.

LV123-1120 If evidence is provided that the filling of media intended for operation does not have any impact on the isolation resistance, filling for the 100% standard production test may be omitted.

LV123-1121 The ambient conditions during the 100% standard production test shall be documented by the supplier.

LV123-1122 The following sequence is recommended for performing the tests intended for the 100% standard production test:

LV123-1123 - For withstand voltage testing, see Section "Test: Withstand voltage"

LV123-1124 - Isolation resistance test, test step 1 in accordance with Sub-Section "Product validation".

LV123-1125 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

10.5.7 Test: Insulation coordination (LV123-1126)

10.5.7.1 Test: General, clearances and creepage distances and solid insulating materials (LV123-2003)

LV123-2308 Note: Bibliographic references: GB/T 18384.1, GB/T 18384.3, ISO 6469-1, ISO 6469-3, ISO/DIS 17409: 2013-09

LV123-1127 Requirement: see Sections "General", "Clearances", Creepage distances" and "Solid insulating materials" in Section "Insulation coordination"

LV123-1128 Test type: Product validation

LV123-1129 Test method: Expert consultation, measurement, HV component and production inspection

LV123-1130 **Product validation**

LV123-1131 The test is required for each HV component.

LV123-1132 In an expert consultation, the supplier shall present and give reasons for the selected design of the clearances on the basis of the design documentation.

LV123-1133 In addition, an inspection of the HV component and of production shall be performed.

LV123-2004 The isolation paths relevant to the required insulation in accordance with Section "General" in Section "Insulation coordination" shall be reported by the supplier.

LV123-2194 The clearances shall be determined according to the requirements of IEC 60664-1.

LV123-2005 Evidence of the clearances shall be provided by the supplier by means of suitable geometry data, e.g. by means of CAD data.

LV123-2006 The creepage distances shall be determined according to the requirements of IEC 60664-1.

LV123-2007 Evidence of the creepage distances shall be provided by the supplier by means of suitable geometry data, e.g. by means of CAD data.

LV123-2008 The pollution degree used shall be reported and documented. The suitability of the pollution degree used shall be demonstrated.

LV123-2009 The insulating material groups shall be reported and documented. The suitability of the insulating material groups used shall be demonstrated.

LV123-2195 If separate individual tests for the verification of clearances and creepage distances are required for particular assemblies of HV components, such tests shall be performed by the supplier in accordance with the requirements of IEC 60664-1 and reported. For this purpose, for example an impulse voltage test may be used.

LV123-1134 If separate individual tests for the verification of solid insulations are required for particular assemblies of HV components or insulations, such tests shall be performed by the supplier in accordance with the requirements of IEC 60664-1 and reported. For this purpose, for example an impulse voltage test may be used.

LV123-1135 The testing of clearances and creepage distances does not replace

- the isolation resistance test in accordance with Section "Test: Isolation resistance", or
- the withstand voltage test in accordance with Section "Test: Withstand voltage".

LV123-1136 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

10.5.7.2 Test: Withstand voltage (LV123-1137)

LV123-1138 Note: Bibliographic references: GB/T 18384.3, ISO 6469-3, ISO/DIS 17409: 2013-09

LV123-1139 Requirement: See Section "Withstand voltage"

LV123-1140 Test type: Product validation and 100% standard production test

LV123-1141 Test method: Measurement

LV123-1142 **Product validation**

LV123-2196 **HV components including the HV battery**

LV123-1143 The withstand voltage test shall be performed for each HV component, including the corresponding cables and plug-in connections, and the HV wiring harness.

LV123-2197 The withstand voltage test shall be carried out such that all relevant isolation paths are tested for the required insulation in accordance with Section "General" in Section "Insulation coordination".

LV123-2198 For HV components excluding an HV battery, special testing requirements are specified in Sub-Section "HV components excluding an HV battery".

LV123-1144 For HV batteries, special test requirements are specified in Sub-Section "HV battery".

LV123-1525 For an FC stack, the requirements for the filling with the media intended for operation and preconditions shall be gathered from the OEM's requirements documentation.

LV123-1145 The test shall be performed on a completely assembled HV component. This includes, among other parts, all corresponding main parts, additional parts, and add-on parts in accordance with Section "HV components".

LV123-2199 Isolation-bridging parts or such arrangements of parts can be removed for the withstand voltage test if these parts and their arrangement in the HV component fulfill the following requirements:

- The clearances and creepage distances shall be verified in accordance with section "Test: General, clearances and creepage distances and solid insulating materials".
- The withstand voltage shall be verified in accordance with the requirements of 100% standard production testing for the withstand voltage in Sub-Section "100% standard production testing".

The application of this measure shall be specified by the supplier and agreed upon with the OEM.

LV123-2015 If separate individual tests for the verification of the withstand voltage are required for individual parts of HV components, such measurements shall be performed by the supplier and reported to the OEM.

LV123-2012 The withstand voltage test of an HV component shall be carried out such that all DC HV circuits and AC HV circuits associated with this HV component which are galvanically connected with each other during operation are included. This requirement shall be fulfilled, for example, for the following versions of HV components:

- HV components with integrated inverter and electric motor that do not comprise AC HV contacting that is accessible from outside
- HV components with integrated mechanical switching devices in HV circuits.

LV123-2013 If an HV component comprises mechanical switching devices in HV circuits, these switching devices shall be switched on for the execution of the measurement, i.e. the switching devices of the switching equipment shall be closed.

LV123-2014 For HV components with an internal galvanic separation to insulate between HV circuits in accordance with Section "Insulation coordination" and which is effective when in switch-on state, a withstand voltage test shall be performed for each insulation path. The following tests shall be conducted:

- Partial test for every HV sub-circuit for the isolation path to electrical ground. If these isolation paths are jointly tested for both HV sub-circuits, it shall be demonstrated that the prerequisites for doing so are fulfilled, e.g. applicability of the same test voltage, inclusion of all relevant sub-circuits.
- Partial test between the galvanically separated HV sub-circuits.

LV123-1146 For HV component testing, the part intended for equipotential bonding, e.g. a cable, shall be connected with an adequate ground belonging to the test setup. Protective covers (e.g. housing, barriers) shall be taken into account during the test.

LV123-1162 For components having a non-conductive housing, the following requirements shall be fulfilled for the test:

- The surface shall be covered with a metal foil that makes contact with the surface.
- If the housing or cover has apertures or gaps, the metal foil shall be pressed into such openings using test equipment appropriate to the degree of protection specified in Section "Protection against direct contact".
- The metal foil shall be connected with the electrical ground.

LV123-1163 An appropriate test for HV cables or an HV wiring harness shall be specified by the supplier. The installation conditions inside the vehicle shall be taken into account.

LV123-1164 If an HV cable or an HV wiring harness does not comprise an integrated EMC shielding, an adequate closed and conductive cover shall be placed around the HV cable or the HV wiring harness for testing purposes. This cover shall be connected to the electrical ground.

LV123-1165 If an HV cable or an HV wiring harness comprises an integrated EMC shielding, the test voltage shall be applied between the connected HV contactings and the EMC shielding.

LV123-2010 Before the withstand voltage test, a vibration test in accordance with the OEM's requirements documentation shall be carried out for each HV component; see Section "Test sequence plan".

LV123-1147 In a next step, the HV component shall be commissioned and shall be supplied with the media intended for operation, e.g. coolant. The operation of the HV component shall be terminated before pre-conditioning.

LV123-1157 Before the electrical test, a pre-conditioning and a conditioning shall be performed for the HV component with the following ambient conditions:

LV123-1158 Pre-conditioning at:

- A temperature of: (30 ± 2) °C
- Normal ambient conditions: relative humidity of approx. 40 % to 50 %
- A duration ensuring thermal equilibrium.

LV123-1159 Conditioning, 48 hours at:

- A temperature of: (23 ± 2) °C
- A relative humidity of: (93 + 5 / - 2) %
- An atmospheric pressure of: 86 kPa to 106 kPa.

LV123-1160 The electrical test shall be performed directly after conditioning.

LV123-1152 The test voltage shall be increased to the required test voltage uniformly over a period of no more than 5 s and shall be applied for a period of at least one minute. The test duration shall be reported by the supplier.

LV123-1161 During the test, neither a dielectric breakdown of the insulation, nor a flashover, shall occur.

LV123-2011 The selected current limit for the withstand voltage test shall be set to a value of 100 mA, see ISO 60664-1.

LV123-931 For all HV components, evidence shall be provided that the HV component, including all related LV electronic systems and parts, withstands the test voltages in accordance with Table "Test voltages withstand voltage - for connection to external electric power supply" or Table "Test voltages withstand voltage - without connection to external electric power supply".

LV123-932 The documentation on the qualification of parts shall be delivered by the supplier and agreed upon with the OEM.

LV123-1148 **HV components, excluding the HV battery**

LV123-1149 The electric energy storages (e.g. HV battery, LV powernet battery), if any, shall be disconnected from the HV circuits and from the LV powernet.

LV123-1150 Both ends of every other electric circuit not to be tested shall be connected conductively to the electrical ground at a common point.

LV123-1151 An AC voltage with a frequency between 50 Hz and 60 Hz shall be selected as test voltage in accordance with the specifications of Table "Test voltages withstand voltage - for connection to external electric power supply" or Table "Test voltages withstand voltage - without connection to external electric power supply".

LV123-1153 Alternatively, a direct voltage can be selected as test voltage according to specifications in Table "Test voltages withstand voltage - for connection to external electric power supply" or Table "Test voltages withstand voltage - without connection to external electric power supply". Approval from the OEM shall be obtained by the supplier for this alternative.

LV123-1154 In principle, for the measurement

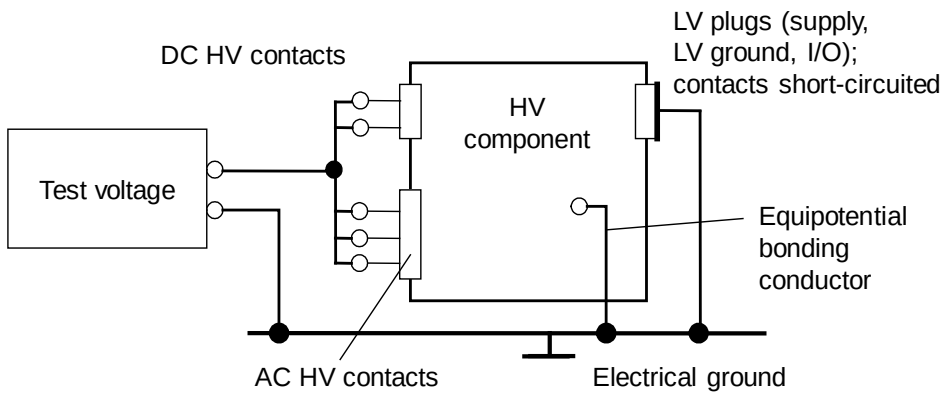
- all HV contactings (DC and AC) of the HV component shall be connected to each other,
- all LV contacts shall be connected to the electrical ground,
- all conductive housing parts shall be connected to the electrical ground, and the means for equipotential bonding shall be connected to the electrical ground.

LV123-1155 The test voltage shall be applied between the connected HV contactings and the electrical ground.

LV123-1156 The test setup for the HV component shall be equipped with an adequate electrical ground that simulates the vehicle ground.

LV123-1526 In principle, a test setup in accordance with Figure "Test setup for HV component withstand voltage" shall be provided for the test of the withstand voltage of an HV component.

LV123-1527



LV123-1528 Figure: Test setup for HV component withstand voltage

LV123-2016 If an HV component contains mechanical switching devices in HV circuits, the test set-up shall be adjusted such that these switching devices can be switched on.

LV123-2017 For HV components with an internal galvanic separation to insulate between HV circuits in accordance with Section "Insulation coordination" and which is effective when in switch-on state, the following test requirements shall be fulfilled:

- All HV contactings in an HV circuit shall be connected with each another.
- The test voltage shall be applied between the connected HV contactings of the HV sub-circuits.
- The test setup in accordance with Figure "Test setup for HV component withstand voltage" shall be adapted accordingly.

LV123-1166 **HV battery**

LV123-1167 For the HV battery, the requirements in accordance with the OEM's requirements documentation shall be complied with.

LV123-1168 For HV battery product validation purposes, a withstand voltage test of the component without battery cells or with dummy cells is required. The test set-up shall be designed in analogy with the test set-up in Figure "Test set-up withstand voltage HV battery. Deviating from this figure, the DC contacts shall be connected with each other.

LV123-2018 Note: A dummy cell has the following characteristics:

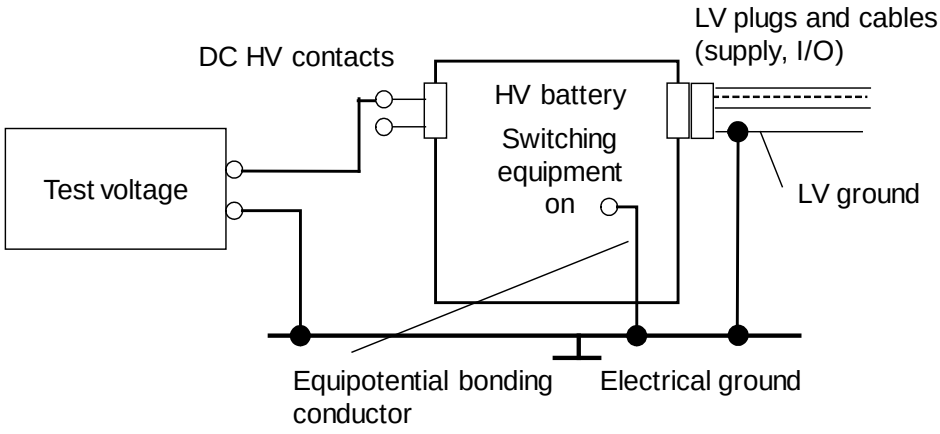
- Dimensions, structure, housing and electrical connections are identical with the original cell
- The dummy cell contains no electrolyte or other chemicals.

LV123-1169 The withstand voltage test for the complete HV battery component is recommended; see OEM's requirements documentation.

LV123-1170 The test shall be performed in such a way that pre-damage to the HV battery is excluded. For this purpose, check tests for testing the isolation resistance of the HV battery (including battery cells) before and after the withstand voltage test shall be performed; see Section "Test: Isolation resistance".

LV123-1171 For the HV battery withstand voltage test, a test setup in accordance with Figure "Test setup for HV battery withstand voltage" shall be provided for.

LV123-1172



LV123-1173 Figure: Test setup for HV battery withstand voltage

LV123-2019 The test setup for the HV battery shall be equipped with an adequate electrical ground that simulates the vehicle ground.

LV123-2020 The HV battery shall be switched on for carrying out the measurement, i.e. the switching devices of the switching equipment shall be closed.

LV123-1174 The test voltage shall be selected according to specifications in Table "Test voltages withstand voltage - for connection to external electric power supply" or Table "Test voltages withstand voltage - without connection to external electric power supply". The selected test voltage shall be reported by the supplier.

LV123-1175 The positive potential of the test voltage shall be connected to the positive terminal of the HV battery. This is intended to prevent an increased voltage load on the other battery terminal caused by the resulting present voltage from the test voltage and the battery voltage.

LV123-1176 **Testing procedure**

LV123-1177 In principle, repeat tests are not permissible within the scope of product validation.

LV123-1178 Procedures deviating from the test requirements, e.g. the testing of subcomponents and repeated tests for subcomponents and for the assembly of a component, shall be separately agreed upon with the OEM by the supplier on a case-by-case basis.

LV123-1179 The supplier of the HV component shall furnish evidence regarding all the tests in the supply chain.

LV123-1180 **Sequence of withstand voltage and isolation resistance tests**

LV123-1181 The following sequence is recommended for performing the tests intended for product validation:

LV123-1182
- Isolation resistance test, test step 1, see Section "Test: Isolation resistance", Sub-Section "Product validation"

LV123-1183
- Test: Withstand voltage

LV123-1184
- Additional isolation resistance check measurement.

LV123-1185 After the test, the HV component tested shall be quarantined in a controlled manner in order to ensure that it is not used again.

LV123-1186 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

LV123-1187 **100% standard production test**

LV123-1188 In principle, 100% standard production testing of an HV component shall be carried out according to the requirements for product validation testing. The following modified test conditions shall be taken into account:

LV123-1189
- The vibration test is omitted.
- Conditioning is omitted.

LV123-1190
- For basic insulation, the full test voltage in accordance with Section "Product validation" shall be used; see Table "Test voltages withstand voltage - for connection to external electric power supply" or Table "Test voltages withstand voltage - without connection to external electric power supply".

LV123-2379
- For double or reinforced insulation, a value between 80 % and 100% of the test voltage according to Sub-Section "Product validation" shall be used; see Table "Test voltages withstand voltage - for connection to external electric power supply" or Table "Test voltages withstand voltage - without connection to external electric power supply". The selected test voltage shall be reported by the supplier.

LV123-2021 The test voltage shall be increased to the required test voltage uniformly over a period of no more than 5 s and shall be applied for a period of at least 1 s. The test duration shall be reported by the supplier.

LV123-2200 The selected current limit for 100% standard production testing may be set to a value lower than the one that applies for product validation, but shall not be set to below 3,5 mA, see ISO 60664-1.
The selected current limit shall be reported by the supplier.

LV123-1191 If evidence is provided that the filling of media intended for operation does not have any impact on the withstand voltage, filling for the 100% standard production test may be omitted.

LV123-1192 It shall be guaranteed that no pre-damage to the HV component occurs as a result of the 100% standard production test.

LV123-1193 The removal of electronic assemblies or Y capacitors is impermissible for the 100% standard production test.

LV123-1194 If repeat tests are planned, they shall be specified by the supplier and agreed upon with the OEM.

LV123-1195 If repeat tests are planned, the test voltage may be reduced to 80 % of the test voltage required for 100% standard production testing. The other requirements for 100% standard production testing shall be complied with. The selected test voltage for a repeat test shall be reported by the supplier.

LV123-1196 The supplier of the HV component shall furnish evidence regarding all the tests in the supply chain.

LV123-1197 For the HV battery, the withstand voltage test for the complete HV battery component shall be performed in accordance with the OEM's requirements documentation. The test is recommended.

LV123-1198 For the HV battery test, care shall be taken to guarantee that pre-damage is excluded. For this purpose, check tests for testing the isolation resistance of the HV battery (including battery cells) before and after the withstand voltage test shall be performed; see Section "Test: Isolation resistance".

LV123-1199 The following sequence is recommended for performing the tests intended for the 100% standard production test:

LV123-1200
- Test: Withstand voltage

LV123-1201
- Isolation resistance test, test step 1, see Section "Test: Isolation resistance", Sub-Section "Product validation".

LV123-1202
- The sequence shall be performed in accordance with Section "Test sequence plan".

LV123-1203 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

10.5.8 Test: Residual voltage (LV123-2022)

LV123-2023 Requirement: See Section "Residual voltage"

LV123-2024 Test type: Product validation and 100% standard production testing

LV123-2025 Test method: Expert consultation, measurement

LV123-2380 **Product validation**

LV123-2026 For a controlled HV component, evidence shall be provided by means of a suitable measurement that when a signal for the shut-off of the HV system is transmitted, the load current is switched off or the no-load status is activated.

LV123-2027 In an expert consultation, the supplier shall provide evidence on the basis of the design documentation and the fully developed HV component that when switched off the HV component complies with the required upper limits for the residual voltage between all specified potentials.

LV123-2028 For an HV component, evidence shall be provided by means of the following measurements that the required upper limits for the residual voltage are complied with between all specified potentials:

- The HV component shall be connected and operated in the same manner as during the intended operation. The HV component shall then be switched off. The voltages at the specified potentials shall then immediately be measured.
- The HV component shall be connected to an LV supply. In this state, the voltages shall be measured at the specified potentials.

LV123-2029 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

LV123-2381 **100% standard production test**

LV123-2382 The HV component shall be connected and operated in the same manner as during the intended operation. The HV component shall then be switched off. A measurement of voltages performed immediately thereafter shall be used to verify that the required upper limits for residual voltage are complied with between all specified potentials.

LV123-2383 This test may be performed within the scope of the agreed functional test.

LV123-2384 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

10.5.9 Test: Active discharge (LV123-1204)

LV123-1205 Requirement: See Section "Active discharge"

LV123-1206 Test type: Product validation and 100% standard production test

LV123-1207 Test method: Expert consultation, measurement

LV123-1208 **Product validation**

LV123-2030 In an expert consultation, the supplier shall describe the active discharge circuit on the basis of the design documentation and the fully developed HV component.

LV123-1209 The HV component shall be operated, in a steady-state operating condition, with the maximum operating voltage of the DC HV circuit. If required, a capacitive equivalent load shall be connected to the HV component for this test in accordance with the OEM's requirements documentation. After this, the active discharge shall be activated.

LV123-1210 The voltage vs. time curve at the interface to the DC HV circuit shall be plotted. Evidence shall be provided that the voltage is lowered to a value < 60 V d.c. within the specified time during active discharging.

LV123-1211 Evidence of the function of the specified control measures shall be provided. Further details shall be gathered from the OEM's requirements documentation.

LV123-1212 An appropriate test procedure, as well as the operating conditions, shall be specified by the supplier and agreed upon with the OEM.

LV123-1213 **100% standard production test**

LV123-1214 The functional capability of the active discharge function shall be verified.

LV123-1215 This test may be performed within the scope of the agreed functional test.

LV123-1216 An appropriate test procedure, as well as the operating conditions, shall be specified by the supplier and agreed upon with the OEM.

10.5.10 Test: Passive discharge (LV123-1217)

LV123-1218 Requirement: See Section "Passive discharge"

LV123-1219 Test type: Product validation and 100% standard production test

LV123-1220 Test method: Measurement

LV123-1221 **Product validation**

LV123-1222 The HV component shall be operated, in a steady-state operating condition, with the maximum operating voltage of the DC HV circuit.

LV123-1223 The HV component shall then be switched off and disconnected from the DC HV circuit.

LV123-1224 The voltage vs. time curve at the interface to the DC HV circuit shall be plotted.

LV123-1225 Evidence shall be provided that the voltage is lowered to a value < 60 V d.c. within the specified time during passive discharging.

LV123-1226 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

LV123-1227 **100% standard production test**

LV123-1228 Evidence of the correct design of the passive discharge function shall be provided by one of the following tests:

- Electrical measurement of the part or circuit (e.g. ICT)
- AOI
- Functional test by measurement of the discharge at the HV component.

LV123-1229 This test may be performed within the scope of the agreed functional test.

LV123-1230 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

10.5.11 Test: X capacitors (LV123-1231)

LV123-1232 Requirement: See Section "X capacitors"

LV123-1233 Test type: Product validation and 100% standard production test

LV123-1234 Test method: Expert consultation, HV component inspection, visual inspection

LV123-1235 **Product validation**

LV123-1236 In an expert consultation, the supplier shall provide evidence on the design of the X capacitor according to the requirements and the selection and arrangement of appropriate parts on the basis of the design documentation and the produced HV component.

LV123-2031 For X capacitors qualified as class X or Y capacitors in accordance with IEC 60384-14, the corresponding qualification shall be documented.

LV123-2201 For X capacitors qualified in accordance with the applicable requirements in IEC 60384-1, the applicable tests shall be carried out and documented.

LV123-2202 For an arrangement of X capacitors, evidence shall be provided by a test that the requirements for insulation coordination in accordance with Section "Insulation coordination" are fulfilled in the event of the failure of one individual part.

LV123-1237 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

LV123-1238 **100% standard production test**

LV123-1239 Evidence of the correct installation of the X capacitor and compliance with the electrical characteristics, including tolerances, shall be provided by means of one of the following tests:

- Electrical measurement of the part or circuit (e.g. ICT)
- AOI.

LV123-1240 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

10.5.12 Test: Y capacitors (LV123-1241)

LV123-1242 Requirement: See Section "Y capacitors"

LV123-1243 Test type: Product validation and 100% standard production test

LV123-1244 Test method: Expert consultation, HV component inspection, visual inspection

LV123-1245 **Product validation**

LV123-1246 For an arrangement of X capacitors, evidence shall be provided by a test that the requirements for insulation coordination in accordance with Section "Insulation coordination" are fulfilled in the event of the failure of one individual part.

LV123-2032 For Y capacitors qualified as class Y or X capacitors in accordance with IEC 60384-14, the corresponding qualification shall be documented.

LV123-2203 For Y capacitors qualified in accordance with the applicable requirements in IEC 60384-1, the applicable tests shall be carried out and documented.

LV123-2204 For an arrangement of Y capacitors, evidence shall be provided by a test that the requirements for insulation coordination in accordance with Section "Insulation coordination" are fulfilled in the event of the failure of one individual part.

LV123-1247 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

LV123-1248 **100% standard production test**

LV123-1249 Evidence of the correct installation of the Y capacitors and compliance with the electrical characteristics, including tolerances, shall be provided by means of one of the following tests:

- Electrical measurement of the part or circuit (e.g. ICT)
- AOI.

LV123-1250 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

10.5.13 Test: Isolation-bridging parts (LV123-2205)

LV123-2206 Note: Bibliographic references: IECQ

LV123-2207 Requirement: See Section "Isolation-bridging parts"

LV123-2208 Test type: Product validation and 100% standard production test

LV123-2209 Test method: Expert consultation, HV component inspection, if necessary measurement, visual inspection

LV123-2210 **Product validation**

LV123-2211 In an expert consultation, the supplier shall provide evidence on the design of the isolation-bridging parts according to the requirements and the selection and arrangement of appropriate parts on the basis of the design documentation and the produced HV component.

LV123-2212 Evidence of the qualification of isolation-bridging parts shall be provided and documented by applicable part tests, the selection of parts according to an applicable standard, and/or another proof of qualification (e.g. selection in accordance with IECQ).

LV123-2213 For an arrangement of isolation-bridging parts, evidence shall be provided by a test that the requirements for insulation coordination in accordance with Section "Insulation coordination" are fulfilled in the event of the failure of one individual part.

LV123-2214 For isolation-bridging parts and such arrangements of parts, the upper current limit shall be verified and documented by means of a measurement or using the design documentation.

LV123-2215 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

LV123-2216 **100% standard production test**

LV123-2217 Evidence of the correct installation of isolation-bridging parts and part arrangements and of compliance with the electrical characteristics, including tolerances, shall be provided by one of the following tests:

- Electrical measurement of the part or circuit (e.g. ICT)
- AOI.

LV123-2218 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

10.5.14 Test: HV contacting (LV123-1251)

LV123-1252 Requirement: See Section "HV contacting"

LV123-1253 Test type: Product validation and 100% standard production test

LV123-1254 Test method: Expert consultation, e.g. visual inspection

LV123-1255 **Product validation**

LV123-1256 In an expert consultation, the supplier shall demonstrate that the design conforms to the corresponding specifications on the basis of the design documentation for the HV component or the produced HV wiring harnesses respectively.

LV123-1257 For fastening means for HV contacting and screws of screwed terminal connections, evidence shall be provided that they do not loosen during driving operation.

LV123-1258 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

LV123-1259 **100% standard production test**

LV123-1260 In the case of plug connections, the required degree of protection for the protection against direct contact in unmated condition shall be verified with an appropriate test, e.g. AOI.

LV123-1261 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

10.5.15 Test: HV interlock (LV123-1262)

LV123-1263 Requirement: See Section "HV interlock"

LV123-1264 Test type: Product validation and 100% standard production test

LV123-1265 Test method: Measurement

LV123-1266 **Product validation**

LV123-1267 **Testing of HV components that are functionally active with regard to the HV interlock**

LV123-1268 In the case of functionally active HV components with regard to the HV interlock function, signal generation and signal detection, if any, shall be tested.

LV123-1269 The following functions shall be verified:

- Proper functional capability of a signal generator, if any
- A discontinuity in the signal contact or in the signal loop activates a signal detector, if any
- The activation of a signal detector, if any, triggers the specified response of the HV component.

LV123-1270 Evidence shall be provided that the HV component cannot be switched on in case of a present interlock event.

LV123-1271 Evidence shall be provided that the HV component will not switch itself on independently when signal contacting is reestablished.

LV123-1272 An appropriate test procedure, including the circuit details of the test setup, shall be specified by the supplier and agreed upon with the OEM.

LV123-1273 The circuitry of the signal contacting in the test setup shall model the circuitry inside the vehicle.

LV123-1274 **Testing of HV components that are functionally passive with regard to the HV interlock (with signal contacts that are only effective outwards)**

LV123-1275 For all functionally passive HV components and subcomponents, closed signal contacting shall be verified when all relevant parts are completely installed.

LV123-1276 Evidence shall be provided that the disconnection of LV contactings that is integrated into the HV interlock leads to a signal contacting interruption.

LV123-1277 Evidence shall be provided that the disconnection of HV contactings that is integrated into the HV interlock leads to a signal contacting interruption.

LV123-1278 If covers are integrated into the HV interlock, evidence shall be provided that their removal leads to a signal contacting interruption.

LV123-1279 A simulation of the signal generator and the signal detectors effected with auxiliary circuits is sufficient for the test.

LV123-1280 An appropriate test procedure, as well as the operating conditions, shall be specified by the supplier and agreed upon with the OEM.

LV123-1281 **100% standard production test**

LV123-1282 The functional capability of the HV interlock shall be verified.

LV123-1283 This test may be performed within the scope of the agreed functional test.

LV123-1284 An appropriate test procedure, as well as the operating conditions, shall be specified by the supplier and agreed upon with the OEM.

10.5.16 Test: Delayed access to live parts (LV123-1285)

LV123-1286 Requirement: See Section "Delayed access to live parts"

LV123-1287 Test type: Product validation and 100% standard production test

LV123-1288 Test method: Expert consultation, HV component inspection

LV123-1289 **Product validation**

LV123-1290 In an expert consultation, the supplier shall present the design conforming to the corresponding specifications on the basis of the design documentation and the produced HV component.

LV123-1291 Evidence shall be provided that the duration of the required manipulation processes is longer than the time required to shut-off the HV system.

LV123-1292 The test shall be carried out with trained personnel and appropriate tools.

LV123-1293 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

LV123-1294 **100% standard production test**

LV123-1295 The functional capability of the delayed access to live parts shall be verified.

LV123-1296 This test may be performed within the scope of the agreed functional test.

LV123-1297 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

10.5.17 Test: Behavior in the event of a crash (LV123-1298)

LV123-1299 Requirement: See Section "Behavior in the event of a crash"

LV123-1300 Test type: Product validation and 100% standard production test

LV123-1301 Test method: Measurement

LV123-1302 **Product validation**

LV123-1303 The test shall be carried out for all HV components for which a behavior in the event of a crash is specified.

LV123-1304 Evidence shall be provided that the signaling function of a crash event leads to the specified HV component switch-off behavior.

LV123-1305 The voltage curve vs. time on the DC HV circuit shall be plotted.

LV123-1306 Evidence shall be provided that the HV component will not switch itself on independently if, after the signaling of a crash event, this signaling is no longer present.

LV123-1307 Evidence shall be provided that the HV component cannot be switched on after the signaling of a crash event.

LV123-1308 An appropriate test procedure, as well as the operating conditions, shall be specified by the supplier and agreed upon with the OEM.

LV123-1309 **100% standard production test**

LV123-1310 The functional capability of the active discharge function when a crash event is signaled shall be verified in accordance with Section "Active discharge". This test may be performed as part of a functional test.

LV123-1311 An appropriate test procedure, as well as the operating conditions, shall be specified by the supplier and agreed upon with the OEM.

10.5.18 Test: Measuring the HV voltage (LV123-1312)

LV123-1313 Requirement: See Section "Measuring the HV voltage"

LV123-1314 Test type: Product validation and 100% standard production test

LV123-1315 Test method: Expert consultation, measurement

LV123-1316 **Product validation**

LV123-1317 The detection and output of the voltage shall be verified with an appropriate test setup. Functional capability shall be verified for the entire specified voltage range; see Table "HV voltage ranges" and Table "Voltage deviations".

LV123-1318 For HV components that can feed electric energy during an intended operation into a DC HV circuit, the additional monitoring function of the DC HV voltage shall be demonstrated, and the functional capability shall be verified.

LV123-1319 The test shall be performed under operational ambient conditions.

LV123-1320 An appropriate test procedure, as well as the operating conditions, shall be specified by the supplier and agreed upon with the OEM.

LV123-1321 **100% standard production test**

LV123-1322 The detection and output of the voltage shall be verified within the scope of the functional tests.

LV123-1323 An appropriate test procedure, as well as the operating conditions, shall be specified by the supplier and agreed upon with the OEM.

10.5.19 Test: Failure of LV supply voltage (LV123-1324)

LV123-1325 Requirement: See Section "Failure of LV supply voltage"

LV123-1326 Test type: Product validation

LV123-1327 Test method: Measurement

LV123-1328 **Product validation**

LV123-1329 The HV component shall be operated under full load and in all operating conditions that are critical with regard to the LV supply voltage failure. The LV supply shall be switched off in these conditions.

LV123-1330 The currents and voltages at the interface to the DC HV circuit shall be measured.

LV123-1331 Evidence shall be provided that the currents and voltages do not assume any values that are not permissible.

LV123-1332 After the LV supply has been switched back on, the HV component shall be ready for operation without restrictions.

LV123-1333 The corresponding operating behavior shall be documented.

LV123-1334 The test shall be performed under operational ambient conditions.

LV123-1335 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

10.5.20 Test: Electrical equivalent circuit diagrams (LV123-1336)

LV123-1337 Requirement: See Section "Electrical equivalent circuit diagrams"

LV123-1338 Test type: Product validation

LV123-1339 Test method: Expert consultation

LV123-1340 **Product validation**

LV123-1341 In an expert consultation, the supplier shall present the electrical equivalent circuit diagrams and provide evidence of their appropriateness.

LV123-2033 The values of the equivalent circuit diagram elements, including tolerances, shall be reported and documented by the supplier.

LV123-1342 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

10.5.21 Test: Installation areas and ambient conditions (LV123-1343)

LV123-2309 Note: Bibliographic references: GB/T 18384.3

LV123-1344 Requirement: See Section "Installation areas and ambient conditions"

LV123-1345 Test type: Product validation

LV123-1346 Test method: Measurement

LV123-1347 **Product validation**

LV123-1348 The tests shall be performed in accordance with the OEM's requirements documentation.

10.5.22 Test: Pre-assembly and mounting (LV123-1349)

LV123-1350 Requirement: See Section "Pre-assembly and mounting"

LV123-1351 Test type: Product validation

LV123-1352 Test method: Expert consultation, if necessary measurement

LV123-1353 **Product validation**

LV123-1354 Individual evidence shall be provided for the requirements regarding the pre-assembly and mounting of an HV component.

LV123-1355 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

10.5.23 Test: Disassembly and disposal (LV123-2034)

LV123-2035 Requirement: See Section "Disassembly and disposal"

LV123-2036 Test type: Product validation

LV123-2037 Test method: Expert consultation, if necessary measurement

LV123-2038 **Product validation**

LV123-2039 Individual evidence shall be provided with respect to the requirements for the disassembly and disposal of an HV component.

LV123-240 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

10.5.24 Test: Underload factors for HV parts (LV123-1362)

LV123-1363 Requirement: See Section "Underload factors for HV parts"

LV123-1364 Test type: Product validation

LV123-1365 Test method: Expert consultation

LV123-1366 **Product validation**

LV123-1367 In an expert consultation, the supplier shall present the design of the underload factors and provide evidence of their appropriateness.

LV123-1368 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

10.5.25 Test: Documentation (LV123-1369)

LV123-1370 Requirement: See Section "Documentation"

LV123-1371 Test type: Product validation

LV123-1372 Test method: Expert consultation, HV component inspection and production process quality audit

LV123-1373 **Product validation**

LV123-1374 In an expert consultation, the supplier shall demonstrate the required identification and documentation of certification-relevant and safety-relevant scopes HV using the product documentation of the HV component.

LV123-1375 The test shall include an inspection of the HV component.

LV123-1376 The supplier of the HV component shall provide evidence that the required measures for safety-relevant HV characteristics are reliably implemented in the series production of the HV component.
An inspection of the series production is required for this purpose.

LV123-1377 This evidence may be provided within the scope of a quality audit for the production process.

LV123-1378 The documented specification of the supplier regarding the description of the HV component for the certification in all planned countries or markets shall be checked within the scope of an expert consultation.

LV123-1379 The test criterion is the release of documentation.

LV123-1380 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

10.5.26 Test sequence plan (LV123-1381)

LV123-1382 For the execution of the tests for

- equipotential bonding,
- isolation resistance, and
- withstand voltage,

their order in a test sequence shall comply with Figure "Test sequence plan".

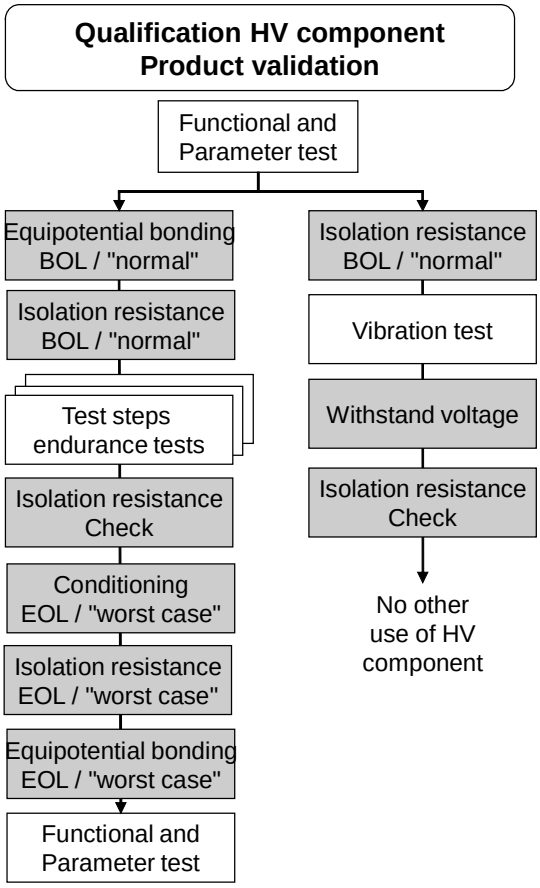
LV123-1383 The test steps for the endurance tests shall correspond to a realistic load for the service life. They shall include at least temperature and corrosion loads.

LV123-1384 The

- tests regarding voltage ranges, and
- the remaining tests regarding electrical characteristics and HV safety

may be performed within the scope of the functional and parameter tests.

LV123-1385



LV123-1386 Figure: Test sequence plan

LV123-1387 The test sequence plan shall be specified by the supplier and agreed upon with the OEM.

10.6 Testing for additional requirements for individual HV components (LV123-1388)

10.6.1 Test: Isolation monitoring (LV123-1389)

LV123-1390 Requirement: See Section "Isolation monitoring"

LV123-1391 Test type: Product validation and 100% standard production test

LV123-1392 Test method: Measurement

LV123-1393 **Product validation**

LV123-1394 Evidence of the detection and output of the isolation resistance according to the specified requirements shall be provided by appropriate measurements.

LV123-1395 Functional capability shall be verified for the entire operating voltage range in accordance with Table "HV voltage ranges" and under operational ambient conditions.

LV123-1396 The rest of the HV system shall be simulated with an appropriate equivalent setup.

LV123-1397 The following evidence shall be provided considering the real operating conditions of the HV system in accordance with Section "Voltage ranges". For this purpose dynamic parameters shall be in accordance with Table "Dynamic parameters":

- Isolation monitoring tolerances
- Measuring time until output of a valid isolation resistance
- Detection of symmetrical and asymmetrical isolation faults in the entire HV system, i.e., DC HV circuits and AC HV circuits
- Switch-off capability
- Self-test and
- Other functions, if applicable.

LV123-2041 The dependency of the time until output of a valid isolation resistance on the Y capacitors of the monitored HV circuit shall be demonstrated for the required value range of the capacitance per DC HV potential by means of an appropriate measurement.

LV123-1398 An appropriate test procedure, as well as the operating conditions, shall be specified by the supplier and agreed upon with the OEM.

LV123-1399 **100% standard production test**

LV123-1400 The functional capability of the isolation monitoring feature, as well as the detection and output of the isolation resistance, shall be verified.

LV123-1401 This test may be performed within the scope of the agreed functional test.

LV123-1402 An appropriate test procedure, as well as the operating conditions, shall be specified by the supplier and agreed upon with the OEM.

10.6.2 Test: Service disconnect function (LV123-1416)

LV123-1417 Requirement: See Section "Service disconnect function"

LV123-1418 Test type: Product validation and 100% standard production testing

LV123-1419 Test method: Measurement

LV123-1420 **Product validation**

LV123-1421 Evidence of the functional capability of the service disconnect function shall be provided.

LV123-1422 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

LV123-1423 **100% standard production test**

LV123-1424 Evidence of the functional capability of the service disconnect function shall be provided.

LV123-1425 This test may be performed within the scope of the agreed functional test.

LV123-1426 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

10.6.3 Test: Pre-charge circuit (LV123-1427)

LV123-1428 Requirement: See Section "Pre-charging"

LV123-1429 Test type: Product validation and 100% standard production test

LV123-1430 Test method: Measurement

LV123-1431 **Product validation**

LV123-1432 The functional capability of the pre-charge circuit shall be verified.

LV123-1433 An appropriate test procedure, as well as the operating conditions, shall be specified by the supplier and agreed upon with the OEM.

LV123-1434 **100% standard production test**

LV123-1435 A test to verify the functional capability of the pre-charge circuit shall be performed.

LV123-1436 This test may be performed within the scope of the agreed functional test.

LV123-1437 An appropriate test procedure, as well as the operating conditions, shall be specified by the supplier and agreed upon with the OEM.

10.6.4 Test: Detection of open HV cables (LV123-1438)

LV123-1439 Requirement: See Section "Detection of open HV cables"

LV123-1440 Test type: Product validation and 100% standard production test

LV123-1441 Test method: Measurement, expert consultation

LV123-1442 **Product validation**

LV123-1443 The selected measure for the detection of open HV cables shall be verified by means of the following tests:

- The functional capability of the technical measure for the detection of open HV cables shall be verified by appropriate measurements.
- The organizational or procedural measures shall be documented and their suitability shall be verified in an expert consultation.

LV123-1444 An appropriate test procedure, as well as the operating conditions, shall be specified by the supplier and agreed upon with the OEM.

LV123-1445 **100% standard production test**

LV123-1446 If a technical measure for the detection of open HV cables is used, its functional capability shall be tested.

LV123-1447 This test may be performed within the scope of the agreed functional test.

LV123-1448 An appropriate test procedure, as well as the operating conditions, shall be specified by the supplier and agreed upon with the OEM.

10.6.5 Test: Additional requirements for HV battery (LV123-1449)

10.6.5.1 Test: Switching equipment HV battery (LV123-1456)

LV123-1450 Requirement: See Section "Switching equipment HV battery" in Section "Additional requirements for HV battery"

LV123-1451 Test type: Product validation and 100% standard production testing

LV123-1452 Test method: Measurement

LV123-1453 **Product validation**

LV123-1457 Individual evidence shall be provided for requirements in accordance with Section "Requirements for HV battery".

LV123-1458 For the individual evidence, unfavorable operating conditions for the function of the switching equipment, e.g. ambient conditions, operation of the HV battery under load before shut-off of the switching equipment, shall be selected.

LV123-1028 For the switching devices of the switching equipment, the switch-off behavior on the upper limit of the specified robustness range shall be verified with a device qualification procedure. Evidence shall be provided that no damage occurs to the switching devices that is outside their specification.

LV123-1030 For the HV battery, the following evidence shall be provided by means of measurements:

- The switching equipment shall not switch off when the maximum operating current has been reached during operation.
- During operation the load current of the HV battery shall rise. Current detection shall be active and the switching equipment shall switch off when the maximum operating current of the HV battery is exceeded in accordance with Figure "Overview of overcurrent protection tripping thresholds". Evidence of the compliance with the specified switch-off time after the specified current limit has been reached, shall be provided.

LV123-1460 An appropriate test procedure, as well as the operating conditions, shall be specified by the supplier and agreed upon with the OEM.

LV123-1461 **100% standard production test**

LV123-1462 A test to verify the functional capability of the switching equipment for all-pole switching on and switching off shall be performed.

LV123-1463 This test may be performed within the scope of the agreed functional test.

LV123-1464 To complete the functional tests before delivery of the battery, a measurement shall be carried out to verify that the HV contacts of all poles have been switched off.

LV123-1465 An appropriate test procedure, as well as the operating conditions, shall be specified by the supplier and agreed upon with the OEM.

10.6.5.2 Test: Overcurrent protection HV battery (LV123-1019)

LV123-1020 Note: Bibliographic references: ECE-R100, ISO 12405-1, ISO 12405-2, ISO/FDIS 12405-3: 2014-01, QC/T 743, SAE J2929, TRIAS 17(2)-R100

LV123-1021 Requirement: See Section "Overcurrent protection HV battery" in Section "Additional requirements for HV battery"

LV123-1022 Test type: Product validation and 100% standard production testing

LV123-1023 Test method: Expert test, if necessary measurement

LV123-1024 **Product validation**

LV123-1025 Evidence shall be provided that the switching device and the fuses are appropriate for interrupting the DC HV circuit in the event of overcurrents up to the magnitude of the short-circuit current of the energy storage. To provide this evidence, the complete permissible temperature range of the HV battery shall be taken into account.

LV123-1026 The supplier shall deliver to the OEM a declaration from a suitable testing laboratory that verifies the functional capability and the adequate dimensioning of the overcurrent protection device and of the switching equipment for overcurrent protection. The test used for verification shall be reported.

LV123-1027 The selection of appropriate and approved subcomponents or parts shall be verified within the scope of expert testing.

LV123-1029 For the fuse, evidence of the tripping behavior in the

- specified overcurrent range, and
- at the lower limit of the tripping range

shall be provided by means of a part qualification.

LV123-2042 Evidence shall be provided by means of a short-circuit test for the HV battery (short-circuit with overcurrent corresponding to the contactors' upper ampacity limit in accordance with Figure " Overview of overcurrent protection tripping thresholds") that no damage to the switching devices of the switching equipment occurs due to jamming of a contactor or conductive failure of a semiconductor switch after the short-circuit current has been switched off. Evidence of the compliance with the specified switch-off time after the occurrence of a short-circuit shall be provided.

LV123-2043 Evidence shall be provided by means of a short-circuit test for the HV battery with an external 5 mOhm short-circuit resistor that the short-circuit current is switched off by the overcurrent protection device of the HV battery, see also ISO 12405-3, ECE-R100. Evidence of the compliance with the specified switch-off time after the occurrence of a short-circuit shall be provided.

LV123-2219 For all short-circuit tests, an inspection of the surrounding area shall be done to verify that no mechanical or thermal damage occurs outside the HV battery and that the housing of the HV battery is not mechanically damaged.

LV123-1031 Unless otherwise specified, appropriate test methods shall be specified by the supplier and agreed upon with the OEM.

LV123-1032 **100% standard production test**

LV123-1033 Evidence of the functional capability of the overcurrent detection shall be provided.

LV123-1034 If the switching equipment is intended for overcurrent protection, evidence of the functional capability of the interruption of a short-circuit current shall be provided.

LV123-1035 The test shall be performed in such a way that pre-damage to the HV component is excluded. For this purpose, an external value can be specified for current detection, for example.

LV123-1036 These tests may be performed within the scope of the agreed functional test.

LV123-1037 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

10.6.6 Test: Additional requirements for DC/DC converter HV/LV (LV123-1466)

LV123-1467 Requirement: See Section "Additional requirements for DC/DC converter HV/LV"

LV123-1468 Test type: Product validation and 100% standard production test

LV123-1469 Test method: Measurement

LV123-1470 **Product validation**

LV123-1471 Functional capability shall be verified

- for the entire operating voltage range in accordance with Table "HV voltage ranges"
- under real operating conditions, including dynamic parameters in accordance with Table "Dynamic parameters", and
- under operational ambient conditions.

LV123-1472 The LV powernet and the remaining HV system shall be simulated with appropriate equivalent set-ups.

LV123-1473 Individual evidence shall be provided for the requirements in accordance with Section "Requirements for DC/DC converter HV/LV".

LV123-1474 An appropriate test procedure, as well as the operating conditions, shall be specified by the supplier and agreed upon with the OEM.

LV123-1475 **100% standard production test**

LV123-1477 Evidence of the functional capability for the detection of a missing electric connection between the DC/DC converter HV/LV and the negative pole of the LV powernet (battery) shall be provided if such a function is provided for.

LV123-1478 This test may be performed within the scope of the agreed functional test.

LV123-1479 An appropriate test procedure, as well as the operating conditions, shall be specified by the supplier and agreed upon with the OEM.

10.6.7 Test: Additional requirements for inverters (LV123-1480)

LV123-1481 Requirement: See Section "Additional requirements for inverters"

LV123-1482 Test type: Product validation and 100% standard production test

LV123-1483 Test method: Measurement

LV123-1484 **Product validation**

LV123-1485 Functional capability shall be verified

- for the entire operating voltage range in accordance with Table "HV voltage ranges"
- under real operating conditions, including dynamic parameters in accordance with Table "Dynamic parameters", and
- under operational ambient conditions.

LV123-1486 The rest of the HV system shall be simulated with appropriate equivalent setups.

LV123-1487 Individual evidence shall be provided for requirements in accordance with Section "Requirements for inverters".

LV123-1488 An appropriate test procedure, as well as the operating conditions, shall be specified by the supplier and agreed upon with the OEM.

LV123-1489 **100% standard production test**

LV123-1490 Functional capability in accordance with the additional requirements for inverters shall be verified.

LV123-1491 This test may be performed within the scope of the agreed functional test.

LV123-1492 An appropriate test procedure, as well as the operating conditions, shall be specified by the supplier and agreed upon with the OEM.

10.6.8 Test: Additional requirements for HV wiring harness (LV123-1493)

LV123-1494 Requirement: See Section "Additional requirements for HV wiring harness"

LV123-1495 Test type: Product validation

LV123-1496 Test method: Expert consultation, HV component inspection

LV123-1497 **Product validation**

LV123-1498 In an expert consultation, the supplier shall demonstrate the conformance to the corresponding specification of the design on the basis of the design documentation and the produced HV wiring harnesses.

LV123-1499 The selection of appropriate integral parts of the HV wiring harness shall be verified.

LV123-1500 An appropriate test procedure shall be specified by the supplier and agreed upon with the OEM.

10.7 Tests regarding additional requirements for connection to an external electric power supply (LV123-2044)

10.7.1 Test: Protective conductor current and touch current (LV123-2045)

LV123-2310 Note: Bibliographic references: IEC 60950-1, IEC 60990, IEC/FDIS 62638: 2013-03, ISO/DIS 17409 (2013-09), UL 2231

LV123-2046 Requirement: See Section "Protective conductor current and touch current"

LV123-2047 Test type: Product validation

LV123-2048 Test method: Measurement

LV123-2049 **Product validation**

LV123-2050 The test shall be performed for the on-board charger in the AC power supply circuit.

LV123-2051 The following requirements shall be fulfilled for all measurements:

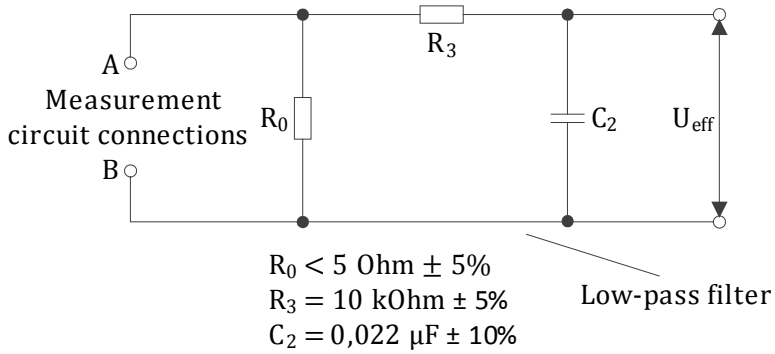
- The on-board charger shall be set up at an isolated location
- The on-board charger shall be connected to the external supply network
- The voltage of the external electric power supply shall be 110 % the highest nominal voltage specified.
- The on-board charger shall be operated at its highest rated power.

LV123-2220 If the test using the least favorable supply voltage is not possible, it is permitted to conduct the test at any voltage in the nominal voltage range and to calculate the results accordingly.

LV123-2221 **Protective conductor current**

LV123-2052 Weighted measurement of the protective conductor current shall be conducted with the network for the low-pass filter in accordance with Figure "Measurement network for protective conductor current".

LV123-2222



LV123-2223 Figure: Measurement network for protective conductor current

LV123-2224 For the measurement, a measurement setup based on Figure "Measurement setup for touch current" shall be used.

LV123-2225 If for the measurement of the protective conductor current a measuring shunt is used with resistance R_0 according to Figure "Measurement network for protective conductor current",
the following requirements shall be fulfilled:

- The protective conductor (PE) shall be interrupted
- Connections A and B of the measurement setup shall be connected with the contacts of the interrupted protective conductor
- The resistance R_0 shall be less than 5 Ohm, see also IEC/FDIS 62638 (2013-03).

LV123-2226 The rms value of voltage U shall be measured and converted to a current using the following formula:

$$I_{eff}\,(A) = \frac{U_{eff}\,(V)}{R_o\,(Ohm)}$$

LV123-2227 The protective conductor current determined during the test shall not exceed the value in accordance with Section "Protective conductor and touch current". If more than one on-board charger is used, the proportionate value of the protective conductor current limit shall not be exceeded.

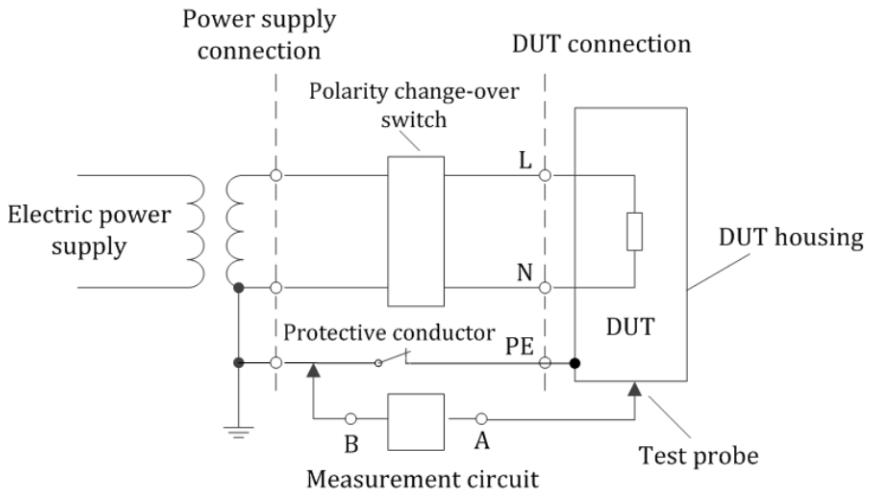
LV123-2228 **Touch current**

LV123-2229 For the measurement of the touch current, an appropriate measurement setup in accordance with Figure "Measurement setup for touch current" shall be used.

LV123-2230 The measurement setup shall be equipped with the following installations:

- Change-over switch for the polarity of the electric power supply
- Switch to interrupt the protective conductor (PE)
- Measurement circuit
- Test probe to connect the measurement circuit with the housing of the DUT.

LV123-2231



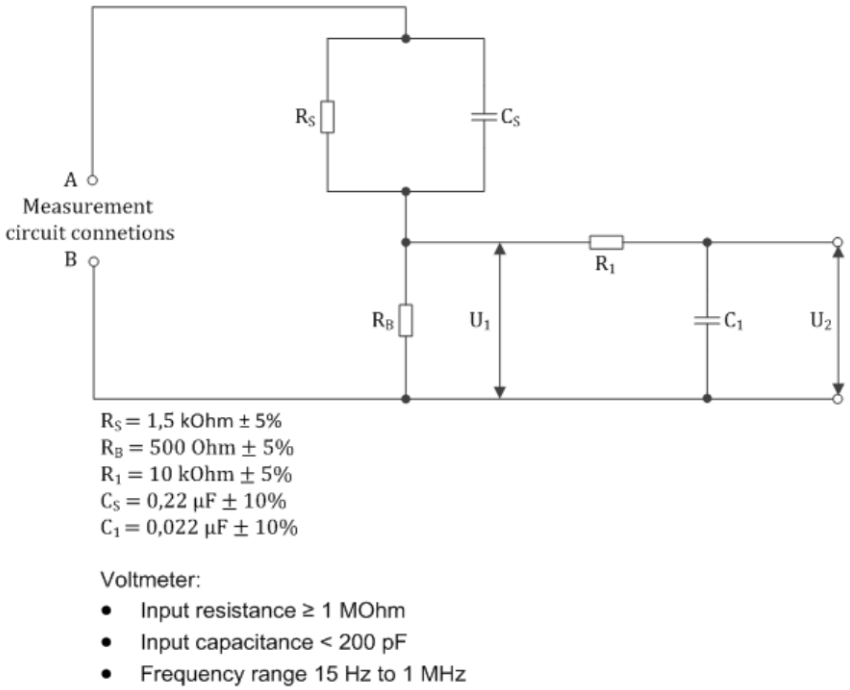
LV123-2232 Figure: Measurement setup for touch current

LV123-2233 Note: Figure "Measurement setup for touch current" shows an example of a measurement setup for single-phase equipment in a TN or TT system in star connection.

LV123-2234 For single-phase and multiphase on-board chargers operated at other external electric power supply systems, the measurement setup shall be adapted based on Figure "Measurement setup for touch current".

LV123-2053 The touch current shall be determined with the measurement network in accordance with Figure "Measurement circuit for touch current", see also IEC 60950-1, IEC 60990 or UL 2231-1.

LV123-2235



$R_S = 1{,}5$ kOhm ± 5%
$R_B = 500$ Ohm ± 5%
$R_1 = 10$ kOhm ± 5%
$C_S = 0{,}22$ µF ± 10%
$C_1 = 0{,}022$ µF ± 10%

Voltmeter:
- Input resistance ≥ 1 MOhm
- Input capacitance < 200 pF
- Frequency range 15 Hz to 1 MHz

LV123-2236 Figure: Measurement circuit for touch current

LV123-2237 Connection B of the measurement circuit shall be connected with the protective conductor of the measurement setup.

LV123-2238 Connection A of the measurement circuit shall be connected with a test probe.

LV123-2239 For the measurement, the protective conductor (PE) shall be interrupted (protective conductor switch opened).

LV123-2240 During the measurement, the measurement setup shall be connected via the test probe with the housing of the on-board charger, see Figure "Measurement setup for touch current".

LV123-2241 The measurement shall be carried out for the entire surface of the on-board charger housing.

LV123-2242 Non-conductive parts of the housing shall be covered with a metal foil for the measurement.

LV123-2243 The voltmeter used to measure voltage U_2 shall fulfill the following requirements:
- Input resistance ≥ 1 MOhm
- Input capacitance < 200 pF
- Frequency range 15 Hz to 1 MHz.

LV123-2244 The rms value of voltage U_2 shall be measured and converted to a current using the following formula:

$$I_{eff}\,(A) = \frac{U_{2eff}\,(V)}{500}$$

LV123-2054 The touch current I_{eff} determined during the test shall not exceed the value in accordance with Section "Protective conductor current and touch current". If more than one on-board charger is used, the proportionate value of the touch current limit shall not be exceeded.

LV123-2245 The measurement shall be repeated with the polarity of the supply voltage reversed provided this is applicable to the particular external electric power supply, see the polarity reversal switch in Figure "Measurement setup for touch current".

LV123-2246 Following each single test, the original operating status of the on-board charger shall be reestablished without any faults or consequential damage.

LV123-2247 **Couplings**

LV123-2055 The coupling capacitances between AC power supply circuit and DC HV circuit in the on-board charger shall be determined by measurement according to the following requirements:

- In addition to the connection to the external electric power supply, an AC test voltage shall be coupled at the connection of the DC HV circuit.
- The AC test voltage shall be coupled in sequence between PE and the DC potentials.
- The peak value of the AC test voltage shall be 0,5 x (50 %) the maximum operating voltage in accordance with Table "HV voltage ranges".
- The frequency of the AC test voltage shall be varied between 40 Hz and 20 kHz.

LV123-2056 The determined couplings shall be measured explicitly for the frequencies of 50 Hz and 60 Hz.

LV123-2057 The determined couplings shall be documented and reported by the supplier to the OEM.

End of main document
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11 Annex A (informative) Bibliographic references (LV123-1511)

LV123-1512 Bibliographic references to standards, regulations or legal regulations are listed below. Some references to standards that are not used in the text of this document have been included for informational purposes.

LV123-2387 The listing of legal regulations or similar regulations does not claim to be complete or fully up to date and serves only to provide supplementary information.

LV123-27 Note: The standards for the external electric power supply connection on the vehicle side are listed in a separate sub-section.

11.1 International references (LV123-28)

LV123-2248 ECE-R12
Regulation No. 12
Uniform Provisions Concerning the Approval of Vehicles with regard to the Protection of the Driver against the Steering Mechanism in the Event of Impact

LV123-2311 Note: German edition:
ECE-R12
Regelung Nr. 12
Einheitliche Bedingungen für die Genehmigung der Kraftfahrzeuge hinsichtlich des Schutzes des Fahrzeugführers vor der Lenkanlage bei einem Aufprall

LV123-2058 ECE-R94
Regulation No. 94
Uniform Provisions Concerning the Approval of Vehicles with regard to the Protection of the Occupants in the Event of a Frontal Crash

LV123-2312 Note: German edition:
ECE-R94
Regelung Nr. 94
Einheitliche Bedingungen für die Genehmigung der Kraftfahrzeuge hinsichtlich des Schutzes der Insassen bei einem Frontalaufprall

LV123-2059 ECE-R95
Regulation No. 95
Uniform Provisions Concerning the Approval of Vehicles with regard to the Protection of the Occupants in the Event of a Lateral Collision

LV123-2313 Note: German edition:
ECE-R95
Regelung Nr. R95
Einheitliche Bedingungen für die Genehmigung der Kraftfahrzeuge hinsichtlich des Schutzes der Insassen bei einem Seitenaufprall

LV123-29 ECE-R100
Regulation No. 100
Uniform Provisions Concerning the Approval of Vehicles with Regard to Specific Requirements for the Electric Powertrain

LV123-2314 Note: German edition:
ECE-R100
Regelung Nr. 100
Einheitliche Bedingungen für die Genehmigung der Fahrzeuge hinsichtlich der besonderen Anforderungen an den Elektroantrieb

LV123-2062
IEC 60445
Basic and safety principles for man-machine interface, marking and identification - Identification of equipment terminals, conductor terminations and conductors

LV123-2315
Note: German edition:
DIN EN 60445
Grund- und Sicherheitsregeln für die Mensch-Maschine-Schnittstelle Kennzeichnung von Anschlüssen elektrischer Betriebsmittel, angeschlossenen Leiterenden und Leitern

LV123-2316
IEC 60747 (all parts)
Discrete semiconductor devices and integrated circuits

LV123-2317
Note: German edition:
DIN EN 60747 (alle Teile)
Einzel-Halbleiterbauelemente und integrierte Schaltungen

LV123-1533
IEC 60950-1
Information technology equipment - Safety - Part 1: General requirements

LV123-2318
Note: German edition:
DIN EN 60950-1
Einrichtungen der Informationstechnik - Sicherheit - Teil 1: Allgemeine Anforderungen

LV123-2319
IEC 60990
Methods of measurement of touch current and protective conductor current

LV123-2320
Note: German edition:
DIN EN 60990
Verfahren zur Messung von Berührstrom und Schutzleiterstrom

LV123-2322
IEC/FDIS 62638: 2013-03
Recurrent test and test after repair of electrical equipment

LV123-2323
IEC 61558 (all parts)
Safety of power transformers, power supplies, reactors and similar products

LV123-2324
Note: German edition:
DIN EN 61558 (alle Teile)
Sicherheit von Transformatoren, Netzgeräten, Drosseln und dergleichen

LV123-2325
IECQ
IEC quality assessment system for electronic components (IECQ system)

LV123-2063
ISO 2575
Road vehicles - Symbols for controls, indicators and tell-tales

LV123-33
ISO 3864-1
Graphical Symbols - Safety Colors and Safety Signs - Part 1: Design Principles for Safety Signs in Workplaces and Public Areas

LV123-34
ISO 3864-2
Graphical Symbols - Safety Colors and Safety Signs - Part 2: Design Principles for Product Safety Labels

LV123-2326
Note: German edition:
DIN ISO 3864-2
Graphische Symbole - Sicherheitsfarben und Sicherheitszeichen - Teil 2: Gestaltungsgrundlagen für Sicherheitsschilder zur Anwendung auf Produkten

LV123-35
ISO 6469-1
Electrically propelled road vehicles - Safety specifications
Part 1: On-board rechargeable energy storage system (RESS)

LV123-36
ISO 6469-2
Electrically propelled road vehicles - Safety specifications
Part 2: Vehicle operational safety means and protection against failures

LV123-37
ISO 6469-3
Electrically propelled road vehicles - Safety specifications
Part 3: Protection of persons against electric shock

LV123-2064
ISO/DIS 6469-4: 2013-02
Electrically propelled road vehicles - Safety specifications -
Part 4: Post crash electrical safety requirements

LV123-38
ISO 6722 (all parts)
Road vehicles - 60 V and 600 V single-core cables

LV123-39
ISO 7000
Graphical symbols for use on equipment - Index and synopsis

LV123-2327
Note: German edition:
DIN ISO 7000
Graphische Symbole auf Einrichtungen - Index und Übersicht

LV123-40
ISO 8713
Electrically propelled road vehicles - Vocabulary

LV123-2249
ISO 8820 (all parts)
Road vehicles - Fuse-links

LV123-2328
Note: German edition:
DIN ISO 8820 (alle Teile)
Straßenfahrzeuge - Sicherungseinsätze

LV123-2065
ISO 12405-1
Electrically propelled road vehicles - Test specification for lithium-ion traction battery packs and systems - Part 1: High-power applications

LV123-2066
ISO 12405-2
Electrically propelled road vehicles - Test specification for lithium-ion traction battery packs and systems - Part 1: High-energy applications

LV123-2067
ISO/FDIS 12405-3: 2014-01
Electrically propelled road vehicles - Test specification for lithium-ion traction battery packs and systems - Part 3: Safety performance requirements

LV123-41
ISO 14572
Road vehicles - Round, sheathed, 60 V and 600 V screened and unscreened single- or multi-core sheathed cables - Test methods and requirements for basic and high performance cables

LV123-42
ISO 16750 (all parts)
Road vehicles - Environmental conditions and testing for electrical and electronic equipment

LV123-46
Standards for the external electric power supply connection on the vehicle side

LV123-47
IEC 61851-1
Electric vehicle conductive charging system -
Part 1: General requirements

LV123-2329
Note: German edition:
DIN EN 61851-1
Elektrische Ausrüstung von Elektro-Straßenfahrzeugen - Konduktive Ladesysteme für Elektrofahrzeuge - Teil 1: Allgemeine Anforderungen

LV123-48
IEC 61851-21
Electric vehicle conductive charging system - Part 2-1: Electric vehicle requirements for conductive connection to an A.C./D.C. supply

LV123-2330
Note: German edition:
DIN EN 61851-21
Elektrische Ausrüstung von Elektro-Straßenfahrzeugen - Konduktive Ladesysteme für Elektrofahrzeuge - Teil 2-1: Anforderung eines Elektrofahrzeugs für konduktive Verbindung an AC/DC-Versorgung

LV123-49
IEC 61851-22
Electric vehicle conductive charging system - Part 2-2: AC electric vehicle charging station

LV123-2331
Note: German edition:
DIN EN 61851-22
Elektrische Ausrüstung von Elektro-Straßenfahrzeugen - Konduktive Ladesysteme für Elektrofahrzeuge - Teil 2-2: Wechselstrom-Ladestation für Elektrofahrzeuge

LV123-2068
IEC/FDIS 61851-23: 2013-11
Electric vehicle conductive charging system - Part 2-3: D.C. electric vehicle charging station

LV123-50
IEC 62196-1
Plugs, socket-outlets, vehicle couplers and vehicle inlets - Conductive charging of electric vehicles - Part 1: General requirements

LV123-2332
Note: German edition:
DIN EN 62196-1
Stecker, Steckdosen, Fahrzeugkupplungen und Fahrzeugstecker - Konduktives Laden von Elektrofahrzeugen - Teil 1: Allgemeine Anforderungen

LV123-2069
IEC 62196-2
Plugs, socket-outlets, vehicle couplers and vehicle inlets - Conductive charging of electric vehicles - Part 2: Dimensional compatibility and interchangeability requirements for a.c. pin and contact-tube accessories

LV123-2333
Note: German edition:
DIN EN 62196-2
Stecker, Steckdosen, Fahrzeugkupplungen und Fahrzeugstecker - Konduktives Laden von Elektrofahrzeugen - Teil 2: Anforderungen und Hauptmaße für die Kompatibilität und Austauschbarkeit von Stift- und Buchsensteckvorrichtungen für Wechselstrom

LV123-2070
IEC/CDV 62196-3: 2013-01
Plugs, socket-outlets, vehicle couplers and vehicle inlets - Conductive charging of electric vehicles - Part 3: Dimensional compatibility and interchangeability requirements for dedicated d.c. and combined a.c./d.c. pin and contact tube vehicle couplers

LV123-2250
IEC/TS 62763
Pilot function through a control pilot circuit using PWM modulation and a control pilot wire

LV123-2334
ISO 15118-1
Road vehicles - Vehicle to grid communication interface - Part 1: General information and use-case definition

LV123-2071
ISO/DIS 17409: 2013-09
Electrically propelled road vehicles - Connection to an external electric power supply - Safety requirements

11.2 References USA, Canada (LV123-52)

LV123-53
ANSI Z535.3
American National Standards Institute. Criteria for safety symbols

LV123-2335
CMVSS 305
Transport Canada, Motor Vehicle Safety Standard No. 305
Electrolyte Spillage and Electrical Shock Protection

LV123-54
FMVSS 305
U.S. Federal Motor Vehicle Safety Standard No. 305
Electric-Powered Vehicles: Electrolyte Spillage and Electrical Shock Protection

LV123-55
SAE J1654
Unshielded High Voltage Primary Cable

LV123-56
SAE J1673
High Voltage Automotive Wiring Assembly Design

LV123-57
SAE J1715
Hybrid Electric Vehicle (HEV) & Electric Vehicle (EV) Terminology

LV123-58
SAE J1742
Connections for High Voltage On-Board Vehicle Electrical Wiring Harnesses - Test Methods and General Performance Requirements

LV123-59
SAE J1766
Recommended Practice for Electric and Hybrid Electric Vehicle Battery Systems Crash Integrity Testing

LV123-60
SAE J2344
Guidelines for Electric Vehicle Safety

LV123-2336
SAE J2501
Round, Screened and Unscreened, 60 V and 600 V Multi-Core Sheathed Cables

LV123-61
SAE J2464
Electric and Hybrid Electric Vehicle Rechargeable Energy Storage System (RESS) Safety and Abuse Testing

LV123-62
SAE J2578
Recommended Practice for General Fuel Cell Vehicle Safety

LV123-2337
SAE J2929
Safety Standard for Electric and Hybrid Vehicle Propulsion Battery Systems Utilizing Lithium-based Rechargeable Cells

LV123-63
TP-305-01
U.S. Department of Transportation, National Highway Traffic Safety Administration, Laboratory Test Procedure for FMVSS 305, Electric Powered Vehicles: Electrolyte Spillage and Electrical Shock Protection

LV123-64
Standards for the external electric power supply connection on the vehicle side

LV123-65
SAE J1772
SAE Electric Vehicle and Plug in Hybrid Electric Vehicle Conductive Charge Coupler

LV123-2338
UL 2202
Electric vehicle (EV) charging system equipment

LV123-2072
UL 2231 (all parts)
Personnel protection systems for electric vehicle (EV) supply circuits

LV123-2385
UL 2251
Plugs, receptacles, and couplers for electric vehicles

LV123-2386 UL 2594
Electric vehicle (EV) supply equipment

11.3 References Japan (LV123-66)

LV123-2366 Agreement Regulation No. 100
see ECE-R100

LV123-69 Attachment 111
Technical Standard for Protection of Occupants against High Voltage after Collision in Electric Vehicles, Hybrid Electric Vehicles and Fuel Cell Vehicles

LV123-2339 TRIAS 17(2) J111(2)
Test for Protection of Occupants against High Voltage in Electric Vehicles, Hybrid Electric Vehicles and Fuel Cell Vehicles after Collision

LV123-2340 TRIAS 17(2)-R012
Test for Protection of Occupants against High Voltage after Frontal Collision (Agreement Regulation No. 12)

LV123-2341 TRIAS 17(2)-R094
Test for Protection of Occupants against High Voltage after Offset Frontal Collision (Agreement Regulation No. 94)

LV123-2342 TRIAS 17(2)-R095
Test for Protection of Occupants against High Voltage after Lateral Collision (Agreement Regulation No. 95)

LV123-2343 TRIAS 17(2)-R100
Test for Protection of Occupants against High Voltage (Agreement Regulation No. 100)

11.4 References China (LV123-2073)

LV123-2344 CNCA-02C-023
Rules for the Implementation of Compulsory Certification of Motor Vehicles

LV123-2345 GB/T 4094.2
Motor vehicles - Symbols for controls, indicators and tell-tales

LV123-2346 GB/T 18384.1
Electric Vehicles - Safety Specifications
Part 1: On-board Energy Storage

LV123-2347 GB/T 18384.2
Electric Vehicles - Safety Specifications
Part 2: Functional Safety Means and Protection against Failures

LV123-2348 GB/T 18384.3
Electric Vehicles - Safety Specifications
Part 3: Protection of Persons against Electric Hazards

LV123-2349 GB/T 18488.1
The electrical machines and controllers for electric vehicles - Part 1: General specification

LV123-2350 GB/T 18488.2
The electrical machines and controllers for electric vehicles - Part 2: Test methods

LV123-2351 GB/T 19596
Terminology of Electric Vehicles

LV123-2352 GB/T 19751
Hybrid Electric Vehicles - Safety Specifications

LV123-2353 GB/T 24347
The DC/DC Converter for Electric Vehicles

LV123-2354 GB/T 24548
Fuel cell electric vehicles - Terminology

LV123-2355 GB/T 24549
Fuel cell electric vehicles - Safety requirements

LV123-2356 GB/T 25087
Road vehicles - Round, screened and unscreened 60 V and 600 V multi-core sheathed cables

LV123-2357 QC/T 743
Lithium-ion Batteries for Electric Vehicles

LV123-2075 **Standards for the external electric power supply connection on the vehicle side**

LV123-2358 GB/T 18487.1
Electric vehicle conductive charging system
Part 1: General requirements

LV123-2076 GB/T 18487.2
Electric vehicle conductive charging system - Electric vehicles requirements for conductive connection to an A.C./D.C. supply

LV123-2359 GB/T 18487.3
Electric vehicle conductive charging system
A.C. /D.C. Electric vehicle charging station

LV123-2360 GB/T 20234.1
Connection set of conductive charging for electric vehicles - Part 1: General requirements

LV123-2361 GB/T 20234.2
Connection set for conductive charging of electric vehicles - Part 2: AC Charging coupler

LV123-2362 GB/T 20234.3
Connection set of conductive charging for electric vehicles - Part 3: DC Charging coupler

LV123-2363 QC/T 895
On-board Conductive Charger for Electric Vehicles

11.5 References Korea (LV123-2364)

LV123-2365 KMVSS Art. 18-2, 18-3, 91
Regulations for Motor Vehicle Safety Standards - Electric vehicles

11.6 References Germany (LV123-70)

LV123-2077 DIN VDE 0100-722
Low voltage electrical installations -
Part 7-722: Requirements for special installations or locations - Supply of electric vehicles

LV123-2078 DIN 72551-7
Road vehicles - Low-voltage cables
Part 7: Colours and colour marking of low-voltage cables

End of Annex A
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