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Electrically propelled road vehicles — Specification of voltage sub-classes for voltage class B

Véhicules routiers à propulsion électrique — Spécification de sous-classes de tension pour les tensions de classe B

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Foreword

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The committee responsible for this document is ISO/TC 22, *Road vehicles*, Subcommittee SC 37, *Electrically propelled vehicles*.

Introduction

Electric systems operating at voltage class B are efficient systems for electrically propelled road vehicles. The requirements for voltage class B electric circuits that are used for electric power transfer for the propulsion of electric road vehicles are significantly different to those of voltage class A electric circuits used for powernets at, for example, 12 V d.c. or 24 V d.c.

This PAS provides definition of voltage sub-classes for rechargeable energy storage system (RESS) and electric propulsion system and lists up specified values based on maximum working voltage. Voltage sub-classes listed in this PAS are used for voltage class B systems of all kinds of current or future electrically propelled road vehicles. It enables vehicles manufacturers and automotive supply industry to evaluate the characteristics of a component according to the specified sub-class.

The voltage sub-class itself and the component characteristics have large cost impact on the component design and the overall design of the electric system. A high variety of different voltage sub-class and operating conditions hinders the use of an existing component in different vehicle models.

Today, a huge variety of different RESS and electric propulsion system maximum working voltages are used for electrically propelled road vehicles on the market. Because some systems use voltage boost converters, maximum working voltage of electric propulsion system can be different from that of RESS. This variety of maximum working voltages often results from different numbers of cells in the design of the electrical energy source, e.g. battery stack or variety of power requirement by each vehicle. As a consequence, many system or component designs of a voltage class B electric circuit are currently related to one specific working voltage. When a maximum working voltage is selected for the design, often only one supplier for a component is available. Hence, a change to another component supplier or a change of the dedicated maximum working voltage is not possible, when the system design is finished. It is necessary to reduce the variety of maximum working voltages in order to

— lower the component and system costs by limiting the variety of maximum working voltages,

— decouple the system or component designs of a voltage class B electric circuit from the design of the electric energy source,

— enable an exchange of components from different suppliers during and after the system development and to enable competition and access to the worldwide market for component suppliers, and

— support the system design by specifying basic voltage sub-classes for automotive propulsion systems within voltage class B.

This PAS lists only those RESS and electric propulsion system voltage sub-classes which are used or will be used in current or planned vehicle models and for which electronic parts, e.g. semiconductor switches, are currently available without any restrictions on the market.

The range of voltage class B is too wide to be used for a component design referring to voltage. Therefore, this PAS divides voltage class B in a set of voltages sub-classes, which enable a component design referring to voltage for each voltage sub-class.

This specification is not intended to restrict the development of component performance or technology. It does not exclude the use of other maximum operating voltages for an individual system design.

Electrically propelled road vehicles — Specification of voltage sub-classes for voltage class B

1 Scope

This PAS provides specification of voltage sub-classes for electric propulsion systems and conductively connected auxiliary electric systems of electrically propelled road vehicles.

The voltage sub-classes are related to d.c. electric circuits.

It applies only to electric circuits and components with maximum working voltages according to voltage class B.

This PAS provides specifications of characteristics which are relevant for design and operation of components and systems for the standardized voltage sub-classes.

It enables vehicle manufacturers and supply industry to evaluate the characteristics of components or systems for their specific vehicle applications.

2 Terms and definitions

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

2.1
component operating status
describes the general functional behaviour of components which depend directly on the voltage in voltage class B electric circuits

2.2
customer
party that is interested in using voltage class B component or system

2.3
DUT
device under test

2.4
electric circuit
entire set of interconnected live parts through which electrical current is designed to flow under normal operating conditions

2.5
electric propulsion system maximum working voltage
highest value of d.c. voltage that can occur in an electric propulsion system under any normal operating conditions according to the customer's specifications, disregarding transients

2.6
maximum working voltage
highest value of a.c. voltage (rms) or of d.c. voltage that can occur in an electric system under any normal operating condition according to the customer's specifications, disregarding transients

Note 1 to entry: In this definition taken from ISO 6469-3, transients include ripple.

2.7
rechargeable energy storage system
RESS
system that stores energy for delivery of electric power and which is rechargeable

EXAMPLE Batteries, capacitors, etc.

2.8
ripple
set of unwanted periodic deviations with respect to the average value of the measured or supplied quantity, occurring at frequencies which can be related to that of components within a system

2.9
supplier
party that provides voltage class B component or system

2.10
transient
pertaining to or designating a phenomenon or a quantity which varies between two consecutive steady states during a time interval short compared with the time-scale of interest

2.11
voltage class B
classification of an electric component or circuit with a maximum working voltage between 30 V a.c. (rms) and 1 000 V a.c. (rms) or between 60 V d.c. and 1 500 V d.c

Note 1 to entry: Values for voltage class B are taken from ISO 6469-3.

2.12
upper voltage limit
maximum voltage of a voltage class B sub-class

Note 1 to entry: Maximum working voltages within a voltage sub-class are less than or equal to the voltage limit.

2.13
voltage range
general term covering voltage sub-class, working voltages and deviations from working voltages

2.14
voltage sub-class
classification of an electric component or circuit with a d.c. voltage within the voltage class B

2.15
working voltage
a.c. voltage (rms) or d.c. voltage that can occur in an electric system under normal operating conditions according to the customer's specifications, disregarding transients

3 Voltage sub-classes

The specifications and requirements on voltage sub-classes shall apply to electric circuits, systems and components at voltage class B.

The specifications and descriptions of voltages for a component shall apply to the voltage at its terminals to the voltage class B electric circuit, if not otherwise stated in this International Standard.

The voltage sub-classes shown in Table 1 are based on the specification of an upper voltage limit for each voltage sub-class.

Table 1 — Voltage sub-classes

Voltage sub-class	Upper voltage limit V d.c.
B_220	U ≤ 220
B_420	U ≤ 420
B_470	U ≤ 470[a]
B_750	U ≤ 750[b]
B_850	U ≤ 850
B_1250	U ≤ 1 250[c]

[a] B_470 is considering 700 V breakdown voltage for IGBT and dedicated module technology (Table A.2).

[b] B_750 is related to a voltage classification of 750 V d.c. given by regulation in Japan.

[c] B_1250 is considering the limit of 1 000 V a.c. for voltage class B.

4 Characteristics of voltage sub-classes

4.1 General

The specifications and characteristics for voltage sub-classes include the following subjects:

— component operating status;

— voltage operating ranges;

— under- and overvoltages;

— voltage transients and ripple for components.

The voltage ranges and operating status shall apply to all components for the selected voltage sub-class. The voltage sub-class depends on a vehicle project and shall be selected by an agreement between customer and supplier.

The requirements in accordance with Table 1 shall apply to a RESS when it is disconnected from the voltage class B electric circuit.

Different requirements may be specified by the customer for a RESS when it is connected to the voltage class B electric circuit because the voltage of RESS is limited to the maximum working voltage of the vehicle project and given by the number of battery cells.

For each voltage sub-class, the corresponding working voltages, component operating status, overvoltage and under-voltage are described as follows.

4.2 Component operating status

The operating status is introduced to describe the general operating behaviour of components that depends directly on the voltage at the terminals of a component of the voltage class B electric circuit and is mainly focused on performance and electrical power.

In every operating status, the components shall fulfil the following requirements:

— it shall be ready to operate;

— it shall not enter any undefined states;

— it shall not cause any failure in other components.

The different operating statuses are described in Table 2.

Table 2 — Component operating status

Operating status	Operating status description
OS1	The component shall provide the specified full performance (reduction of performance not allowed). The component shall automatically change its operating status depending on the voltage relevant for the operating status.
OS2	The component shall provide the specified reduced performance within its permissible deviations (reduction of performance allowed). The component shall automatically change its operating status depending on the voltage relevant for the operating status.
OS3	The component may derate or cut-off its performance for self-protection purpose. The component shall automatically change its operating status depending on the voltage relevant for the operating status.
OS4	The component may cut-off its performance. Triggered by a reset or an external event (e.g. change of ignition status, restart vehicle), the component shall change its operating status depending on the voltage relevant for the operating status.

The specified operating statuses in Table 2 are valid exclusively for functions that depend directly on the voltage in voltage class B electric circuits.

Detailed requirements for an operating status for individual voltage class B components shall be based on an agreement between customer and supplier.

4.3 Voltage operating ranges

For further description of characteristics of a voltage sub-class, different voltage operating ranges are introduced as follows:

— upper limited operating capability;

— unlimited operating capability;

— lower limited operating capability.

Figure 1 shows an overview on the voltage operating ranges of a voltage sub-class.

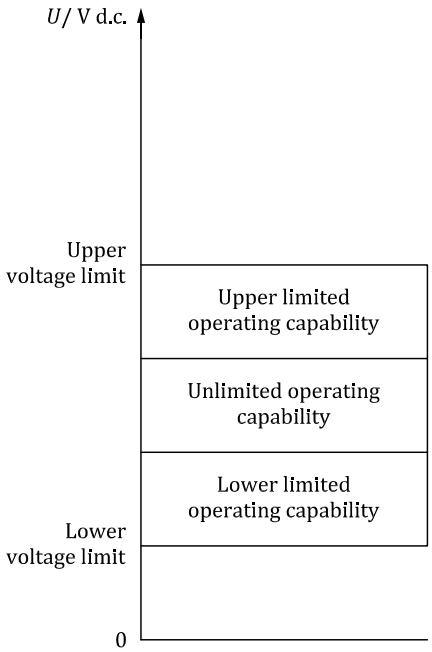


Figure 1 — Overview on voltage operating ranges at a voltage sub-class

The specific values for voltage operating ranges (upper limited, unlimited and lower limited operating capability) are specified by the customer for a vehicle project.

The characteristics of a component in the different voltage operating ranges are specified by the allocation of operating statuses to the voltage operating ranges as described in 4.5.

4.4 Under- and overvoltage

4.4.1 General

Voltage deviations are deviations from normal system operation. These deviations can occur intentionally (e.g. as a consequence of a system or component reaction) or may be caused by a fault.

Voltage deviations as follows are considered:

— overvoltage;

— undervoltage.

4.4.2 Overvoltage

The overvoltage range is the range between

— upper voltage limit, and

— overvoltage limit (see Figure 2).

The overvoltage limit is the maximum voltage that can occur under abnormal operating conditions. The overvoltage limit is the maximum voltage a component shall withstand without impact on its specified service life. Within the overvoltage range, the operating status OS3 or OS4 according to Table 2 shall be fulfilled.

When the voltage exceeds the overvoltage limit temporarily or continuously, a severe fault, e.g. breakdown of a component, may occur.

4.4.3 Undervoltage

The undervoltage range is the range between

— 0 V d.c., and

— the lower voltage limit (see Figure 2).

The lower voltage limit is the lowest voltage for which a component shall fulfil OS2 or OS1.

Within the undervoltage range, the operating status OS3 or OS4 according to Table 2 shall be fulfilled.

4.5 Allocation of voltage ranges and operation status — Overview

Figure 2 shows the allocation of a component operating status to the voltage operating ranges of a voltage sub-class.

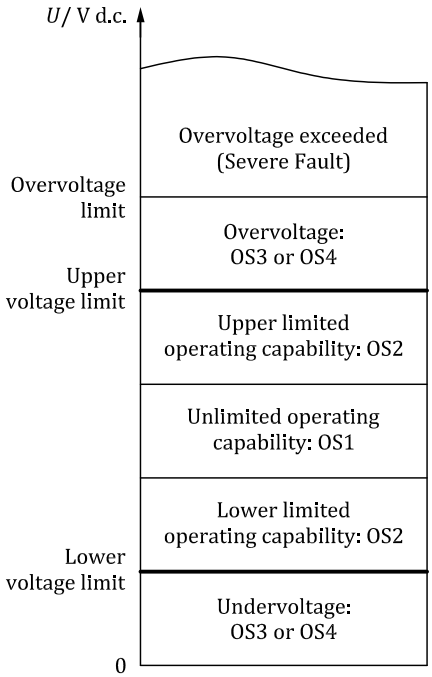


Figure 2 — Component operating status at a voltage sub-class

NOTE An example for voltage operating ranges of voltage sub-class B_220 is given in Table A1.

A dedicated voltage sub-class can be used for different vehicle projects. Within this sub-class, different values for operating ranges and minimum and maximum working voltages can be used.

The maximum working voltage for the vehicle project shall be less or equal than the upper voltage limit of this voltage sub-class.

The minimum working voltage is the lowest voltage that can occur under normal operating conditions for a vehicle project. The minimum working voltage for a project shall be higher than or equal to the lower voltage limit of the components.

A component developed for a dedicated voltage sub-class can be used for different vehicle projects which are using different voltage ranges within this voltage sub-class.

Figure 3 shows how a sub-class B_x component can be used for different vehicle projects with different working voltages.

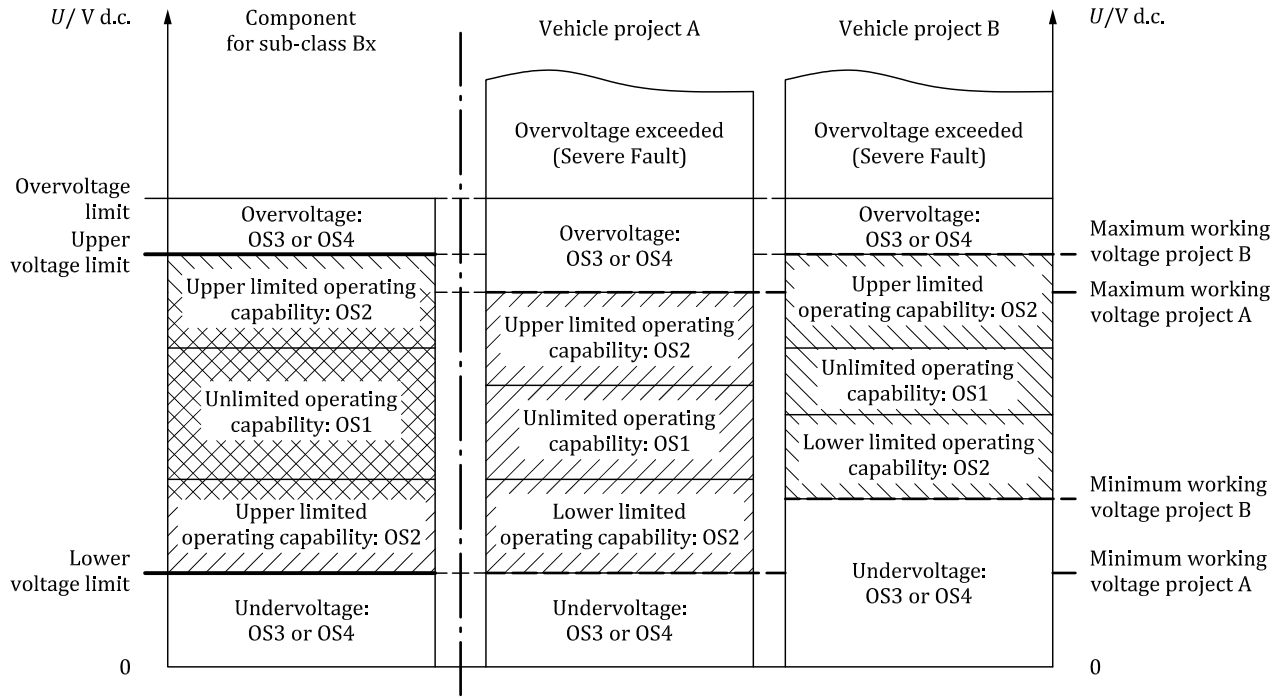


Figure 3 — Use of a component for sub class B_x for different vehicle projects — Example

4.6 Voltage transients and ripple

4.6.1 General

Voltage transients can occur due to switching on or off of electrical loads, rapid load changes and electric load unbalance. Ripple is caused by switching of semiconductors. For this International Standard, only those transients are considered, which have an effect on the voltage at the terminals of a component to the voltage class B electric circuit. In Table 3, an overview is given on characteristics for transients and ripple, which are considered in this International Standard.

Table 3 — Overview on voltage transients and ripple

Parameter	Unit
Generated voltage transient (slope, ΔV)	V/ms; V
Present voltage transient (slope, ΔV)	V/ms; V
Generated voltage ripple (V pp)	V
Present voltage ripple (V pp)	V
Load dump transient (slope, V peak)	V/ms; V

In the following, it is assumed that the system is operated with an RESS (RESS switched on). If it is intended to run a component in a system without RESS (RESS switched off), different values for requirements on voltage dynamics need to be considered.

4.6.2 Voltage slope

A voltage slope is a singular dynamic change of the working voltage expressed in voltage difference over time. It does not occur periodically or continuously. It is typically due to a change of power demand or caused by the unbalance between input and output power and is mostly associated to a component action (e.g. control loop regulation by software).

Generated voltage transient (slope)

Every component that is controlled by power electronics shall limit the change of the d.c. circuit voltage across time according to the specified maximum generated voltage transient (slope).

Maximum value for generated voltage transient shall be agreed between customer and supplier.

Present voltage transient (slope)

In the event of a change over time of the d.c. circuit voltage according to the specified maximum present voltage transient (slope), the component shall fulfil the conditions according to the corresponding operating status.

Maximum value for present voltage transient shall be agreed between customer and supplier.

4.6.3 Voltage ripple

Voltage ripple is an overlay of an a.c. voltage on the d.c. voltage. This overlay is caused by switching of semiconductor switches inside components. The ripple is specified by its peak to peak voltage and a frequency range. It occurs quasi-periodically or continuously.

A component shall not change its operating status due to the specified voltage ripple.

An example for a voltage ripple is given in Figure 4.

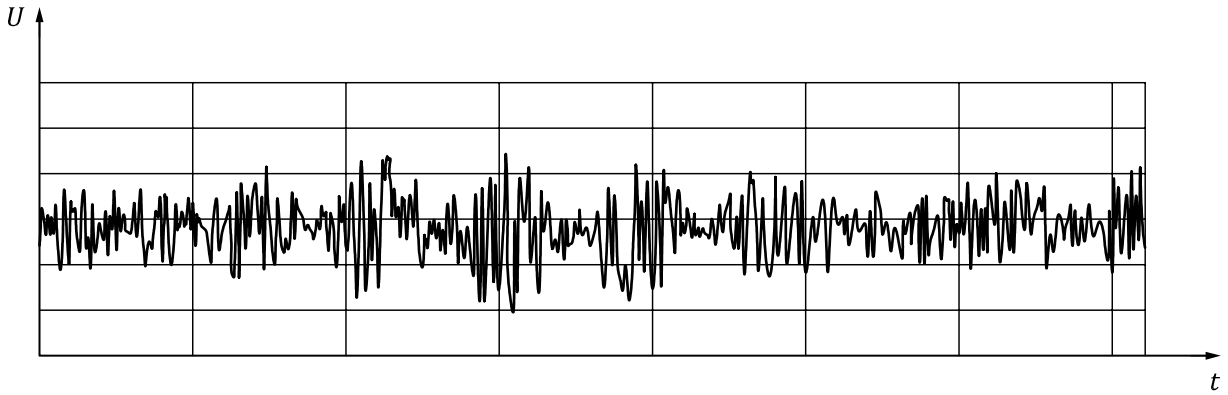


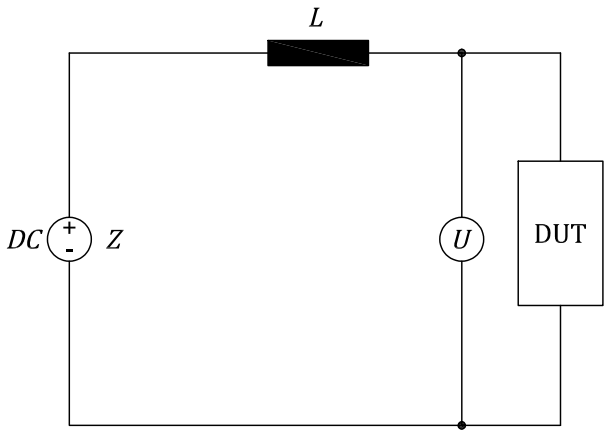
Figure 4 — Example for voltage ripple

Generated voltage ripple

In general, the generated voltage ripple in the d.c. circuit should be optimized.

Every component controlled by power electronics shall limit its generated voltage ripple (amplitude and frequency range) to the values agreed between customer and supplier.

An example for a test setup for measuring a generated voltage ripple is given in Figure 5.



Key

Z impedance of DC power supply

L inductance of wiring

Figure 5 — Example for test setup for measurement of generated voltage ripple

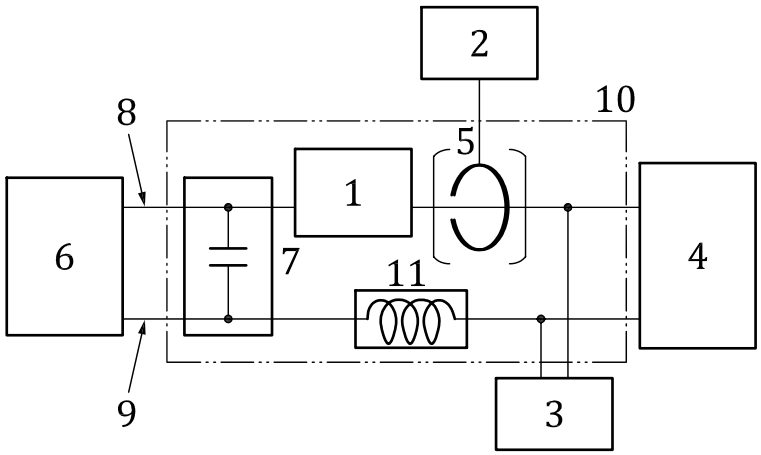
The test setup shall be agreed between customer and supplier.

Present voltage ripple

For every component, robustness and stable operation shall be fulfilled when there is a voltage ripple present during the operation of the system.

The present voltage ripple (amplitude and frequency range) at the terminals of the DUT shall be as agreed between customer and supplier.

An example for a test setup to apply a present voltage ripple is given in Figure 6.



Key

1 ripple supply instrument
2 current measuring instrument
3 voltage measuring instrument
4 DUT
5 current probe
6 DC power supply
7 capacitor
8 DC- line
9 DC+ line
10 shielded box
11 series inductance

Figure 6 — Example for test setup to apply a present voltage ripple

The test setup shall be agreed between customer and supplier.

4.6.4 Load dump

Load dump is a sudden increase of the voltage caused by a failure. The voltage might exceed the overvoltage limit if no means for protection of the component are provided.

A load dump can occur when a component feeds electrical energy into the voltage class B electric circuit and high load is disconnected abruptly.

Every component which is able to feed electrical energy into the voltage class B electric circuit shall limit the slope and the peak value of the voltage according to the specifications agreed between customer and supplier.

Figure 7 shows an example of a load dump without suppression.

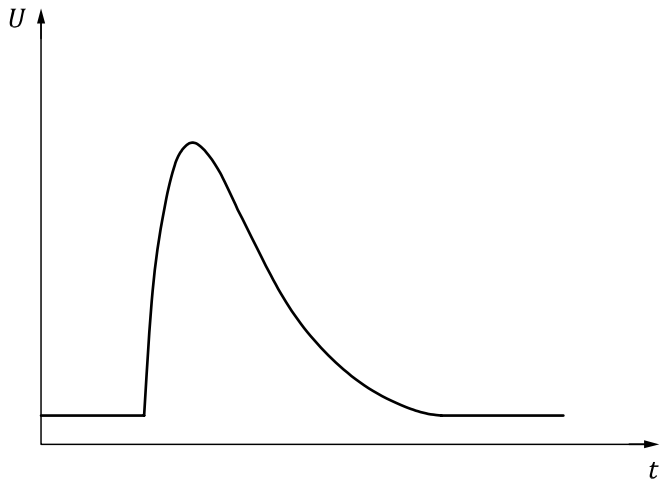


Figure 7 — Example for load dump without suppression

Annex A
(informative)

Example for voltage ranges per voltage sub-class

A.1 General

Table A.1 — Example of voltage operating ranges per voltage sub-class

Voltage ranges	Operating status	Unit	B_220 example only
Overvoltage in the event of load dump[b]	OS3/OS4	V pk	250
Overvoltage limit[b]	OS3/OS4	V pk	250
Upper voltage limit[a]		V d.c.	220
Upper limited operating capability[a]	OS2	V d.c.	>190 to 220
Unlimited operating capability[a]	OS1	V d.c.	90 to 190
Lower operating capability[a]	OS2	V d.c.	60 to <90
Lower voltage limit[a]		V d.c.	60
Undervoltage[b]	OS3/OS4	V d.c.	0 to <60
[a] Working voltages.			
[b] Voltage deviations.			

A.2 Technical background for selection of voltage sub-classes

Table A.2 — Voltage sub-classes and related semiconductor technologies

Voltage sub-class	Upper voltage limit (RESS or Electric propulsion system) V d.c.	Related semiconductor technology — Example
B_220	U ≤ 220	MOSFETs 300 V breakdown voltage
B_420	U ≤ 420	Standard IGBTs and MOSFETs 600 V breakdown voltage
B_470	U ≤ 470	Selected IGBTs 700 V breakdown voltage and dedicated module technology
B_750	U ≤ 750	IGBTs 1 200 V breakdown voltage
B_850	U ≤ 850	IGBTs 1 200 V breakdown voltage
B_1250	U ≤ 1 250	IGBTs 1 700 V breakdown voltage

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