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Cycles — Safety requirements for bicycles —

Part 10: Safety requirements for electrically power assisted cycles (EPACs)

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Foreword

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

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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

This document was prepared by Technical Committee ISO/TC 149, *Cycles*, Subcommittee SC 1, *Cycles and major sub-assemblies*.

A list of all parts in the ISO 4210 series can be found on the ISO website.

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

Introduction

This document combines several countries' safety requirements for Electrically Power Assisted Cycles (EPACs). The commercialization of EPACs has accelerated in the global market, in response to global concerns about CO_2 reduction and energy saving. EPAC technologies for performance, electrical control, battery management and battery charging are currently developing rapidly in a competitive market. It is therefore necessary to standardize the safety of these technologies for EPACs.

This documentation will allow an easy and clear understanding of requirements for different types of EPAC.

This document includes safety requirements for the charging of EPACs. This includes off-board parts and EPAC battery chargers.

This document does not state the limit for the maximum permissible load of the EPAC. The manufacturer is advised to consider amongst other factors the maximum permissible load (luggage plus rider) as well as the intended use of the EPAC. Both have an influence on the mechanical requirements.

Cycles — Safety requirements for bicycles —

Part 10:
Safety requirements for electrically power assisted cycles (EPACs)

1 Scope

This document specifies safety and performance requirements for the design, marking, assembly, and testing of two wheeled electrically power assisted cycles (hereafter EPACs), fully assembled EPACs and subassemblies, and provides guidelines for information supplied by the manufacturers (i.e. instructions on the use and care of such EPACs).

This document applies to two wheeled EPACs that have a maximum saddle height of 635 mm or more and are intended for private and commercial use with exception of EPACs intended for hire from unattended stations.

This document is intended to cover all common significant hazards, hazardous situations and events listed in 5.3 of EPACs, when used as intended or under conditions of misuse that are reasonably foreseeable by the manufacturer.

This document specifies requirements and test methods for engine power management systems, electrical circuits including the charger for the assessment of the design and assembly of EPACs and sub-assemblies for systems having a Safety Extra Low Voltage (SELV) maximum voltage up to 60 V d.c. including tolerances.

2 Normative references

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

ISO 2409, *Paints and varnishes — Cross-cut test*

ISO 4210-1, *Cycles — Safety requirements for bicycles — Part 1: Terms and definitions*

ISO 4210-2:2015, *Cycles — Safety requirements for bicycles — Part 2: Requirements for city and trekking, young adult, mountain and racing bicycles*

ISO 4210-4:2014, *Cycles — Safety requirements for bicycles — Part 4: Braking test methods*

ISO 4210-5:2014, *Cycles — Safety requirements for bicycles — Part 5: Steering test methods*

ISO 4210-6:2015, *Cycles — Safety requirements for bicycles — Part 6: Frame and fork test methods*

ISO 4210-9:2014, *Cycles — Safety requirements for bicycles — Part 9: Saddle and seat-post test methods*

ISO 7010:2011, *Graphical symbols — Safety colours and safety signs — Registered safety signs*

ISO 11451-1, *Road vehicles — Vehicle test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 1: General principles and terminology*

ISO 11451-2, *Road vehicles — Vehicle test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 2: Off-vehicle radiation sources*

ISO 11452-1, *Road vehicles — Component test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 1: General principles and terminology*

ISO 11452-2, *Road vehicles — Component test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 2: Absorber-lined shielded enclosure*

ISO 11452-4:2011, *Road vehicles — Component test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 4: Harness excitation methods*

ISO 11898-1, *Road vehicles — Controller area network (CAN) —Part 1: Data link layer and physical signalling*

ISO 11898-2, *Road vehicles — Controller area network (CAN) —Part 2: High-speed medium access unit*

ISO 12100, *Safety of machinery — General principles for design — Risk assessment and risk reduction*

ISO 13849-1, *Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design*

ISO 13849-2, *Safety of machinery — Safety-related parts of control systems — Part 2: Validation*

IEC 60034-1, *Rotating electrical machines — Part 1: Rating and performance*

IEC 60068-2-27, *Environmental testing — Part 2-27: Tests — Test Ea and guidance: Shock*

IEC 60335-2-29, *Household and similar electrical appliances — Safety — Part 2-29: Particular requirements for battery chargers*

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

IEC 62133-1:2017, *Secondary cells and batteries containing alkaline or other non-acid electrolytes — Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications — Part 1: Nickel systems*

IEC 62133-2:2017, *Secondary cells and batteries containing alkaline or other non-acid electrolytes — Safety requirements for portable sealed secondary lithium cells, and for batteries made from them, for use in portable applications — Part 2: Lithium systems*

CISPR 12:2007 + A1:2009, *Vehicles, boats and internal combustion engines — Radio disturbance characteristics — Limits and methods of measurement for the protection of off-board receivers*

CISPR 16-1-1:2015, *Specification for radio disturbance and immunity measuring apparatus and methods — Part 1-1: Radio disturbance and immunity measuring apparatus — Measuring apparatus*

CISPR 25:2016, *Vehicles, boats and internal combustion engines — Radio disturbance characteristics — Limits and methods of measurement for the protection of on-board receivers*

EN 50604-1:2016, *Secondary lithium batteries for light EV (electric vehicle) applications — Part 1: General safety requirements and test methods*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 4210-1 and the following apply.

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

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

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

3.1
cycle
any vehicle which has at least two wheels and is propelled by the muscular energy of the person on that vehicle, in particular by means of pedalling or the possibility of adding assistance provided by electric motor when pedalling

Note 1 to entry: Pedalling also refers to use of hand cranks or other similar devices.

3.2
electrically power assisted cycle
EPAC
cycle (3.1), equipped with pedals and an auxiliary electric motor, which cannot be propelled exclusively by means of this auxiliary electric motor, except in the walk assistance mode

3.3
mountain EPAC
electrically power assisted cycle (3.2) designed for use off-road on rough terrain, on public roads, and on public pathways, equipped with a suitably strengthened frame and other components, and, typically, with wide-section tyres with coarse tread patterns and a wide range of transmission gears

[SOURCE: ISO 4210-1:2014, 2.30, modified — bicycle has been changed to electrically power assisted cycle.]

3.4
braking device cut-off switch
device that cuts off the motor assistance while braking

3.5
continuous rated power
output power specified by manufacturer, at which the motor reaches its thermal equilibrium at given ambient conditions

3.6
assisted rate
ratio of between mechanical motor output-power and muscular human input-power

3.7
thermal equilibrium
temperatures of motor parts which do not vary more than 2 °C/h

3.8
assistance cut-off speed
speed at which the motor controller cuts off the assistance of the auxiliary electric motor

3.9
walk assistance mode
function by which the user can activate the auxiliary electric motor to propel the EPAC up to a defined maximum speed without pedalling

3.10
electromagnetic compatibility
ability of an EPAC or one of its electrical/electronic systems to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbance to anything in that environment

[SOURCE: IEC 60050-161:1990/AMD8:2018, IEV ref. 161-01-07, modified — an EPAC or one of its electrical/electronic systems have been specified.]

3.11
ESA
electronic subassembly
electrical subassembly
electronic and/or electrical component, or an assembly of components provided for installation into an EPAC, together with all electrical connections and associated wiring for the execution of several specific functions

3.12
motor controller
device or group of devices that serves to govern in some predetermined manner the performance of an electric motor

Note 1 to entry: Means for manual or automatic ON/OFF, selecting the drive direction, regulating the speed, limiting the torque and providing protection against faults.

3.13
fault condition
condition in which one or more fault is present which could cause hazard

3.14
charging configuration
sets of physical parameters which are predefined to control a charging process

3.15
battery management system
BMS
local energy management system for the battery system, protecting the battery system from damage, monitoring and increasing the lifetime, and maintaining the functional state

Note 1 to entry: BMS and BCU (according to ISO 12405) do not have the same functions.

3.16
narrow-band emission
emission which has a bandwidth less than that of a specific receiver or measuring instrument

3.17
no load current point
current measured at battery output with no change to the operating status of any auxiliary systems during the test

3.18
safety extra-low voltage
SELV
voltage not exceeding ripple-free 60 V d.c. between conductors and earth, the no load voltage not exceeding ripple-free 60 V d.c.

3.19
anti-tampering measures
technical requirements and specifications which prevent, as far as possible, unauthorized modifications of the EPAC's drive system which may prejudice functional safety

3.20
maximum permissible load
maximum permissible weight of rider and luggage as defined by the manufacturer

3.21
proprietary system
manufacturer-specific system

3.22
non-proprietary system
non manufacturer-specific system

3.23
charger inlet
inlet on the EPAC or battery side for charging

[SOURCE: IEC 60050-714:1990, IEV ref. 714-03-04, this source is only for “inlet”]

3.24
charger connector
connector on charger side for charging

[SOURCE: IEC 60050-151:2001, IEV ref. 151-12-19, this source is only for “connector”]

3.25
rigid seat-post
seat-post that cannot be raised or lowered independently of the seat tube clamp, while riding, and does not provide controlled axial flexibility to reduce the transmission of road shocks to the rider.

3.26
suspension seat-post
seat-post incorporating controlled, axial flexibility to reduce the transmission of road shocks to the rider

3.27
dropper seat-post
seat-post that can be raised or lowered independently of the seat tube clamp while riding

3.28
suspension dropper seat-post
seat-post incorporating controlled, axial flexibility to reduce the transmission of road shocks to the rider and incorporating the capability of raising and lowering independently of the seat tube clamp while riding

4 Abbreviated terms

See Table 1.

Table 1 — Abbreviated terms

Abbreviation	Description	Definition or occurrence
AC	Alternating current	C.3.1.1
ACK	Acknowledge	C.2.5.3.1
ALSE	Absorber-lined shielded enclosure	B.3.4
AM	Amplitude modulation	A.4.6.1
BCI	Bulk current injection	B.2.6.3
BCU	Battery control unit	3.15
BMS	Battery management system	3.15
BPSK	Biphase shift keying	C.2.5.4.1
CAN	Controller area network	C.3.1.1
CC	Constant current mode	Table C.10
CCF	Common cause failure	F.2.4.1.2
CDB	Command descriptor block	C.2.6.3.1
CSMA/CR	Carrier sense multiple access with collision resolution	C.3.1.2

Table 1 *(continued)*

Abbreviation	Description	Definition or occurrence
CV	Constant voltage mode	Table C.10
DA	Destination address	Figure C.10
DC	Direct current	C.2.1.1
DFMEA	Design failure mode and effect analysis	5.2
DLC	Data length code	C.3.6.2.1
DUT	Device under test	F.2.3.4.2
EMC	Electromagnetic compatibility	6.12
EPAC	Electrically power assisted cycle	Introduction
ESA	Electronic/electrical subassembly	3.11
FCS	Frame check sequence	Table C.9
FMEA	Failure mode and effect analysis	5.2
FTA	Fault tree analysis	5.2
HMI	Human machine interface	Figure C.20
MPU	Micro processing unit	Figure C.1
NDN	Network device number	Table C.10
NM	Network management	C.3.6.2.4
NRZ	Non-return-to-zero	C.2.5.4.2
PC	Page control	Table C.40
PL	Performance level	5.3.2.2.2
PLC	Power line communication	Figure C.1
PM	Pulse modulation	A.4.6.1
PnP	Plug and play	C.2.6.2
PS	Parameter saveable	C.2.6.5.12
RA	Risk assessment	5.2
RF	Radio frequency	B.3.3
R-map	Risk-map	5.2
rms	Root mean square	A.2.6.3
RT	Room temperature	F.2.4.1.3
SA	Source address	Figure C.12
SELV	Safety extra low voltage	Clause 1
SOPC	Sub operation code	Table C.33
SP	Save pages	C.2.6.5.12
TLS	Transmission-line-system	A.4.6.3
ToR	Type of request	C.2.6.5.7.2
VDD	Voltage drain	Figure C.1

5 General requirements

5.1 Lighting systems, reflectors and warning device

EPACs shall be in accordance with the requirements of ISO 4210-2:2015, 4.20 and 4.21.

5.2 Risk assessment

EPAC shall be designed using principles of Risk Assessment (RA) in accordance with ISO 12100.

The following RA methodology may be used, but is not limited to:

— fault tree analysis (FTA);

— failure mode and effect analysis (FMEA);

— design failure mode and effect analysis (DFMEA);

— risk-map (R-map).

EPAC shall be designed in accordance with the principles of ISO 12100 for relevant hazards which are not dealt with by this document. This includes evaluation of such risks for all relevant components.

5.3 Significant hazards and safety functions

5.3.1 Significant hazards

The following significant hazards of EPACs have been considered in this document:

a) mechanical hazards: deceleration, acceleration, instability, kinetic energy, rotating elements and moving elements, rough or slippery surfaces, sharp edges;

b) electrical hazards: electromagnetic phenomena, electrostatic phenomena, overload, short-circuit, thermal radiation;

c) thermal hazards: explosion, flame, radiation from heat sources, objects or materials with a high or low temperature;

d) ergonomic hazards: effort, local lighting, posture;

e) hazards associated with the environment in which the EPAC is used: water (dust).

5.3.2 Safety function for control system of EPACs

5.3.2.1 General

The EPAC control system risk shall be assessed in accordance with the series of ISO 13849.

The following methodology may be used, but is not limited to:

— IEC 61508 (all parts);

— R-map.

5.3.2.2 Requirements

5.3.2.2.1 Safety related parts of the mechanical, hydraulic control systems

The necessary performance levels and requirements which are related to the identified hazards are covered by Clause 7.

5.3.2.2.2 Safety related parts of the electrical control systems

The safety requirements of Table 2 shall be necessary for an EPAC. If necessary, the manufacturer shall add more safety requirements and determine the necessary PL or safety level for each of these safety requirements and the related safety functions.

Table 2 — Safety functions related to defined hazards

Safety function	Performance Level
Prevention of electric motor assistance functions without pedalling, and without activation of the walk assistance mode	PLr c
Prevention of risk of fire in case of management system failure for batteries with electric energy above 100 Wh	PLr c

5.3.2.3 Verification of the safety functions

The whole procedure for achieving functional safety shall be in accordance with the series of ISO 13849.

System suppliers shall document this process and take measures to achieve the required performance level (see Table 2).

The minimum set of safety related functions shall be implemented at least by both system suppliers and the manufacturer to achieve conformity with this document.

5.4 Prevention of unauthorized use

Means shall be provided to the user to prevent an unauthorized use of the electric assistance/walk assistance mode of the EPAC e.g. key, locks, electronic control device.

5.5 Failure mode

5.5.1 Requirement

It shall be possible to ride the EPAC by pedalling even if the assistance failed. This requirement shall be checked as described in 5.5.2.

5.5.2 Test method

a) Remove or disconnect the battery pack.

b) Ride the EPAC up to 10 km/h.

6 Electrical requirements

6.1 Motor controller

The motor controller shall be designed so that it switches off the power to the electric motor if a fault condition occurs.

Subsequent switch on shall only be possible after user interaction.

6.2 Controls and symbols

A control device shall be fitted to switch on and off the assistance.

The control device shall be apparent, easy to reach and unmistakable. This control device shall be activated by voluntary action.

Designs of the On/Off symbol, lighting symbol and audible warning device symbol shall be in accordance with Annex D.

6.3 Batteries

The EPAC and batteries shall be designed in accordance with Annex F to avoid risk of fire and mechanical deterioration resulting from abnormal use.

In case the EPAC batteries may be subjected to country-specific regulations, batteries should conform to the country-specific regulations.

Batteries and the charger unit shall be labelled or be uniquely designed in order to ensure their compatibility and prevent incorrect plugging.

6.4 Battery charger

6.4.1 Requirements for proprietary system

A proprietary system consists of batteries and chargers, that are not interoperable. By design intended only to operate in combination with each other. A proprietary plug system shall assure that the EPAC batteries are only to be charged with the dedicated charger. The specific combination of charger and battery shall be considered for the hazard and risk analysis, as well as in the implementation of the safety functions.

The battery charger for proprietary system shall be in accordance with the requirements of IEC 60335-2-29.

6.4.2 Requirements for non-proprietary system

6.4.2.1 General

For non-proprietary systems, interoperable charging may be possible. The safety and risk analysis shall consider charging processes where battery and charger are released independently from each other. Therefore the safety requirements for the charging process on the EPAC side and on the charger side shall be described. To guarantee a safe charging process of the EPAC for a non-proprietary system, safety requirements shall be taken into consideration to prevent:

a) overvoltage and overcurrent;

b) over temperature;

c) hot disconnect;

d) short circuit.

For the charging configuration it is important, that the roles between the EPAC and the charger are uniquely defined. The EPAC shall be the master and the charger shall be the slave. This means that the EPAC controls the charging current and charging voltage at any time.

It shall only be possible to charge the EPAC, after a communication between the EPAC and the charger has been established. If this communication is interrupted, the charging process shall be stopped and the power lines shall become zero potential immediately.

The interface between EPAC and charger consists of a standardized plug system and a communication protocol.

6.4.2.2 Protocol requirements

The following protocol requirements shall be satisfied:

a) heart beat: for bilateral continuous presence detection of the EPAC and the charger. The EPAC shall transmit a heartbeat signal to the charger every 10 ms and the charger shall transmit a heartbeat signal to the EPAC every 200 ms;

b) property exchange: to exchange property information between EPAC and charger;

c) charging configuration to adjust charger to the required voltage and current of the EPAC;

d) strategy to avoid overvoltage and overcurrent;

e) strategy to avoid charging at over temperature and under temperature;

f) diagnostic functions to avoid charging after occurrence of safety-critical malfunctions.

The communication between EPAC and charger, necessary for the charging process, shall be separated from the EPAC internal communication.

6.4.2.3 Mechanical requirements

The following mechanical requirements shall be satisfied:

a) the charger connector cannot be disconnected from the charger inlet during power transfer (shall have latch function and/or have enough time to stop the supplying power after detecting its removal during the charging.);

b) A manufacturer device may be fitted to an EPAC to allow the charging of a proprietary battery system using a non-proprietary charger.

The charger shall provide the requested energy with an accuracy of 0/–2 %.

6.4.3 Solutions for non-proprietary systems

Solution approaches concerning battery chargers for non-proprietary systems including the described requirements are described in Annex C.

Manufacturers and/or service providers of non-proprietary system shall select System A or System B in Annex C.

6.5 Electric cables and couplers

Electric cables and coupler shall be selected in consideration of designed maximum current, maximum temperature and environmental conditions. Conformity is tested by inspection.

6.6 Wiring

Requirements on wiring shall be checked in accordance with the following sequence at an ambient room temperature (20 ± 5) °C.

a) Wire ways shall be smooth and free from sharp edges.

b) Wires shall be protected so that they do not come into contact with burrs, cooling fins or similar sharp edges that may cause damage to their insulation. Holes in metal through which are insulated wires pass shall have smooth well-rounded surfaces or be provided with bushings.

c) Wiring shall be effectively prevented from coming into contact with moving parts.

Conformity with a), b), c) shall be checked by inspection.

d) Separate parts of the EPAC that can move in normal use or during user maintenance relative to each other, shall not cause undue stress to electrical connectors and internal conductors, including those providing ground continuity.

Conformity with d) shall be checked by inspection and by the following test method.

If flexing occurs in normal use, the appliance is placed in its normal operational position and is supplied at rated voltage under normal operation.

The movable part is moved backwards and forwards, so that the conductor shall be flexed through the largest angle permitted by its construction.

For conductors that are flexed in normal use, flex movable part for 10 000 cycles at a test frequency of 0,5 Hz.

For conductors that are flexed during user maintenance, flex the movable part for 100 cycles at the same frequency.

If an open coil spring is used to protect wire, it shall be correctly installed and insulated. Flexible metallic tubes shall not cause damage to the insulation of the conductors contained within them.

6.7 Protection against ingress of water (IP code)

The electrical components of a fully assembled Mountain EPAC shall be tested and shall be in accordance with at least IPX5 requirements of IEC 60529. The electrical components of a fully assembled EPAC of the other bicycle types shall be tested and shall be in accordance with at least IPX4 requirements of IEC 60529.

NOTE Battery charger is not included in the electrical components of a fully assembled EPAC.

These requirements should be checked for each rational component or unit of EPAC (e.g. the handle assembly including the control switch, display, lamp and other electrical components, the drive unit, the battery unit, etc.).

If any water has entered, it shall not be sufficient to interfere with the correct operation of the equipment or impair safety.

6.8 Environmental and operational conditions

See Annex E.

6.9 Mechanical strength of the electrical components

6.9.1 General

The electrical components shall have adequate mechanical strength and be constructed to withstand such rough handling that may be expected in normal use.

NOTE 1 Both complete EPAC and sub assembly conditions are acceptable.

NOTE 2 For environmental test, see Reference [15].

6.9.2 Function related shock test

In accordance with IEC 60068-2-27, half sine shocks shall be applied with a peak acceleration of 150 m/s^2 and a duration equal to the nominal impulse of 6 ms in both directions of each of the three perpendicular axes. Number of shocks in each direction: 100 ± 3 shocks (a total of 600 shocks). After the test, the performance of the components shall be fully maintained and no failure shall occur.

6.9.3 Impact related shock test

The impact related shock test shall be carried out on a fully assembled EPAC.

Lateral overturning: The EPAC shall be left to fall 25 times both to the left and to the right from its upright position. For this purpose, the steering shall be aligned in the straightforward position, and

crank shall be aligned horizontally prior to each fall. The test shall be carried out on a hard surface (concrete or sett).

NOTE 25 times to the left and 25 times to the right, total 50 times.

After the test, electrical components shall not have any detachment any tearing out or any breaking of fastening elements; Detachable electrical components shall not have any functional impairment (e.g. inserting and removing the battery).

6.10 Performance measurement

6.10.1 General

Electrically power assisted system for EPAC has 2 types. One is the system based on the maximum continuous rated power, another is the system based on the maximum assisted rate. Each measurement is dependent on the requirement(s) from local regulation(s).

6.10.2 System based on maximum continuous rated power

6.10.2.1 Maximum speed for which the electric motor gives assistance

6.10.2.1.1 Requirements

The electrical motor assistance shall stop at velocity required from local regulation or lower values, limited by design. The maximum speed of the EPAC for which the electric motor gives assistance shall not differ by more than +10 % from the maximum assistance speed indicated in the marking required by Clause 9.

6.10.2.1.2 Test method

6.10.2.1.2.1 Test conditions

a) The test shall be performed either on a test track (See 6.10.2.2.2.2), a test bench or on a stand that keeps the motor driven wheel free off the ground.

b) The speed-measuring device used for the test shall have the following characteristics:

   1) Accuracy: ±2 %;

   2) Resolution: 0,1 km/h.

c) The ambient temperature shall be between 5 °C and 35 °C.

d) Maximum wind speed: 3 m/s.

e) The battery shall be fully charged in accordance with the manufacturer instructions.

6.10.2.1.2.2 Test procedure

The assistance cut-off speed can be measured by measuring either the motor torque output or the motor current. Other appropriate method the pertinence of which has been demonstrated can be used.

The following example describes the assistance cut-off speed test.

a) Pre-condition the EPAC by running it for 5 min at 80 % of the maximum assistance speed as declared by the manufacturer.

b) Record continuously the current and note the speed at which the current drops to a value equal to or less than “no load current point” (see definition 3.17).

c) While pedalling, ride steadily to reach a speed equal to 1,25 times (if possible by design) the maximum assistance speed as declared by the manufacturer.

d) Verify that the noted value in b) is the no load current point.

6.10.2.2 Power management

6.10.2.2.1 Requirements

a) When tested by the method described in 6.10.2.2.2 the recordings shall show that assistance shall be provided only when the rider pedals forward. This requirement shall be checked in accordance with the test methods described in 6.10.2.2.2.3;

b) Assistance shall be assistance cut-off when the rider stops pedalling forward and the assistance cut-off distance shall not exceed 2 m;

c) If all braking devices (e.g. levers, back pedal) are equipped with assistance cut-off switches (braking device cut-off switch, see 3.4), the assistance cut-off distance shall not exceed 5 m;

d) The power output or assistance shall be progressively reduced and finally assistance cut-off as the EPAC reaches the maximum assistance speed as designed. This requirement shall be checked in accordance with the test methods described in 6.10.2.2.2;

e) The assistance shall be progressively and smoothly managed (e.g. no hunting);

f) Two independent applying actions shall be required to start the electrical assistance mode (e.g. power switch and forward pedalling activation);

NOTE A traffic caused stop (e.g. traffic lights) is not subject to this requirement.

g) After a deactivation of the electrical assistance mode due to any hazardous electric drive malfunction, the electric drive shall not start automatically without rider intervention (pedalling is not considered as rider intervention).

6.10.2.2.2 Test method

6.10.2.2.2.1 Test conditions

a) The test may be performed either on a test track, a test bench or on a stand which keeps the motor driven wheel free of the ground;

b) The test track shall be in accordance with 6.10.2.2.2.2;

c) The time-measuring device shall have an accuracy of ±2 %;

d) The ambient temperature shall be between 5 °C and 35 °C;

e) Maximum wind speed over ground shall not exceed 3 m/s;

f) The battery shall be fully charged in accordance with the manufacturer's instructions;

g) Speed measurement shall have an accuracy of ±2 %.

The test to ensure the conformity to this clause shall be adapted to the technology used;

for example:

— pedal backwards and check the no load current point (see 3.17)

or

— pedal backwards and check that no torque is delivered on the driving wheel.

For the test, the worst case conditions of gear ratio and speed shall be applied. The worst condition for speed is defined as 90 % of assistance cut-off speed (see 3.8).

6.10.2.2.2.2 Test track

The gradient of the track shall not exceed 0,5 %. If the gradient is less than 0,2 % carry out all runs in the same direction. If the gradient lies between 0,2 % and 0,5 % carry out alternate runs in opposite directions.

The surface shall be hard concrete or fine asphalt free from loose dirt or gravel. The minimum coefficient of friction between the dry surface and the EPAC tyre shall be 0,75.

6.10.2.2.2.3 Test procedure

a) Pedal backwards and check that no electric motor assistance is provided. The test to ensure the conformity to this clause shall be adapted to the technology used.

b) Check the assistance cut-off distance:

   1) pedal so that the EPAC reach 90 % of the assistance cut-off speed;

   2) stop pedalling without braking;

   3) measure the assistance cut-off distance;

   4) carry out the test 3 times; the result is the average of this measurement after rejection of invalid points.

c) If braking device cut-off switches are fitted, actuate each brake device separately and verify the initiation of the assistance cut-off signal while pedalling.

6.10.2.3 Measurement of the maximum continuous rated power

The maximum continuous rated power shall be measured at the driven wheel of the EPAC in accordance with IEC 60034-1 when the motor reaches its thermal equilibrium as specified by the manufacturer.

In circumstance where the power is measured directly at the shaft of the electric motor, the result of the measurement shall be decreased by 1,10 to consider the measurement uncertainty and then by 1,05 to include for example the transmission losses, unless the real values of these losses are determined.

6.10.3 System based on maximum assisted rate

6.10.3.1 Maximum speed and assisted rate for which the electric motor gives assistance

6.10.3.1.1 General

The electrical motor power shall be controlled in accordance with a specified assistance ratio. The electrical motor power shall stop at the speed required by local regulations or at a lower value, limited by design.

6.10.3.1.2 Test method

6.10.3.1.2.1 Test conditions

Conditions of EPAC, power supplies and meters to be tested shall be as follows:

a) **Preparation and maintenance of EPAC**

The EPAC shall be driven for 30 min by 15 km/h prior to test and given maintenance to be brought to a condition where it is capable of driving under its inherent usage before starting of the test. The tyre pressure and chain tension, especially, shall be maintained in accordance with manufacturer's instructions.

b) **Power supplies**

1) In the case of using constant-voltage power supplies, they shall be maintained and adjusted the settings before the test.

2) In the case of using batteries, they shall be fully charged in advance.

c) **Meters**

The meter shall be operated for more than 30 min break-in by 15 km/h prior to test and brought to a condition where stable riding is possible before starting the test. The loss of the test bench (e.g. the frictional resistance of the test bench) is measured before test and correct the driving force. Select a meter which shall be a correction factor with a maximum 5 % of the targeted amount.

d) **Setting of weight**

Measures shall be taken to reproduce the right rolling resistance (e.g. to avoid tire slip). A dummy weight shall be mounted on the saddle and the EPAC including their jig shall be set up in such a way that the mass is loaded on the roller of the test bench. The test condition shall be described in the test report.

e) **Derailleur**

For the EPAC with derailleur, test it at the gear position where the assisted rate becomes maximum.

f) **Setting of test load**

Each load shall be set to the target value of speed and wheel driving force in setting conditions-1 and setting conditions-2.

6.10.3.1.2.2 Measuring method and calculation formulae

The measuring methods and calculation formulae shall be as follows.

a) **Items, summaries and units of measurement**

1) **Input rotation speed:** N

— use the rotation speed of the driving actuator;

— express in unit of r/min.

2) **Input torque:** T

— use the axial torque of the driving actuator;

— express in unit of N·m.

3) **Speed:** v

— use the speed of the roller;

— set so that the error is within 5 % of the targeted value;

— include the loss of test bench;

— express in unit of km/h.

4) **Wheel driving force:** F

— use the driving force obtained from the load indicated by the torque meter of the test bench;

— set so that the error is within 5 % of the targeted value;

— express in unit of N.

b) **Calculation formulae**

1) **Power of input of bottom-bracket spindle:** P_1

$$P_1 = \frac{2\times\pi}{60}\times N\times T \quad (1)$$

where

P_1 is the power of input of bottom-bracket spindle [W];

N is the input rotation speed [r/min];

T is the input torque [N·m].

2) **Driving power of the EPAC:** P_2

$$P_2 = \frac{1}{3{,}6}\times v\times F \quad (2)$$

where

P_2 is the driving power of the EPAC [W];

v is the speed [km/h];

F is the wheel driving force [N].

3) **Assisted rate:** α

$$\alpha = (P_2 - P_1)/P_1 \quad (3)$$

where

α is the assisted rate;

P_1 is the power of input of bottom-bracket spindle [W];

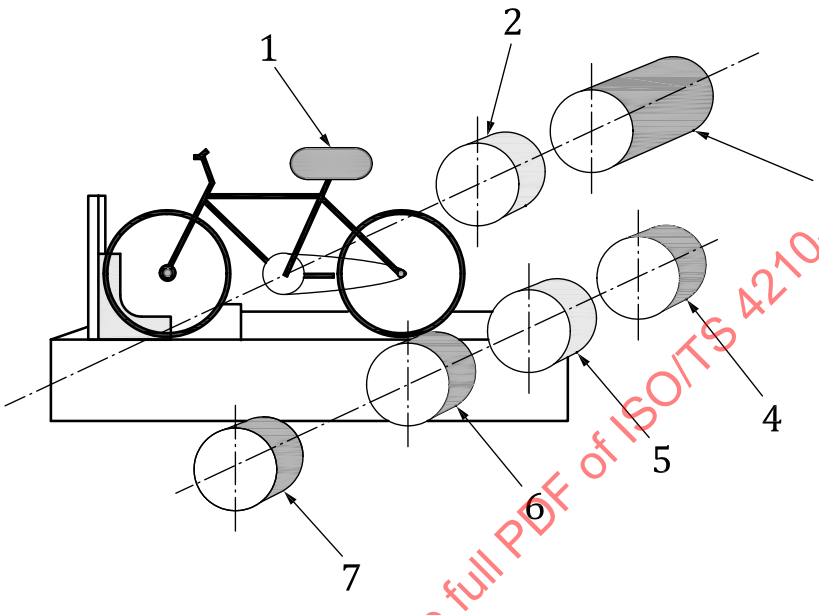
P_2 is the driving power of the EPAC [W].

6.10.3.1.2.3 Overview diagram of equipment for testing assisted rate

Overview diagram of equipment for testing assisted rate shall be as shown in Figure 1.

Measure the input rotation speed and input torque with the crank driving actuator which is composed of the outside motor (item 3 in Figure 1) and the torque meter and the rotation speed meter (item 2 in Figure 1).

Ground the drive wheel to the roller (item 6 in Figure 1) of the test bench, and measure the speed of EPAC and the wheel driving force by the torque meter and rotation speed meter (item 5 in Figure 1) of the test bench. In case of the front wheel driving, ground both wheels to the same roller of the test bench.



Key

1 weight loaded on saddle
2 torque meter and rotation speed meter
3 outside motor
4 power absorber (which let out the power)
5 torque meter and rotation speed meter
6 roller
7 fly wheel

Figure 1 — Overview diagram of equipment for testing assisted rate

6.10.3.1.2.4 Setting of test load

Setting of test load shall be as follows.

a) **Setting condition-1** (see Table 3 and Table 4.)

Table 3 is shown the measurement points of assisted rate at setting condition-1, which is simulated a road of gentle ascent.

Measurement numbers 3 and 4 of Table 3 are designed to measure the maximum assisted rate. The manufacturer shall declare the targeted speed v_3 and v_4 from Table 4 at the speed of which the maximum assisted rate is provided. Targeted wheel driving force F_3 and F_4 are defined in Table 4 corresponding to v_3 and v_4.

The points of measurement numbers 5 and 6 are designed to verify the assistance cut-off speed.

The manufacturer shall declare the targeted speed v_5 from Table 4 at the speed of which is equal to or less-than the assistance cut-off speed. The manufacturer shall declare the targeted speed v_6 from Table 4 at the speed of which is greater than assistance cut-off speed.

Table 3 — Loading condition when travelling a road of gentle ascent

Measurement number	Targeted speed km/h	Targeted wheel driving force N
1	5	30
2	10	33
3	v_3	F_3
4	v_4	F_4
5	v_5	F_5
6	v_6	F_6

Table 4 — Targeted wheel driving force corresponding to targeted speed arbitrarily designated at measurement numbers 3, 4, 5 and 6

Targeted speed km/h	Targeted wheel driving power N
11	34
12	35
13	36
14	37
15	38
16	40
17	41
18	42
19	44
20	45
21	47
22	49
23	50
24	52
25	54
26	56
27	59
28	61
29	63
30	65
31	68
32	70
33	73
34	76
35	78

b) **Setting condition-2** (see Table 5 and Table 6.)

Table 5 is shown the measurement points of assisted rate at setting condition-2, which is simulated a road of steep ascent.

Measurement numbers 9 and 10 of Table 5 are designed to measure the maximum assisted rate. The manufacturer shall declare the targeted speed v_9 and v_{10} from Table 6 at the speed of which the

maximum assisted rate is provided. Targeted wheel driving force F_9 and F_{10} are defined in Table 6 corresponding to v_9 and v_{10}.

The points of measurement numbers 11 and 12 are designed to verify the assistance cut-off speed.

The manufacturer shall declare the targeted speed v_{11} from Table 6 at the speed of which is equal to or less-than the assistance cut-off speed. The manufacturer shall declare the targeted speed v_{12} from Table 6 at the speed of which is greater than assistance cut-off speed.

Table 5 — Loading condition when travelling a road of steep ascent

Measurement number	Targeted speed km/h	Targeted wheel driving force N
7	5	55
8	10	58
9	v_9	F_9
10	v_{10}	F_{10}
11	v_{11}	F_{11}
12	v_{12}	F_{12}

Table 6 — Targeted wheel driving force corresponding to targeted speed arbitrary designated at measurement numbers 9, 10, 11 and 12

Targeted speed km/h	Targeted wheel driving power N
11	59
12	60
13	61
14	62
15	63
16	64
17	65
18	67
19	68
20	70
21	72
22	73
23	75
24	77
25	79
26	81
27	83
28	85
29	88
30	90
31	92
32	95
33	98
34	100

Table 6 *(continued)*

Targeted speed km/h	Targeted wheel driving power N
35	103

6.10.3.1.2.5 Test procedure

This test shall be carried out in accordance with the following procedure by mounting the EPAC on the test bench, with the bottom bracket spindle connected to the external driving actuator and in the order corresponding to setting condition-1 and setting condition-2.

a) Measure the loss of the test bench. In case of the front driving wheel, add the rolling resistance of front wheel to the loss of the test bench.

b) Switch on the power assisting system of the EPAC.

c) Start the driving actuator and adjust the speed to the targeted value.

d) Increase power absorption of the test bench and adjust the wheel driving force to the targeted value.

e) Confirm that the speed and wheel driving force fall within their respective permitted ranges.

f) Record each average measurement value under constant condition.

g) In accordance with each formula, calculate the assisted rate by each measurement number.

6.11 Walk assistance mode

6.11.1 Requirements

If local regulation allows walk assistance mode, EPAC can be equipped with a walk assistance mode that operates up to a maximum speed of 6 km/h.

This mode shall be activated by the voluntary and maintained action of the user either when riding without pedalling or when the user is pushing the EPAC. Conformity is checked by the test described in 6.11.2.

6.11.2 Test method for EPAC with walk assistance mode

6.11.2.1 Test conditions

The test may be performed either on a test track (See 6.10.2.2.2.2), a test bench or on a stand that keeps the motor driven wheel free of the ground.

The speed-measuring device shall have the following characteristics:

a) accuracy: ±2 %;

b) resolution: 0,1 km/h.

The ambient temperature shall be between 5 °C and 35 °C.

Maximum wind speed: 3 m/s.

The battery shall be fully charged in accordance with the manufacturer's instructions.

6.11.2.2 Test procedure

a) Activate the walk assistance mode and verify that the speed increases up to 6 km/h maximum designed speed or lower value.

b) Verify that the speed reduces progressively to 0 km/h when the walk assistance mode is deactivated.

c) Activate the walk assistance mode and maintain it for 1 min. Verify that speed is equal to or less than 6 km/h.

d) Verify that the walk assistance mode is activated only when the actuation of the device to initiate it is maintained.

6.12 Electromagnetic compatibility (EMC)

6.12.1 Requirement

EPACs shall be in accordance with Annex A.

NOTE 1 EPACs can be subject to the requirements of the national regulations in the country where the EPAC is marketed.

NOTE 2 For ESAs, see Annex B.

6.13 Anti-tampering measure

6.13.1 General

Anti-tampering measures apply to tampering or modifications that general consumers as well as other market actors (e.g. retailers) carry out concerning the motor controller, drive unit or other parts of power assisting system by using commercially available tools, equipment or parts.

6.13.2 Prevention of tampering of the motor

The following anti-tampering requirements shall be taken into account as a minimum:

a) Anti-tampering relevant parameters indicated below shall only be accessible to the manufacturer or authorized persons and changes of software configuration parameters shall require programming tools that are not commercially available or which are security protected:

   1) maximum speed with motor assistance (all systems);

   2) parameters affecting the maximum EPAC speed limited by design;

   3) maximum gear ratio (system with middle motors);

   4) maximum motor power (all systems);

   5) maximum speed of walk assistance;

   6) maximum power assistance ratio, or the relationship between EPAC speed and maximum power assistance ratio (where local regulations for assistance ratio apply).

b) Reasonably foreseeable tampering with configuration parameters relevant to the conformity of the EPAC shall be prevented or compensated for by effective countermeasures, e.g. plausibility logic to detect tampering with sensors or falsification of sensor input;

c) Closed set of components (i.e. operation only with released battery);

d) Protection against opening of relevant components without traces (sealing).

6.14 Thermal hazards

6.14.1 Non-continuous contact surface

Warning symbol W017 in accordance with ISO 7010:2011 shall be placed on the surface, if the temperature of the non-continuous contact surface can be above the limits of 1 s contact period defined in ISO 13732-1. Brake systems are excluded from this requirement.

NOTE A non-continuous contact surface is a surface on an EPAC which has a possibility of touching the rider's hands, legs etc. during normal use and maintenance.

6.14.2 Continuous contact surface

Continuous contact surface of at least 10 minutes contact period shall not exceed the temperature limit defined in ISO 13732-1.

NOTE Surface of continuous contact is handlebar grip, handle grip lever and seat.

6.14.3 Ambient temperature

Test condition of 6.14.1 and 6.14.2 shall be 25 (0/−5) °C.

7 Mechanical requirements

7.1 General

EPACs shall be in accordance with the requirements of ISO 4210-2:2015, Clause 4 in accordance with their specific bicycle type.

In addition, EPACs which have assisted ratio greater than 2 shall be in accordance with the requirements which are specified from 7.2 to 7.14.

Each frame test shall include the battery system and electric drive unit or the false "dummy" example of the similar mass ±1 kg as the battery system and electric drive unit.

7.2 Brakes — Heat-resistance test

The parameters of the test described in ISO 4210-4:2014, Table 1 shall be replaced by parameters given in Table 7. All other parameters shall be kept.

Table 7 — Total braking energy

Bicycle type	City and trekking
Total braking energy, E Wh	75

7.3 Handlebar and stem assembly — Lateral bending test

The parameters of the test described in ISO 4210-5:2014, Table 2 shall be replaced by parameters given in Table 8. All other parameters shall be kept.

Table 8 — Forces on handlebars

Bicycle type	City and trekking
Force, F_2 N	800

7.4 Handlebar stem — Forward bending test

The parameters of the test described in ISO 4210-5:2014, Table 3 shall be replaced by parameters given in Table 9. All other parameters shall be kept.

Table 9 — Forces on stems

Forces in newtons

Bicycle type		City and trekking
Stage 1	Force, F_3	1 600
Stage 2	Force, F_4	2 600

7.5 Handlebar to handlebar stem — Torsional security test

The parameters of the test described in ISO 4210-5:2014, Table 4 shall be replaced by parameters given in Table 10. All other parameters shall be kept.

Table 10 — Torque on handlebar

Torques in newton metres

Bicycle type	City and trekking
Torque, T_1	70

7.6 Handlebar and stem assembly — Fatigue test

The parameters of the test described in ISO 4210-5:2014, Table 7 shall be replaced by parameters given in Table 11. All other parameters shall be kept.

Table 11 — Forces on handlebars and bar-ends

Forces in newtons

Bicycle type		City and trekking
Stage 1	Force, F_6	220
Stage 2	Force, F_7	280

7.7 Frame — Impact test (falling mass)

The parameters of the test described in ISO 4210-6:2015, Table 1 shall be replaced by parameters given in Table 12. All other parameters shall be kept.

Table 12 — Drop heights

Dimensions in millimetres

Bicycle type	City and trekking
Drop height, h_1	360

7.8 Frame and front fork assembly — Impact test (falling frame)

The parameters of the test described in ISO 4210-6:2015, Table 2 shall be replaced by parameters given in Table 13. All other parameters shall be kept.

Table 13 — Drop heights and distribution of masses at seat post, steering head, and bottom bracket

Bicycle type	City and trekking
Mass 1 Seat-post, M_1 kg	30
Mass 2 Steering head, M_2 kg	10
Mass 3 Bottom bracket, M_3 kg	50
Drop height, h_2 mm	300

7.9 Frame — Fatigue test with horizontal forces

The parameters of the test described in ISO 4210-6:2015, Table 4 shall be replaced by parameters given in Table 14. All other parameters shall be kept.

Table 14 — Forces and test cycles on front fork dropouts

Bicycle type		City and trekking	Mountain
Front wheel driven EPAC	Forward force, F_2 N	600	1 200
	Rearward force, F_3 N	600	600
Other driving systems	Forward force, F_2 N	500	1 200
	Rearward force, F_3 N	500	600
Test cycles, C_1		100 000	100 000
Locking conditions of the suspension fork and/or the suspension unit kg		90	80

7.10 Frame — Fatigue test with a vertical force

The parameters of the test described in ISO 4210-6:2015, Table 5 shall be replaced by parameters given in Table 15. All other parameters shall be kept.

Table 15 — Forces on seat stem

Forces in newtons

Bicycle type	City and trekking	Mountain
Force, F_4	1 100	1 400

7.11 Front fork — Static bending test

The requirement in ISO 4210-2:2015, 4.9.4 shall be replaced as follows for mountain EPAC.

When tested by the method described in ISO 4210-6:2014, 5.3, there shall be no fractures or visible cracks in any part of the fork.

The parameters of the test described in ISO 4210-6:2015, Table 6 shall be replaced by parameters given in Table 16. All other parameters shall be kept.

Table 16 — Forces on loading attachment

Forces in newtons

Bicycle type	City and trekking	Mountain
Force, F_5	1 500	2 000

7.12 Front fork — Rearward impact test

The parameters of the test described in ISO 4210-6:2015, Tables 7 and 8 shall be replaced by parameters given in Tables 17 and 18. All other parameters shall be kept.

Table 17 — Drop heights

Dimensions in millimetres

Bicycle type		City and trekking
Drop height, h_4	Forks made entirely of metal	360
	Forks which have composite parts	360

Table 18 — Torque on fork

Torques in newton metres

Bicycle type	City and trekking
Torque, T	80

7.13 Front fork — Bending fatigue test plus rearward impact test

The parameters of the test described in ISO 4210-6:2015, Table 9 shall be replaced by parameters given in Table 19. All other parameters shall be kept.

Table 19 — Forces on loading attachment

Forces in newtons

Bicycle type	City and trekking	Mountain
Force, F_6	±500	±675

7.14 Seat-post — Fatigue test

The parameters of the test described in ISO 4210-9:2014, Table 2 shall be replaced by parameters given in Table 20. All other parameters shall be kept.

Table 20 — Forces on seat-post

Forces in newtons

Bicycle type	Mountain	
Force, F_3	Dropper seat-post/ Suspension dropper seat-post	Rigid seat-post/ Suspension seat-post
	1 320	1 400

8 Manufacturer's instructions

These instructions shall be in accordance with ISO 4210-2:2015, Clause 5 and provisions in force in the country in which the product is marketed.

In addition, instructions shall contain the following information:

a) concept and description of electric assistance including varying levels of motor assistance;

b) explanation of product use (e.g. switch on/off);

c) meaning of symbol and visual tell-tales used shall be explained in the instruction for use;

d) specific EPAC warnings as follows:

— inappropriate use including manipulation of the electric engine power management system;

— contact with hot surfaces.

e) recommendation for cleaning and the use of high pressure cleaners;

f) specific EPAC recommendation for use (e.g. removal of the battery, temperature range for the use of the EPAC including battery, use of walk assistance mode);

g) recommendations about charging:

— temperature range for charging;

— indoor or outdoor charging;

— importance of the instructions contained on the label of, and in the instructions of, the charger and battery.

h) information about consequences to the user in case of tampering;

i) the A-weighted emission sound pressure level at the rider ears is less than 70 dB(A), if required by regional regulation;

j) recommendation for charger and battery compatibility.

NOTE It is permitted to include any other relevant information at the discretion of the manufacturer.

9 Marking

The marking shall be in accordance with ISO 4210-2:2015, Clause 6.

EPACs shall be marked with the following information at a readily visible location such as near the seat post or handlebar:

— maximum permissible load;

— nominal mass of EPAC;

— type and model of bicycle.

The frame shall be visibly and durably marked with following information:

— name of the manufacturer of complete EPAC or the manufacturer's representative;

— the number of this document, i.e. ISO TS 4210-10 (letter), e.g.

ISO TS 4210-10 C = City and Trekking EPAC,

M = Mountain EPAC,

R = Racing EPAC,

Y = Young adult EPAC.

NOTE 1 The mark “ISO 4210-2” which is required in ISO 4210-2:2015, 6.1 b) is unnecessary.

NOTE 2 The markings below are required if required by regional regulation:

— CE marking;

— contact and address of the manufacturer or authorized representative;

— assistance cut-off speed XX km/h;

— maximum continuous rated power XX kW;

— year of construction, that is the year in which the manufacturing was completed (it is not possible to use a code).

Annex A
(normative)

Electromagnetic compatibility of EPACs

A.1 Type testing procedures

An EPAC shall be type tested directly by following the provisions laid down in A.2.

A.2 EPAC requirements

A.2.1 General

If an EPAC installation is tested, it shall fulfil the requirements of this Annex under normal conditions of use. An EPAC shall be tested for radiated emissions and for immunity to radiated disturbances. Tests for conducted emissions or immunity to conducted disturbances are not required.

A.2.2 Test plan

Prior to performing the tests, a test plan should be generated containing at least mode of operation, stimulated function(s), monitored function(s), pass/fail criteria and, for intentional radiators, intended emissions.

A.2.3 Broadband electromagnetic radiation from EPACs

A.2.3.1 Method of measurement

The electromagnetic radiation generated by the EPAC representative of its type shall be measured using the method described in A.3.

A.2.3.2 EPAC broadband limits

A.2.3.2.1 Limit for 10 m measurement distance

If measurements are made using the method described in A.3 using a EPAC-to-antenna spacing of (10,0 ± 0,2) m, the limits shall be 32 dB(μV/m) in the 30 MHz to 75 MHz frequency band and 32 dB(μV/m) to 43 dB(μV/m) in the 75 MHz to 400 MHz frequency band, this limit increasing logarithmically with frequencies above 75 MHz (see Table A.1 and Figure A.1). In the 400 MHz to 1 000 MHz frequency band the limit remains constant at 43 dB(μV/m).

A.2.3.2.2 Limit for 3 m measurement distance

If measurements are made using the method described in A.3 using a EPAC-to-antenna spacing of (3,0 ± 0,05) m, the limits shall be 42 dB(μV/m) in the 30 MHz to 75 MHz frequency band and 42 dB(μV/m) to 53 dB(μV/m) in the 75 MHz to 400 MHz frequency band, this limit increasing logarithmically with frequencies above 75 MHz (see Table A.1 and Figure A.1). In the 400 MHz to 1 000 MHz frequency band the limit remains constant at 53 dB(μV/m).

A.2.3.2.3 Requirement

On the EPAC representative of its type, the measured values, expressed in dB(μV/m) shall be below the EPAC broadband limits stated above.

A.2.4 Narrowband electromagnetic radiation from EPACs

A.2.4.1 Method of measurement

The electromagnetic radiation generated by the EPAC representative of its type shall be measured using the method described in A.3.

A.2.4.2 EPAC narrowband limits

A.2.4.2.1 Limit for 10 m measurement distance

If measurements are made using the method described in A.3 using a EPAC-to-antenna spacing of (10,0 ± 0,2) m, the limits shall be 22 dB(µV/m) in the 30 MHz to 75 MHz frequency band and 22 dB(µV/m) to 33 dB(µV/m) in the 75 MHz to 400 MHz frequency band, this limit increasing logarithmically with frequencies above 75 MHz (see Table A.1 and Figure A.1). In the 400 MHz to 1 000 MHz frequency band the limit remains constant at 33 dB(µV/m).

A.2.4.2.2 Limit for 3 m measurement distance

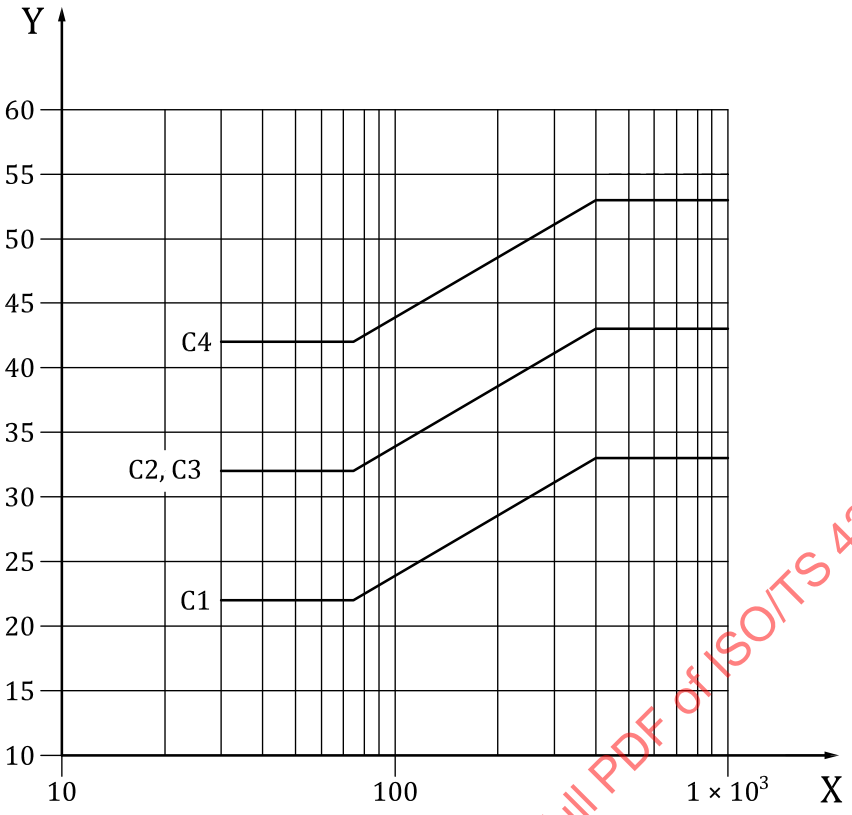
If measurements are made using the method described in A.3 using a EPAC-to-antenna spacing of (3,0 ± 0,05) m, the limits shall be 32 dB(µV/m) in the 30 MHz to 75 MHz frequency band and 32 dB(µV/m) to 43 dB(µV/m) in the 75 MHz to 400 MHz frequency band, this limit increasing logarithmically with frequencies above 75 MHz (see Table A.1 and Figure A.1). In the 400 MHz to 1 000 MHz frequency band the limit remains constant at 43 dB(µV/m).

A.2.4.2.3 Requirement

On the EPAC representative of its type, the measured values, expressed in dB(µV/m) shall be below the EPAC broadband limits stated above.

A.2.5 Overview of radiated emission limits for EPACs

Radiated emission limits for EPACs are shown in Figure A.1 and Table A.1.



Key

X frequency f in MHz
Y field strength limit in dB (µV/m)
C1 narrowband radiation emission limit for EPACs, antenna at 10 m
C2 broadband radiation emission limit for EPACs, antenna at 10 m
C3 narrowband radiation emission limit for EPACs, antenna at 3 m
C4 broadband radiation emission limit for EPACs, antenna at 3 m

NOTE 1 The limits are identical to the limits defined in UNECE R10 revision 5 Appendices 2 to 5 which are applicable to Speed-EPACS.

NOTE 2 The limits take into account measurement uncertainties.

Figure A.1 — Radiated emission limits for EPACs

Table A.1 — Radiated emission limits for EPACs

Curve No.	Disturbance category	Detector acc. to CISPR 16-1-1	Measurement distance m	Equation for limit [dB(µV/m)] with frequency, f [MHz]		
				$30 \le f \le 75$	$75 < f < 400$	$400 \le f \le 1\,000$
C1	Narrowband	Average	10	22	$22 + 15{,}13 \cdot \log(f/75)$	33
C2	Broadband	Quasi-peak	10	32	$32 + 15{,}13 \cdot \log(f/75)$	43
C3	Narrowband	Average	3	32	$32 + 15{,}13 \cdot \log(f/75)$	43
C4	Broadband	Quasi-peak	3	42	$42 + 15{,}13 \cdot \log(f/75)$	53

A.2.6 EPAC immunity to electromagnetic radiation

A.2.6.1 Method of testing

The immunity to electromagnetic radiation of the EPAC representative of its type shall be tested by the method described in A.4.

A.2.6.2 Performance criteria and monitoring

The EPAC is deemed to fulfil the requisite immunity conditions if, during the tests carried out in the manner required by A.4, there are no abnormal changes in the speed of the EPAC drive wheels, there are no deteriorations in the direct control of the EPAC which might be observed by the rider and there are no signs of operational deterioration which might mislead other road users.

For the purpose of monitoring the external part of the EPAC and of determining whether the above conditions have been met, a video camera may be used.

If an EPAC fails the test defined in this annex, it shall be verified as having failed under the relevant test conditions and not as a result of the generation of uncontrolled fields.

A.2.6.3 EPAC immunity test levels

If tests are made using the method described in A.4, the field strength shall be 30 V/m root-mean-square (rms) in over 90 % of the 20 MHz to 2 000 MHz frequency band and a minimum of 25 V/m rms over the whole 20 MHz to 2 000 MHz frequency band.

The EPAC representative of its type shall be considered as conforming to the immunity requirements if, during the tests performed in accordance with A.4, the performance criteria in accordance with A.2.6.2 are fulfilled.

A.3 Method of measurement of radiated electromagnetic emissions from EPACs

A.3.1 General

This test is intended to measure the radiated broadband and narrow-band emissions generated by electrical or electronic systems fitted to the EPAC (electric motors, microprocessor-based systems etc.).

As far as not otherwise stated in this annex the test shall be performed in accordance with CISPR 12.

A.3.2 Test location

In accordance with CISPR 12:2007, 5.2.

A.3.3 Measuring equipment

In accordance with CISPR 12:2007, 5.1.

Measuring instrument parameters in accordance with CISPR 12:2007, 5.1.2 (use of scanning receiver) or 5.1.1 (use of spectrum analyser), respectively.

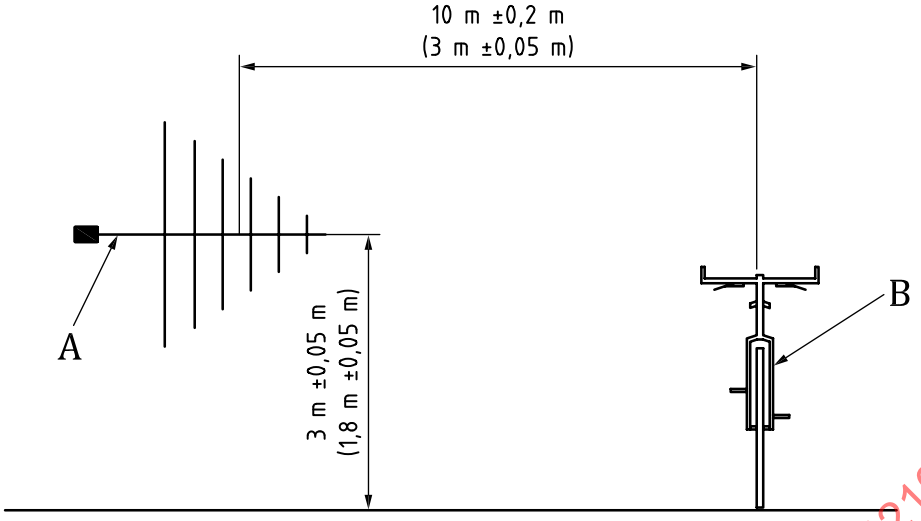
Antenna type in accordance with CISPR 12:2007, 5.1.3.

A.3.4 Test setup

Measuring distance, antenna height and antenna polarisations in accordance with CISPR 12:2007, 5.2.3.

The left and right side of the EPAC shall be measured.

There shall be no electrical connection between the EPAC and the test surface and no connections between the EPAC and the measuring equipment. Contact between the wheels and the test surface is not regarded as an electrical connection. Test setup is shown in Figure A.2.



Key

A antenna

B EPAC

Figure A.2 — Principle test setup for radiated emissions from EPACs

A.3.5 Test procedure and test method

In accordance with CISPR 12 as far as not otherwise stated in this annex.

A.3.6 Test requirements for broadband emissions

A.3.6.1 General

The radiated broadband emissions shall be measured in the 30 MHz to 1 000 MHz frequency range. The left and right side of the EPAC shall be measured with the antenna in horizontal and vertical polarisation.

A.3.6.2 Detector

A quasi-peak detector in accordance with CISPR 16-1-1 shall be used to measure broadband electromagnetic radiation. For time efficiency it is possible to use a peak detector. Any peak measurements with results at or above the quasi-peak limit shall be re-measured using the quasi-peak detector.

A.3.6.3 EPAC state during test

The EPAC shall be driven on a dynamometer without load or minimum possible load at 100 % of the design maximum assistance speed (EPAC operating with motor assistance, “engine running”). All EPAC systems including light shall be activated.

NOTE CISPR 12 states “shall be tested with the vehicle driven on a dynamometer without a load” for vehicles with an electric propulsion motor, but an EPAC can require a low load to enable proper operation of the motor assistance.

A.3.7 Test requirements for narrow-band emissions

A.3.7.1 General

The radiated narrow-band emissions shall be measured in the 30 MHz to 1 000 MHz frequency range. The left and right side of the EPAC shall be measured with the antenna in horizontal and vertical polarisation.

A.3.7.2 Detector

An average detector in accordance with CISPR 16-1-1 shall be used to measure narrowband electromagnetic radiation.

A.3.7.3 EPAC state during test

The EPAC shall be operated in standstill mode: All EPAC systems including light activated, EPAC ready to be started, but no assistance given by the motor ("key on, engine off").

A.4 Methods of testing EPAC immunity to electromagnetic radiation

A.4.1 General

This test is intended to demonstrate the immunity of the EPAC electronic systems. The EPAC shall be subject to electromagnetic fields as described in this Annex. The EPAC shall be monitored during the tests. As far as not otherwise stated in this annex the test shall be performed in accordance with ISO 11451-2.

A.4.2 Test location

In accordance with ISO 11451-2:2015, Clause 5.

A.4.3 Test instrumentation

In accordance with ISO 11451-2:2015, Clause 6.

A.4.4 Test setup

In accordance with ISO 11451-2:2015, Clause 7 as far as not otherwise stated in this annex. There shall be no electrical connection between the EPAC and the test surface and no connections between the EPAC and the test equipment. Contact between the wheels and the test surface is not regarded as an electrical connection

A.4.5 Test procedure and test method

In accordance with ISO 11451-2:2015, Clause 8 as far as not otherwise stated in this annex.

A.4.6 Test requirements

A.4.6.1 Frequency range, dwell time, polarisation, modulation

The EPAC shall be exposed to electromagnetic radiation in the 20 MHz to 2 000 MHz frequency range in vertical polarisation.

The test signal modulation shall be:

a) AM (amplitude modulation) with 1 kHz modulation and 80 % modulation rate in accordance with ISO 11451-1 in the 20 MHz to 800 MHz frequency range, and

b) PM (pulse modulation) with 577 µs pulse width and 4 600 µs pulse repetition period in accordance with ISO 11451-1 in the 800 MHz to 2 000 MHz frequency range.

Frequency step size and dwell time shall be chosen in accordance with ISO 11451-1.

A.4.6.2 EPAC state during tests

The test shall be done in the following operating modes:

a) Standstill mode (all EPAC systems including light activated, EPAC ready to be started, but no assistance is given by the motor);

b) EPAC operating (with motor assistance) at 90 % of the design maximum assistance speed.

A.4.6.3 Reference point and position of EPAC

The front side of the EPAC shall be exposed to the electromagnetic fields. The reference point is the point at which the field strength shall be established and is defined as follows:

a) At least 2 m horizontally from the antenna phase centre or at least 1 m vertically from the radiating elements of the transmission-line-system (TLS);

b) On the EPAC's centre line (plane of longitudinal symmetry);

c) At a height of (1,0 ± 0,05) m above the plane on which the EPAC rests;

d) At (0,2 ± 0,2) m behind the vertical centreline of the EPAC's front wheel.

Annex B
(informative)

Electromagnetic compatibility of ESAs

B.1 Type testing procedures for ESAs

B.1.1 General

One of the following procedures for ESA type testing may be used.

B.1.2 Presumption of EPAC conformity by testing individual ESAs

The EPAC manufacturer may presume EPAC conformity with this Annex by demonstrating that all the relevant ESAs (ESAs which may emit significant broadband or narrowband radiation and/or which may affect the immunity of the EPAC) have met the ESA requirements laid down in B.2 and have been installed in accordance with the manufacturer's specification.

NOTE The ESA emission limits and the ESA immunity test levels have been selected much more severe than the corresponding EPAC limits and test levels in order to minimise the risk of getting a non conform EPAC when assembling several ESAs to an EPAC.

B.1.3 Testing of ESA as part of an EPAC

An ESA may be type tested as part of a typical EPAC by testing the EPAC in accordance with A.2.

B.2 ESA requirements

B.2.1 General

If an individual ESA is tested, the ESA shall fulfil the ESA requirements of this Annex under normal conditions of use. ESA(s) shall be tested for radiated emissions and for immunity to radiated disturbances. Tests for conducted emissions or immunity to conducted disturbances are not required.

NOTE Battery chargers of EPACs are under the scope of appropriate product or generic standards.

B.2.2 Test plan

Prior to performing the tests, a test plan should be generated containing at least mode of operation, stimulated function(s), monitored function(s), pass/fail criteria and, for intentional radiators, intended emissions.

B.2.3 Broadband electromagnetic radiation from ESAs

B.2.3.1 Method of measurement

The electromagnetic radiation generated by the ESA representative of its type shall be measured by the method described in B.3.

B.2.3.2 ESA broadband limits

If measurements are made using the method described in B.3, the limits shall be 32 dB(µV/m) in the 30 MHz to 75 MHz frequency band and 32 dB(µV/m) to 43 dB(µV/m) in the 75 MHz to 400 MHz band,

this limit increasing logarithmically with frequencies above 75 MHz (see Table B.1 and Figure B.1). In the 400 MHz to 1 000 MHz frequency band the limit remains constant at 43 dB(µV/m).

On the ESA representative of its type, the measured values, expressed in dB(µV/m), shall be below the ESA broadband limits stated above.

B.2.4 Narrowband electromagnetic radiation from ESAs

B.2.4.1 Method of measurement

The electromagnetic radiation generated by the ESA representative of its type shall be measured by the method described in B.3.

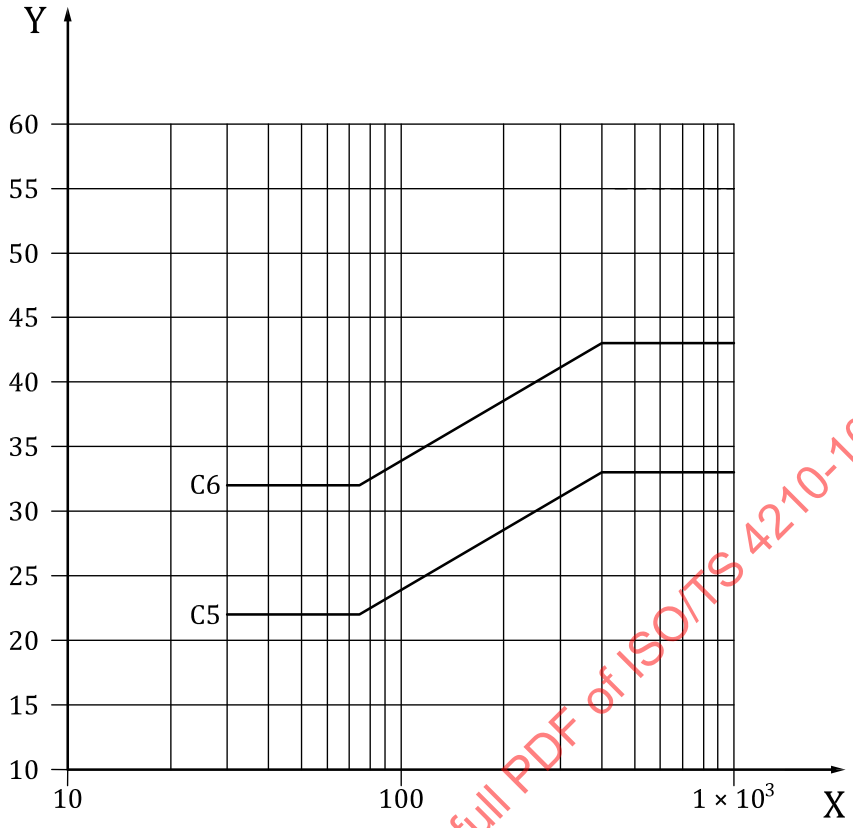
B.2.4.2 ESA narrowband limits

If measurements are made using the method described in B.3, the limits shall be 22 dB(µV/m) in the 30 MHz to 75 MHz frequency band and 22 dB(µV/m) to 33 dB(µV/m) in the 75 MHz to 400 MHz band, this limit increasing logarithmically with frequencies above 75 MHz (see Table B.1 and Figure B.1). In the 400 MHz to 1 000 MHz frequency band the limit remains constant at 33 dB(µV/m).

On the ESA representative of its type, the measured value, expressed in dB(µV/m) shall be below the ESA narrowband limits stated above.

B.2.5 Overview of radiated emission limits for ESAs

Radiated emission limits for ESAs are shown in Figure B.1 and Table B.1.



Key

X frequency f in MHz
Y field strength limit in dB (µV/m)
C5 narrowband radiation emission limit for ESAs, antenna at 1 m
C6 broadband radiation emission limit for ESAs, antenna at 1 m

NOTE 1 The limits are derived from the EPAC limits by first converting the EPAC limits to 1 m distance (by means of applying a distance correction factor of 20 dB per decade) and then reducing them by 20 dB.

NOTE 2 The limits take into account measurement uncertainties.

Figure B.1 — Radiated emission limits for ESAs

Table B.1 — Radiated emission limits for ESAs

Curve No.	Disturbance category	Detector acc. to CISPR 16-1-1	Measurement distance m	Equation for limit [dB(µV/m)] with frequency, f [MHz]		
				$30 \le f \le 75$	$75 < f < 400$	$400 \le f \le 1\,000$
C5	Narrowband	Average	1	22	$22 + 15{,}13 \cdot \log(f/75)$	33
C6	Broadband	Quasi-peak	1	32	$32 + 15{,}13 \cdot \log(f/75)$	43

B.2.6 ESA immunity to electromagnetic radiation

B.2.6.1 Method of testing

The immunity to electromagnetic radiation of the ESA representative of its type shall be tested by the method(s) chosen from those described in B.4.

B.2.6.2 Performance criteria and monitoring

The ESA shall continue to operate as intended during and after the test. No degradation of performance or loss of function is allowed below a performance level specified by the ESA manufacturer, when the

ESA is used as intended. If the minimum performance level is not specified by the ESA manufacturer, it may be derived from the product description and documentation and what the user may reasonably expect from the ESA if used as intended.

B.2.6.3 ESA immunity test levels

If tests are made using the methods described in B.4, the immunity test levels shall be 120 mA rms for the bulk current injection (BCI) testing method and 60 V/m rms for the free field testing method in over 90 % of the 20 MHz to 2 000 MHz frequency band, and to a minimum of 100 mA rms for the bulk current injection (BCI) testing method and 50 V/m rms for the free field testing method over the whole 20 MHz to 2 000 MHz frequency band.

The ESA representative of its type shall be considered as conforming to the immunity requirements, if during the tests performed in accordance with B.4, the performance criteria in accordance with B.2.6.2 are fulfilled.

B.3 Method of measurement of radiated electromagnetic emissions from ESAs

B.3.1 General

This test is intended to measure the radiated broadband and narrow-band emissions from ESAs (electric motors, microprocessor-based systems etc.).

As far as not otherwise stated in this Annex the test shall be performed in accordance with CISPR 25.

B.3.2 Drive system component (usually non 12 V)

A drive system component is an ESA which is essentially required to enable the electric motor assistance of the EPAC.

B.3.3 Simulator box

To ensure correct operation of the drive system components, a simulator box shall be used which simulates the residual EPAC system. The simulator box is a shielded enclosure that contains all external electrical interfaces (sensors, loads, battery etc.) normally seen by the ESA. The simulator box also serves as an RF boundary for the ESA cable harness (common mode impedance and/or differential mode impedance for each input/output connected to the ESA) and as an interface to potentially required support and monitoring equipment. The metallic case of the simulator box shall be electrically bonded to the test setup ground plane (via screws, ground straps and/or copper tape with conductive adhesive). In normal cases the components inside the simulator box shall be insulated from the metallic case of the simulator box by means of a 5 cm high non-conductive, low relative permittivity support. Only in case of components with metallic case which are designed to be directly bonded to the metallic EPAC frame, an electrical low impedance connection to the case of the simulator box may be considered.

The simulator box has to be located inside the test location. Therefore, the disturbance levels generated by the simulator box shall be at least 6 dB below the specified test limits and the immunity of the simulator box has to be above the specified test levels.

B.3.4 Test location

Absorber-lined shielded enclosure (ALSE) in accordance with CISPR 25:2016, 4.3.

B.3.5 Measuring equipment

In accordance with CISPR 25:2016, 4.4.

Measuring instrument parameters in accordance with CISPR 25:2016, 4.4.3 (use of scanning receiver) or 4.4.2 (use of spectrum analyser), respectively.

Antenna types in accordance with CISPR 25:2016, 6.5.2.2.

B.3.6 Test setup

Test setup (including measuring distance, antenna height, antenna polarisations, ESA location, length of test harness etc.) in accordance with CISPR 25:2016, 6.5.2 and Figures 16 and 17 as far as not otherwise stated in this Annex.

B.3.6.1 12 V load components

Additions to/deviations from CISPR 25 setup:

— The case of the ESA shall not be grounded to the reference ground plane. Only in case of an ESA with metallic case which is designed to be directly bonded to the metallic EPAC frame, grounding to the reference ground plane may be considered;

— The power return line/the power supply minus terminal shall not be connected to the reference ground plane.

B.3.6.2 Drive system components

Additions to/deviations from CISPR 25 setup:

— The case of the ESA shall not be grounded to the reference ground plane. Only in case of an ESA with metallic case which is designed to be directly bonded to the metallic EPAC frame, grounding to the reference ground plane may be considered;

— No use of power supply (outside simulator box), automotive battery and artificial network;

— Neither the minus terminal nor the plus terminal of the battery (may be the ESA under test or a component inside the simulator box) shall be connected to the reference ground plane;

— The “load simulator” has to be replaced by the simulator box. The simulator box shall be placed on the reference ground plane and shall be bonded to it.

B.3.7 Test procedure and test method

In accordance with CISPR 25:2016, 6.5.1 and 6.5.3 as far as not otherwise stated in this annex.

B.3.8 Test requirements for broadband emissions

B.3.8.1 General

The radiated broadband emissions shall be measured in the 30 MHz to 1 000 MHz frequency range with the antenna in horizontal and vertical polarisation.

B.3.8.2 Detector

A quasi-peak detector in accordance with CISPR 16-1-1 shall be used to measure broadband electromagnetic radiation. For time efficiency it is possible to use a peak detector. Any peak measurements with results at or above the quasi-peak limit shall be re-measured using the quasi-peak detector.

B.3.8.3 ESA state during test

In accordance with CISPR 25:2016, 4.1.4 and 6.5.3 as far as not otherwise stated in this annex.

B.3.9 Test requirements for narrow-band emissions

B.3.9.1 General

The radiated narrow-band emissions shall be measured in the 30 MHz to 1 000 MHz frequency range with the antenna in horizontal and vertical polarisation.

B.3.9.2 Detector

An average detector in accordance with CISPR 16-1-1 shall be used to measure narrowband electromagnetic radiation.

B.3.9.3 ESA state during test

In accordance with CISPR 25:2015, 4.1.4 and 6.5.3 as far as not otherwise stated in this annex.

B.4 Methods of testing ESA immunity to electromagnetic radiation

B.4.1 General

This test is intended to demonstrate the immunity of the ESA. The ESA shall be subject to electromagnetic fields as described in this Annex. The ESA shall be monitored during the tests. As far as not otherwise stated in this annex the test shall be performed in accordance with ISO 11452-2 or ISO 11452-4, respectively.

B.4.2 Drive system component (usually non 12 V)

See B.3.2.

B.4.3 Simulator box

See B.3.3.

B.4.4 BCI test method, 20 MHz to 200 MHz frequency range

B.4.4.1 Test location

In accordance with ISO 11452-4:2011, Clause 5.

B.4.4.2 Test instrumentation

In accordance with ISO 11452-4:2011, Clause 6.

B.4.4.3 Test setup

In accordance with ISO 11452-4:2011, Clause 7 and Figure 1 as far as not otherwise stated in this annex.

B.4.4.3.1 12 V load components

Additions to/deviations from ISO 11452-4 setup:

— The case of the ESA shall not be grounded to the ground plane. Only in case of an ESA with metallic case which is designed to be directly bonded to the metallic EPAC frame, grounding to the ground plane may be considered;

— The power return line/the power supply minus terminal shall not be connected to the ground plane.

B.4.4.3.2 Drive system components

Additions to/deviations from CISPR 25 setup:

— The case of the ESA shall not be grounded to the ground plane. Only in case of an ESA with metallic case which is designed to be directly bonded to the metallic EPAC frame, grounding to the ground plane may be considered;

— No use of power supply (outside simulator box), automotive battery and artificial network;

— Neither the minus terminal nor the plus terminal of the battery (may be the ESA under test or a component inside the simulator box) shall be connected to the ground plane;

— The “load simulator” has to be replaced by the simulator box. The simulator box shall be placed on the ground plane and shall be bonded to it.

B.4.4.4 Test procedure and test method

In accordance with ISO 11452-4:2011, Clause 8 and 6.1.

The substitution method in accordance with ISO 11452-4:2011, 8.3.1.2 shall be used.

B.4.4.5 Test requirements

B.4.4.5.1 Frequency range, dwell time, modulation, ports under test

— The ESA shall be tested to BCI in the 20 MHz to 200 MHz frequency range;

— The test signal modulation shall be AM (amplitude modulation) with 1 kHz modulation and 80 % modulation rate in accordance with ISO 11452-1;

— Frequency step size and dwell time shall be chosen in accordance with ISO 11452-1;

— All ports of the ESA shall be tested:

  a) Ports to be tested separately (cable of one port inside injection clamp, only);

  b) Ports to be tested together (all cables inside injection clamp).

— The injection clamp shall be placed at 15 cm from the ESA’s port(s) under test;

— The current monitoring probe shall to be used and shall be placed at 5 cm from the ESA’s port(s) under test.

B.4.4.5.2 ESA state during tests

In accordance with ISO 11452-4:2011, 6.1.4.

B.4.5 ALSE test method, 200 MHz to 2 000 MHz frequency range

B.4.5.1 Test location

In accordance with ISO 11452-2:2004, Clause 5.

B.4.5.2 Test instrumentation

In accordance with ISO 11452-2:2004, Clause 6.

B.4.5.3 Test setup

B.4.5.3.1 General

In accordance with ISO 11452-2:2004, Clause 7 and Figures 1 to 3 as far as not otherwise stated in this Annex.

B.4.5.3.2 12 V load components

Additions to/deviations from ISO 11452-2 setup:

— The case of the ESA shall not be grounded to the ground plane. Only in case of an ESA with metallic case which is designed to be directly bonded to the metallic EPAC frame, grounding to the ground plane may be considered;

— The power return line/the power supply minus terminal shall not be connected to the ground plane.

B.4.5.3.3 Drive system components

Additions to/deviations from CISPR 25 setup:

— The case of the ESA shall not be grounded to the ground plane. Only in case of an ESA with metallic case which is designed to be directly bonded to the metallic EPAC frame, grounding to the ground plane may be considered;

— No use of power supply (outside simulator box), automotive battery and artificial network;

— Neither the minus terminal nor the plus terminal of the battery (may be the ESA under test or a component inside the simulator box) shall be connected to the ground plane;

— The “load simulator” has to be replaced by the simulator box. The simulator box shall be placed on the ground plane and shall be bonded to it.

B.4.5.4 Test procedure and test method

In accordance with ISO 11452-2:2004, Clause 8.

B.4.5.5 Test requirements

B.4.5.5.1 Frequency range, dwell time, modulation, ESA orientations

— The ESA shall be exposed to electromagnetic radiation in the 200 MHz to 2 000 MHz frequency range;

— The test shall be performed with horizontal and vertical antenna polarisation;

— The test signal modulation shall be:

  a) AM (amplitude modulation) with 1 kHz modulation and 80 % modulation rate in accordance with ISO 11452-1 in the 200 MHz to 800 MHz frequency range;

  b) PM (pulse modulation) with 577 µs pulse width and 4 600 µs pulse repetition period in accordance with ISO 11452-1 in the 800 MHz to 2 000 MHz frequency range.

— Frequency step size and dwell time shall be chosen in accordance with ISO 11452-1;

— ESA orientations:

  a) 1 ESA orientation with ESA’s connector side faced to front edge of ground plane in the 200 MHz to 1 000 MHz frequency range (antenna phase centre in line with centre of wiring harness);

b) 3 orthogonal ESA orientations (if possible) in the 1 000 MHz to 2 000 MHz frequency range (antenna phase centre in line with ESA).

B.4.5.5.2 ESA state during tests

In accordance with ISO 11452-2:2004, 8.1.

Annex C
(normative)

The battery chargers for non-proprietary system

C.1 General

This annex contains the description of the protocol and the mechanical interface for non-proprietary systems for EPACs, as described in 6.4.3.

The battery chargers for non-proprietary system shall be applied to Table C.1. Manufacturers and/or service providers of non-proprietary system may select System A or System B in this annex.

Table C.1 — Subclause table for each system

Type of system	System A	System B
Type of System (General)	C.2	C.3
System Configuration	C.2.1	C.3.1
Functions	C.2.2	C.3.2
Operating Condition	C.2.3	C.3.3
Specifications (mechanical/electrical)	C.2.4	C.3.4
Communication Media	C.2.5	C.3.5
Communication protocol	C.2.6	C.3.6

Moisture resistance of a non-proprietary system shall be designed to be in accordance with IPX4.

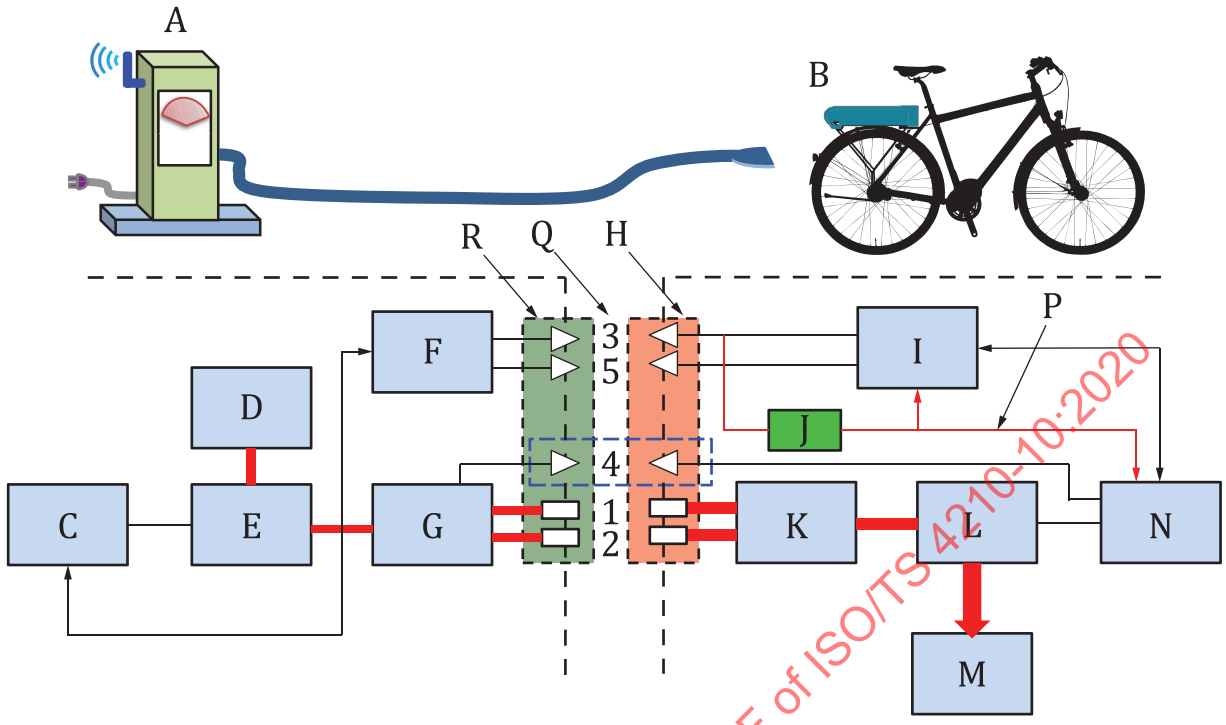
C.2 System A

C.2.1 System Configuration

C.2.1.1 System Diagram

Figure C.1 shows a connection diagram for the charger, EPAC and battery. This non-proprietary system shall be adapted the 5 terminals to connect between EPAC and charger.

NOTE This charger may be connect to the battery instead of EPAC.



Key

A	battery charger for non-proprietary system
B	EPAC
C	micro processing unit (MPU)
D	power supply unit
E	voltage and current controller
F	power line communication (PLC) controller
G	circuit protection
H	charger inlet
I	PLC controller
J	power supply
K	circuit protection
L	charging controller
M	EPAC battery
N	MPU
P	VDD
Q	No. of pins
R	charger connector
1 to 5	See Table C.5

Figure C.1 — Block diagram of non-proprietary system

EPAC and charger shall be connected with five terminals (see C.2.4.1.5). First the two terminals to supply EPAC with electric power (DC+, GND_{DC}). Next are two terminals for communication between EPAC and charger (PLC+, G_{PLC}). And the remaining one terminal to detect the connection (MON).

In this system, after negotiation via communication between EPAC and charger, charger shall supply the electric power to DC+ by EPAC permission. These actions are performed while charger detects the connection via the charger connector and charger inlet. When the charger detects the disconnection, it shall stop to supply electric power immediately.

Safety functions against electrical malfunctions shall be equipped for EPAC and chargers.

C.2.1.1.1 Master unit

In this system, EPAC shall be designed to control the non-proprietary system charger. The non-proprietary system charger shall be designed to connect and charge maximum 29 EPACs via the address management.

This system shall have only one master unit. Two or more master units shall not be permitted.

The master unit as EPAC, which connects to the non-proprietary system charger first, shall be given the address 0. The address 0 shall only be assigned on the local network of the non-proprietary system charger.

The master unit shall always send Beacon periodically to inform that it is ready for communication. The communication is described in C.2.2.1 when any EPAC is connected to the network of the non-proprietary system charger.

The master unit shall assign the address for next EPAC on the network, and the network shall be designed not to have the same address.

C.2.1.1.2 Logical unit

Those units connected to the network other than the master unit are called logical units. A logical unit given an address by the master unit on the network can receive the Beacon signal sent from the master and send the data onto slot having its own address.

C.2.2 Functions

C.2.2.1 Dynamic attach and detach

The act of plugging or unplugging a logical device shall not affect the functionality of another device on other segments of the network. Unplugging a device will stop any transactions in progress between that the logical unit and the master unit.

The logical unit can be connected and disconnected while the power is ON (hot plugging). When detected that any new logical unit is connected, the master unit assign each new addresses to new logical unit.

When the master unit is disconnected from the network, it cannot communicate.

C.2.2.2 Error management of the system

C.2.2.2.1 General

When problems occur in the non-proprietary system, EPAC and charger shall operate safely. The error management system shall provide procedures and means to properly deal with problems occurring between EPAC and charger.

C.2.2.2.2 Definition of errors

The CHECK CONDITION status in Table C.3 has Sense Keys for showing more detailed information. The following Table C.2 shows a list of Sense Keys.

S1 means Sense Key. Sense Key is a category of errors. S2 is an ID of each error.

If any of the following conditions occur during the execution of a command, the logical unit shall return CHECK CONDITION status. The appropriate Sense Key and additional sense code shall be set. The

following list illustrates some error conditions and the applicable Sense Keys. The list does not provide an exhaustive enumeration of all conditions that may cause the CHECK CONDITION status.

Table C.2 — Definition of errors

S1	Type of parameter	Reference
00	Status Good	
01	Caused by charger	
02	Caused by communication	
03	Caused by hard	
04	ILLEGAL REQUEST	
50	Errors not categorise	
80	VENDOR SPECIFIC	

C.2.2.2.3 Basic Error code

The following Table C.3 shows a list of basic error codes.

Table C.3 — Basic error list

S1	S2	Description	Type
00	00	No additional sense code (Good)	General
01	10	low voltage	charge
01	11	over voltage	charge
01	12	low current	charge
01	13	over current	charge
01	14	low temperature	charge
01	15	over temperature	charge
01	16	no match the type of battery	charge
01	17	can't recognized the battery	charge
02	00	busy	
02	01	wait	
02	10	no authentication	N/A
02	11	Connection Error	communication
02	12	timeout error	communication
02	24	Invalid field in CDB	
04	00	CHECK CONDITION	
04	01	Unsupported option requested	
04	02	Invalid Page Code	
50	00	other error	
80	xx	VENDOR SPECIFIC	
All codes not shown are reserved.			

C.2.2.2.4 Error of over voltage and over current

The following Figure C.2 shows transaction of over voltage error for example. The following figure explains over voltage as an example. It is also same transaction in case of over current.

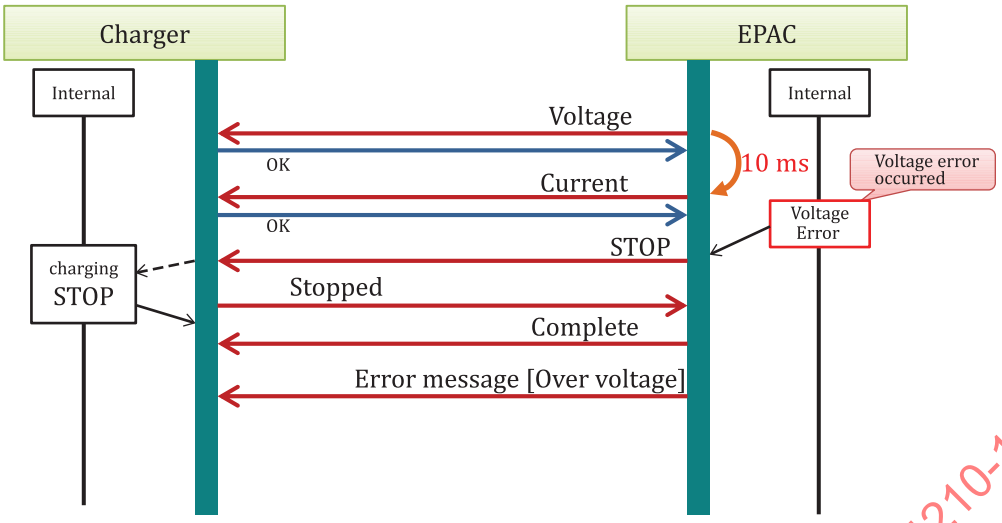


Figure C.2 — Case of over voltage and over current error

C.2.2.2.5 Error of over temperature and under temperature

The following Figure C.3 shows transaction of over temperature error for example. The following figure explains over temperature as an example. It is also same transaction in case of under temperature.

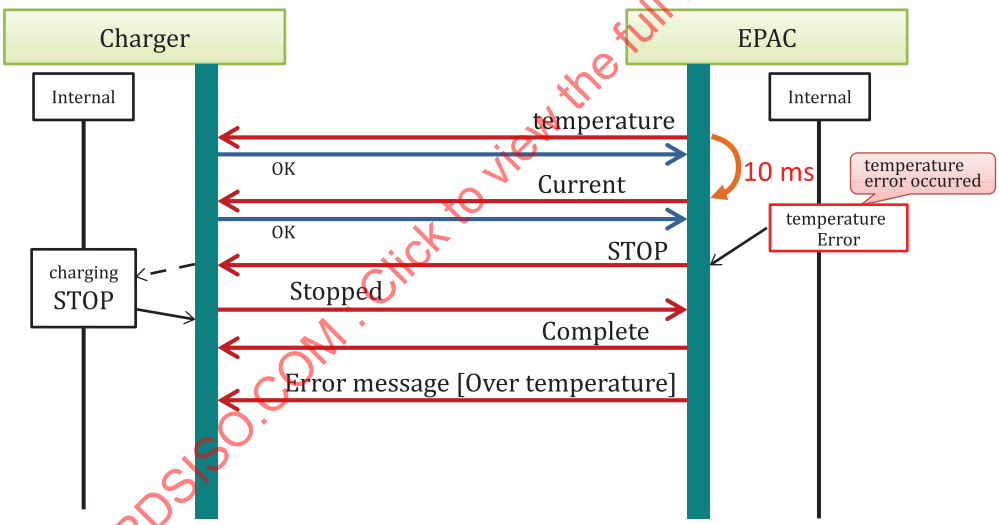


Figure C.3 — Case of over temperature

C.2.2.2.6 Error reporting

This Annex lists error codes that may be generated by logical units. Specific commands specify that certain errors occur in response to certain conditions, but each command does not contain a comprehensive list of possible error conditions.

Although a particular command lists a set of errors, some of those errors may be typically reported to a subsequent command due to deferred error reporting.

C.2.2.2.7 Error tables

Table C.2 lists errors that may occur at any time, typically in response to a protocol or hardware error or user intervention.

C.2.3 Operating conditions

C.2.3.1 General

The operating and storage conditions of the charger shall be guaranteed normal operation under the conditions described in Table C.4.

Table C.4 — Operating and storage condition(environment)

	Conditions	Units	MIN	MAX
Temperature	Operating	°C	–10	50
	Storage	°C	–20	70
Humidity (no condensation)	Operating	%	30	80
	Storage	%	15	90

C.2.3.2 Latency tolerance messaging

In communication between EPAC and charger, it shall shorten the communication delay time as much as possible. For this reason, latency tolerance messaging should be designed up to 40 ms. If there is no response from the transmission partner even if it exceeds the latency tolerance messaging time, the transmitted device will handle it as timeout error.

For signal deterioration, temporary abnormality, etc. on the communication path may occur, so the receiving apparatus immediately returns a reception completion signal for each transmission slot. If the reception completion signal does not return to the slot, the transmission device transmits the data again.

C.2.4 Specifications (mechanical/electrical)

C.2.4.1 Charger inlet and charger connector

C.2.4.1.1 General

Charger inlet and charger connector used for non-proprietary system has power supply terminals, communication terminals, and connection detection terminals.

Charger connector shall have the durability of insertion and removable of 10 000 times or more. Charger inlet shall have the durability of insertion and removable of 3 000 times or more.

Charger inlet and charger connector shall have a structure to prevent miss-insertion.

C.2.4.1.2 Charger connector

Charger connector is shown in Figure C.4.

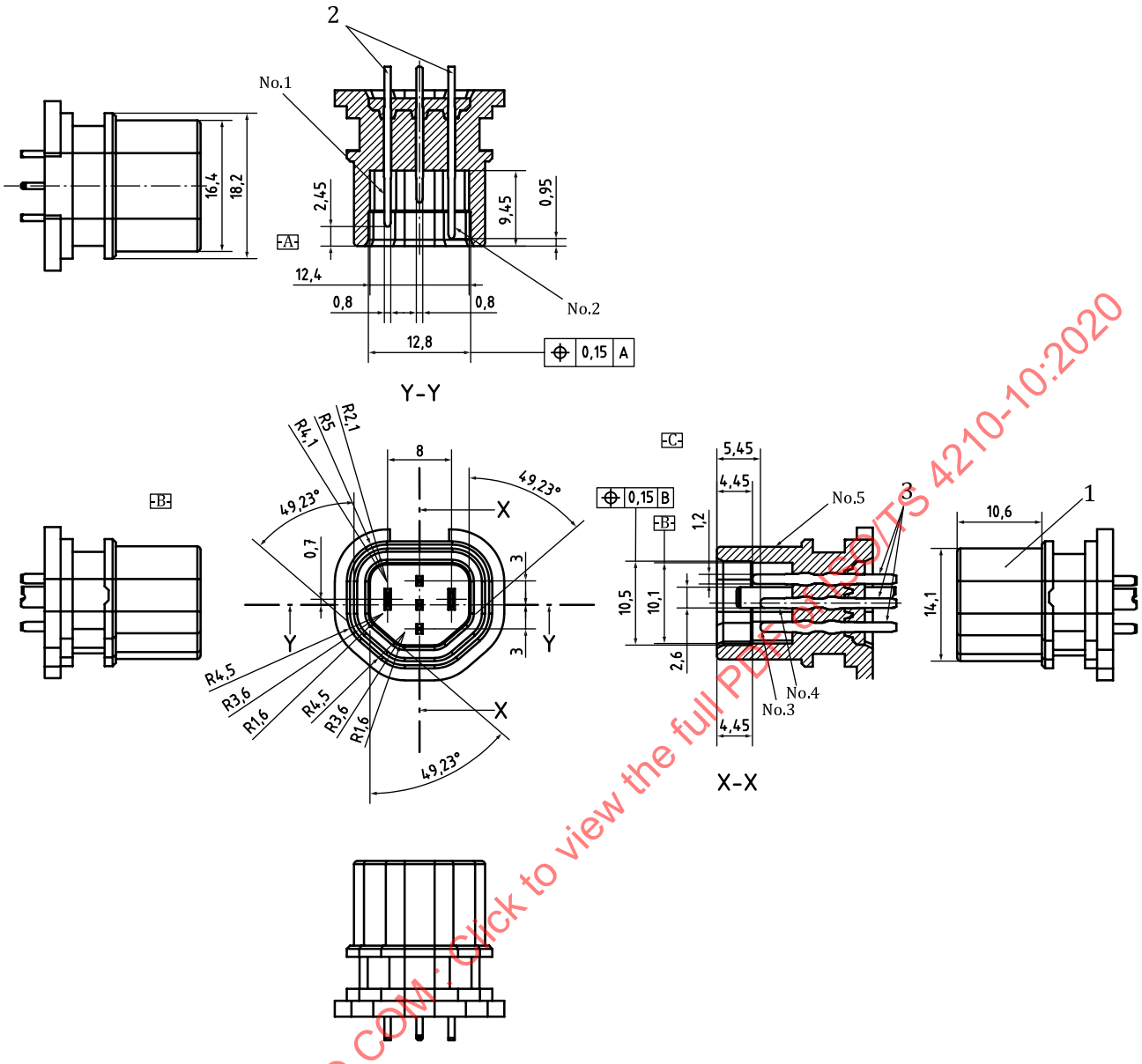


Figure C.4 — Charger connector (on the charger)

C.2.4.1.3 Charger inlet

Charger inlet shown in Figure C.5 is installed in a EPAC and can be used for charging.

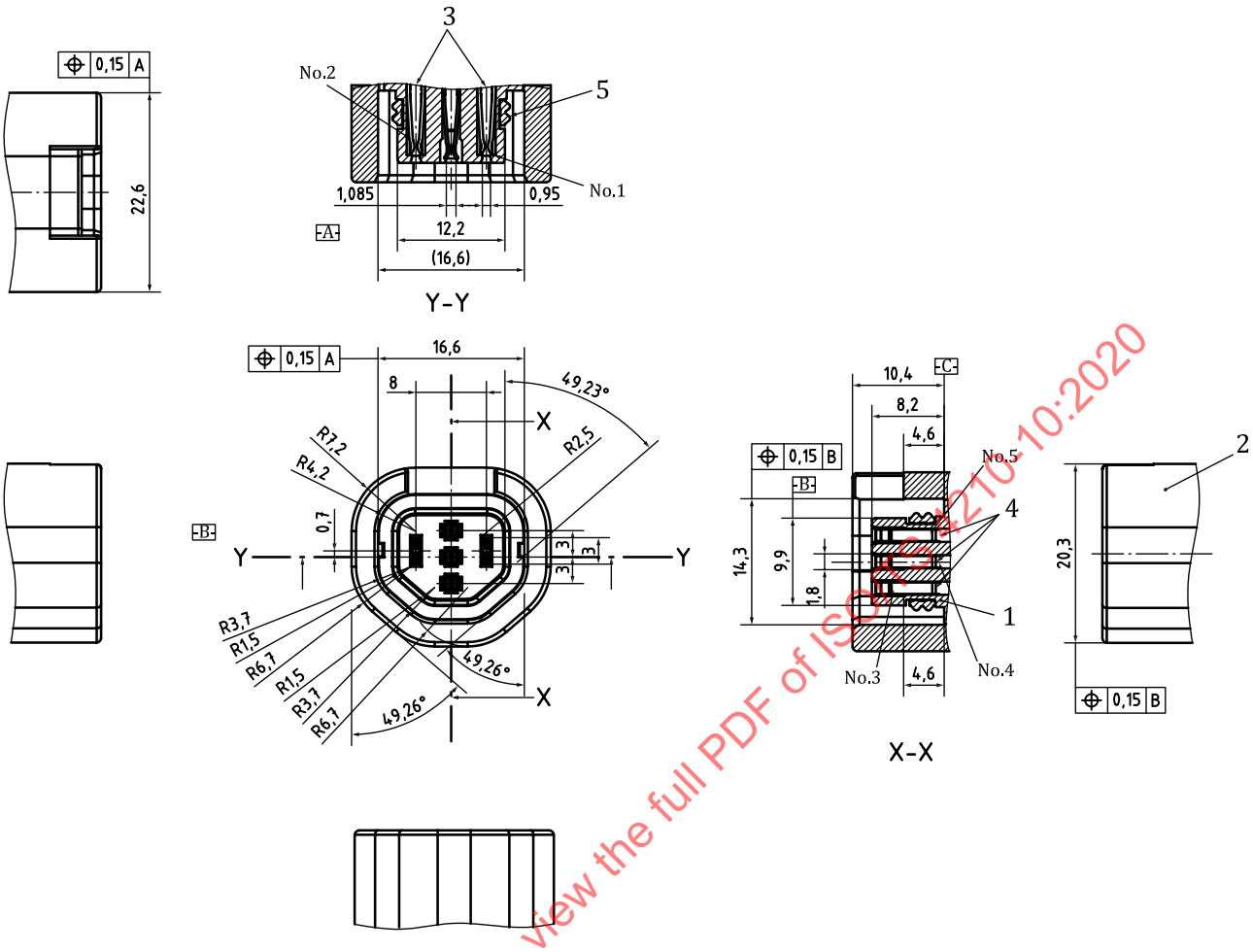


Figure C.5 — Charger inlet (on EPAC side)

C.2.4.1.4 Sample for the charger connector assembly

Figure C.6 shows a sample of charger connector assembly.

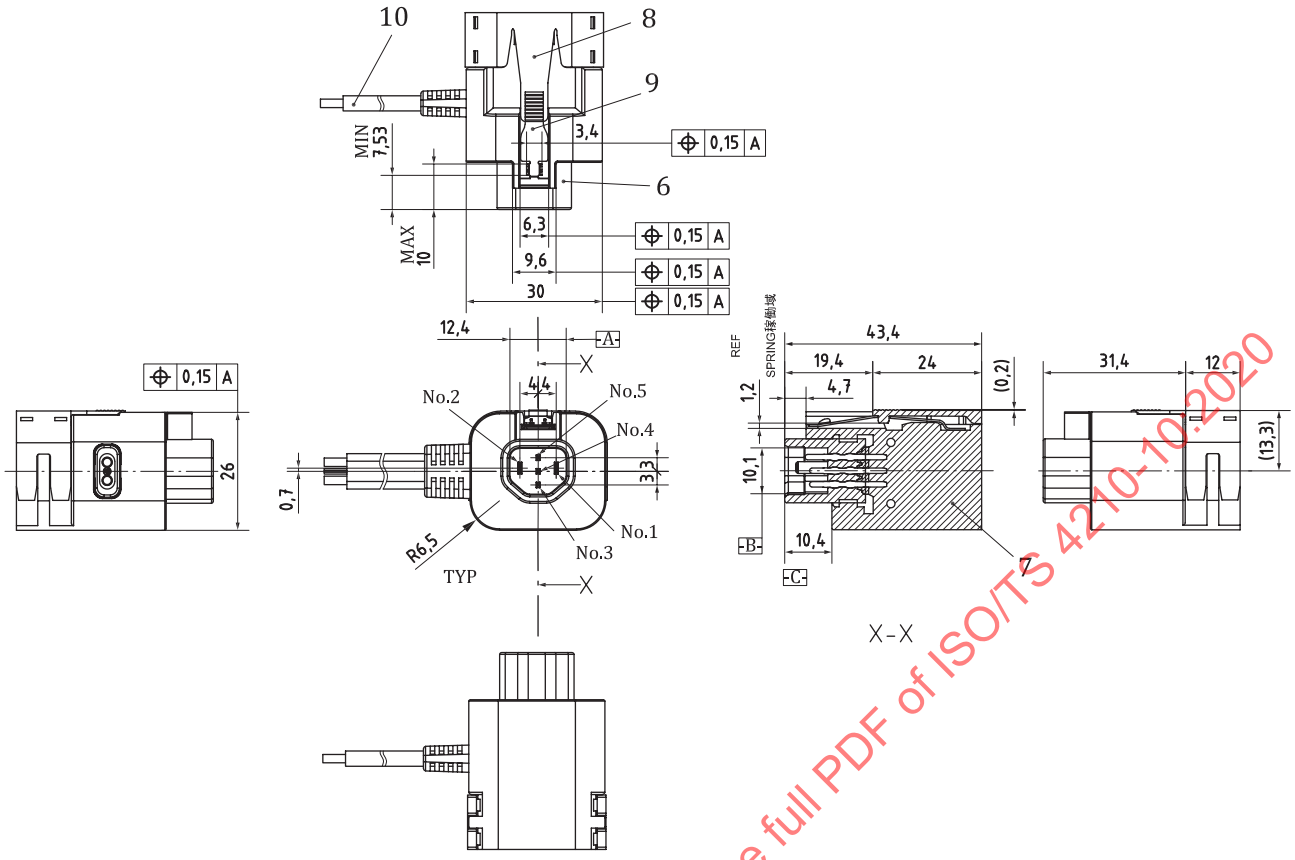


Figure C.6 — Sample for the charger connector assembly (on the charger)

C.2.4.1.5 Function of charger inlet and charger connector

The terminal arrangement of charger inlet and charger connector is shown in Table C.5. The terminal numbers shown in Figures C.4 to C.6 are as shown in Table C.5.

Table C.5 — Pin assignments and description

Pin No.	Charger connector	Charger inlet	Comment
1	Charging pin (DC+)	Charging pin (DC+)	These pins to supply electric power from the non-proprietary system charger
2	Charging pin (GND)	Charging pin (GND)	
4	Connection monitor pin (MON)	Connection monitor pin (MON)	This pin to detect the connection between EPAC and the non-proprietary system charger. Pull down resistor in the charger is larger than 1 kΩ. The terminal on the part of battery is driven to high by MPU.
3	Communication power pin (PLC+)	Communication (auxiliary) power pin (PLC+)	These pins are for PLC (Power Line Communication) communication.
5	Communication power pin (G_{PLC})	Communication (auxiliary) power pin (G_{PLC})	

To prevent malfunction of EPAC and charger, the Communication power pin (G_{PLC}) shall have the same electrical potential as the charging pin (GND). In addition, it shall protect the circuit on Communication power pin (G_{PLC}) when the charging pin (GND) is broken during charging.

The Connection monitor pin shall be designed with the specification in Table C.6.

Table C.6 — Monitor level specification

	Conditions	Units	MIN	TYP	MAX
Connection monitor pin Level	V_{OH}[a]	V	3,5		8,5
	V_{OL}[b]	V	−0,3		1,5

[a] V_{OH}: Output voltage high level.

[b] V_{OL}: Output voltage low level.

Connection monitor pin and Communication power pin (+) shall be equipped with each protection circuit so that the device will not be damaged even if charging voltage is accidentally applied.

C.2.4.1.6 DC and PLC Terminals Specification

The electrical characteristics of the DC and power line communication (PLC) pins are shown in Table C.7. The power supply for communication and the power supply for charging are separated, and voltage and current are specified for each.

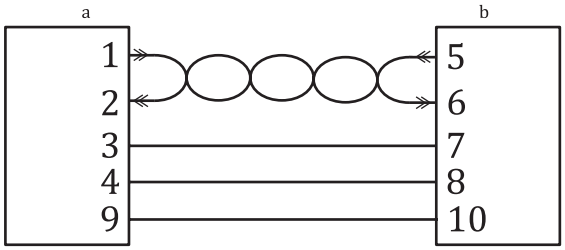
Table C.7 — Connector specification

		Rated power	Peak power
Power supply for charging	Voltage	60 V d.c.	60 V d.c.
	Current	40 A d.c.	40 A d.c.
Power supply for communication	Voltage	7,5 V d.c.	10 V d.c.
	Current	1 A d.c.	3 A d.c.

C.2.4.2 Cables

C.2.4.2.1 Cable characteristics

Figure C.7 shows examples of non-proprietary systems. Note that the figure does not depict all allowed configurations.



Key

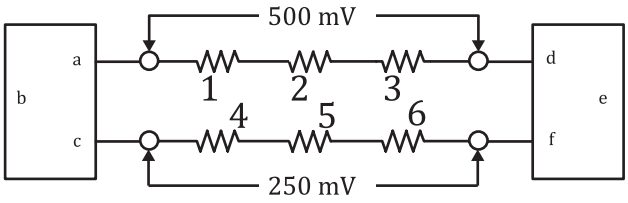
1 PLC+
2 G_{PLC}
3 Vch
4 GND
5 PLC+
6 G_{PLC}
7 Vch
8 GND
9 MON
10 MON
a Charger.
b EPAC.

Figure C.7 — Implementation example

C.2.4.2.2 Cable IR drop

The IR drop including the contact point of the connector and the cable is described in Figure C.8.

This non-proprietary system for charging shall be designed to be considered the voltage drop such as which is shown in Figure C.8.



Key

1 $R_{contact}$
2 R_{cable}
3 $R_{contact}$
4 $R_{contact}$
5 R_{cable}
6 $R_{contact}$
a PLC+.
b Source.
c GND.
d PLC+.
e Sink.
f GND.

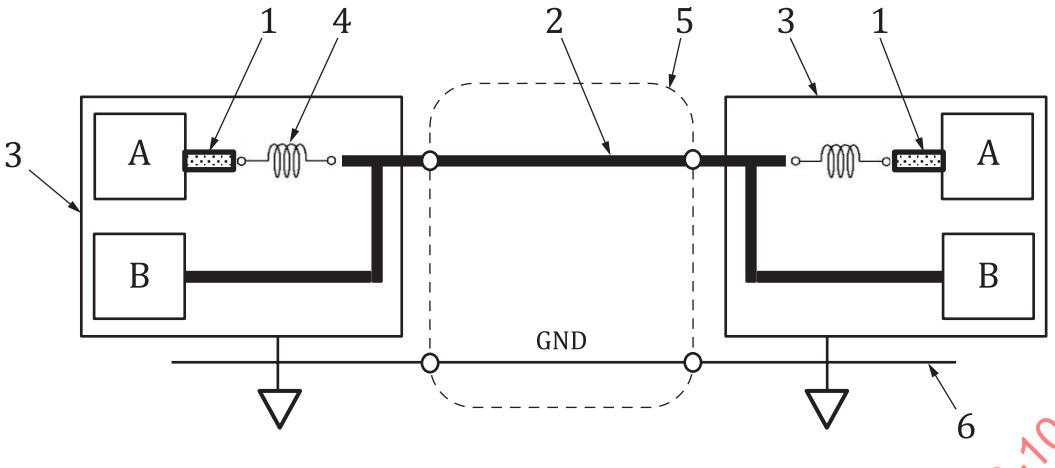
Figure C.8 — Cable IR drop

Figure C.8 illustrates what parameters contribute to the IR drop and where it shall be measured. The IR drop includes the contact resistance of the mated plug and receptacles at each end. In this case, source means battery charger and sink means the battery or EPAC.

C.2.4.2.3 PLC line

The PLC line is a method of transmitting communication and the power used for it by the same cable. The key 2 in Figure C.9 indicates that the communication power and the communication signal are transmitted together by this cable. This system shall be designed with cables which have sufficient impedance to transmit the signal for the frequency band of the signal to be transmitted.

The key 1 in Figure C.9 supply electric power for the communication circuit. This shall be designed for keeping low impedance to stabilize the power supply. Therefore, in order to isolate the signal frequency band to prevent noise of input signal, PLC apparatus may insert the inductance for separation as key 4 in Figure C.9.



Key

1 VDD with low impedance
2 VDD with high impedance at communication band (PLC+)
3 function unit
4 inductor
5 cable
6 signal GND (G_{PLC})
A power block
B communication circuit

Figure C.9 — Implementation specimen

C.2.4.2.4 Power line

To prevent performance degradation due to this voltage drop, EPAC shall be designed to measure the voltage of the power supply and to feedback the value to the charger. The charger shall control the output voltage so that its value becomes the desired voltage.

NOTE After the non-proprietary system charger is connected to the EPAC, a large current that voltage set by the charger flows through the cable and a large voltage drop (IR drop) can occur due to the impedance of the cable.

C.2.5 Communication media

C.2.5.1 PLC specification

The signal for communication shall be designed to multiplex with electrical power as PLC. The electrical characteristics of the PLC terminals shall be designed for 7,5 V d.c. and the maximum current 1,0 A (See Table C.8.).

In order to realize power supply and signal transmission on a common line, impedance near the carrier frequency of the signal of each device shall be designed to 50 Ω. Therefore, a circuit that switches impedance in the vicinity of the carrier frequency may be necessary between the low impedance power supply circuit system and the PLC system where the signal is superimposed (See C.2.4.2.3.).

Table C.8 — Operating condition (electric)

	Conditions	Units	MIN	TYP	MAX
Supply voltage	Nominal	V	6,5	7,5	8,5
Rated current	Nominal	A			1,0
Max current	<100 ms	A			4,5
Impedance of line	at 1 MHz	Ω		50	

C.2.5.2 Getting signals

Data is transmitted on the network at intervals of approximately 1 ms to 7 ms. Up to 32 Data Packets are sent within this interval. These packets are mixed with Unicast and Broadcast transmission type data. The receiving apparatus shall be designed to receive necessary information in the broadcast data which is sent to the network and to send the data via slot (which is depending on network address) which assigned to itself.

Minimum cycles of signals in this communication system are between about 1 ms to 7 ms. Transmitting apparatus shall handle signals within every 1 ms and send the transmitting data. This system can assign one unit to a slot. Each unit can communicate using the assigned slot.

C.2.5.3 Physical layer format

C.2.5.3.1 General

The format of communication used for PLC communication is shown below.

This PLC communication has frames as one unit and contains 32 slots in one frame. Only one logical unit is allocated to each of these 32 slots and communicates using the designated slot. By this method, even if multiple logical units simultaneously transmit signals, it is possible to communicate without collision.

The slot is composed of the header and the data. The slot 0 shall be assigned to the non-proprietary system charger, and the header of the slot is a signal having a special meaning of Beacon representing the beginning of each frame.

When each slot is correctly received at the destination, the receiving apparatus shall be designed to send back an ACK (Acknowledge) signal to notify the sender that it received correctly just after that slot.

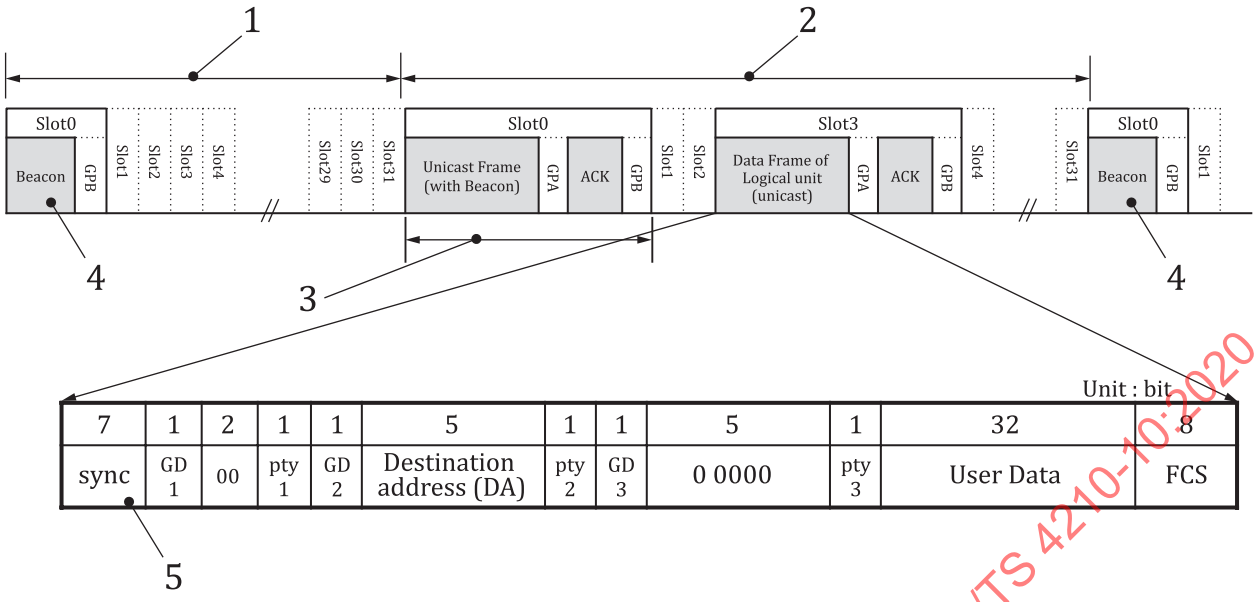
Signals (slot number) transmitted in each frame are not the same. Therefore, if the slots assigned to logical unit without data transmission, slot length are compressed. And it is shortening the frame transmission cycle.

As a result, the cycle of one frame of frame varies depending on the amount of data to be transmitted, and changes from a minimum of about 1 ms to a maximum of about 7 ms.

C.2.5.3.2 Frame format

A frame is composed of 32 slots from 0 to 31. Slot 0 is dedicated to master unit, and its Header is put as beacon. The frame format is shown in Figures C.10 to C.13.

Frame is variable length cycle depending on the amount of data transmitted at the same time. Item 1 in Figure C.10 represents the frame of the shortest period, and item 2 in Figure C.10 shows the case where there are transmission data in several slots.



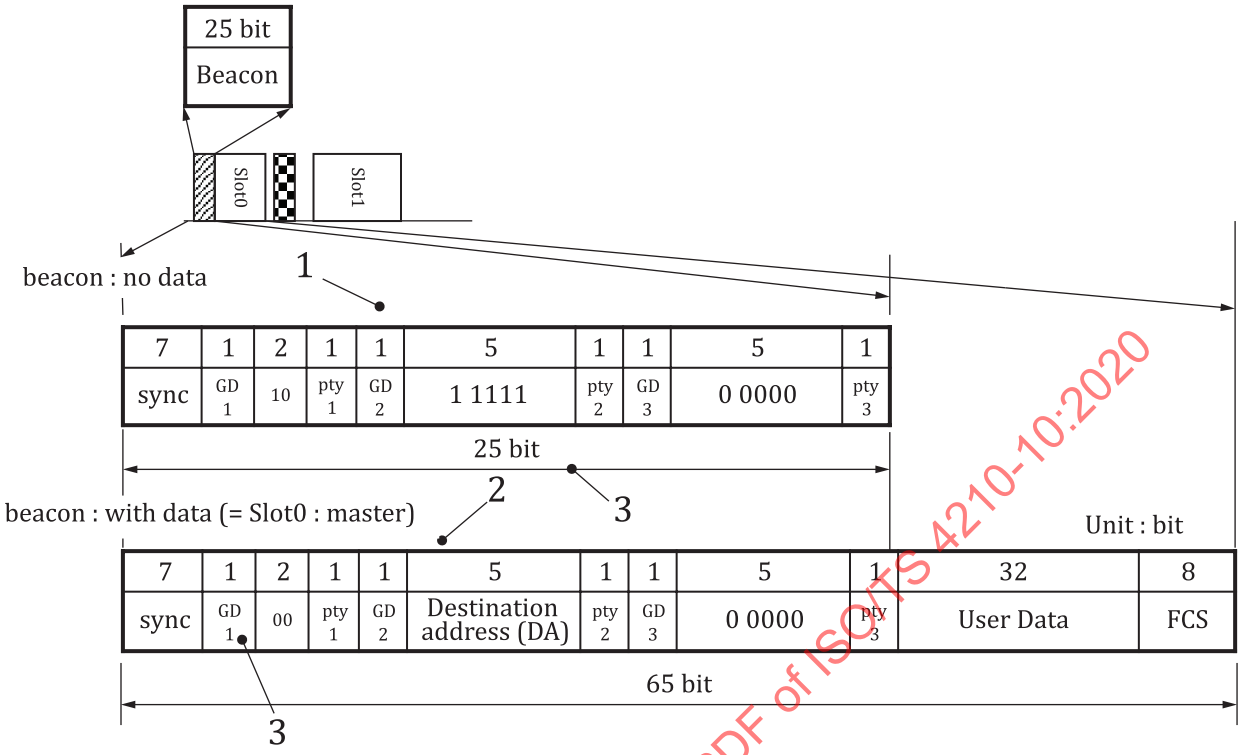
Key

1 frame (w/o data = min. cycle)
2 frame (with some data)
3 slot 0
4 beacon
5 sync

Figure C.10 — Frame format

C.2.5.3.3 Beacon

Figure C.11 shows the details of the beacon that is part of the data frame shown in Figure C.10.



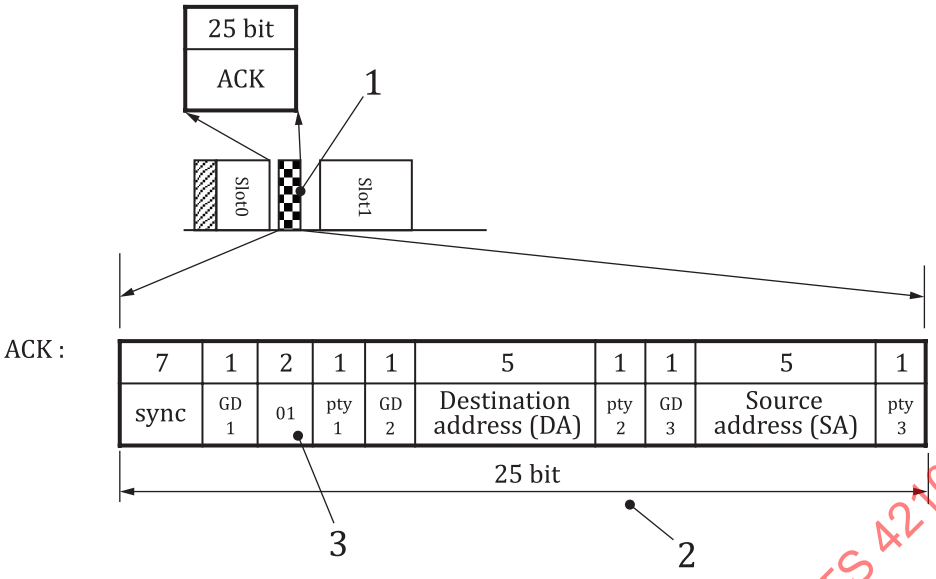
Key

1 beacon (without data)
2 beacon (with data)
3 type field

Figure C.11 — Beacon

C.2.5.3.4 Acknowledge (ACK)

Figure C.12 shows the details of the acknowledge (ACK) that is part of the data frame shown in Figure C.10.



Key

1 ACK
2 ACK (expanded)
3 type field

Figure C.12 — Acknowledge (ACK)

C.2.5.3.5 Description of format

Figure C.13 shows an overview of the data frame shown in Figure C.10.

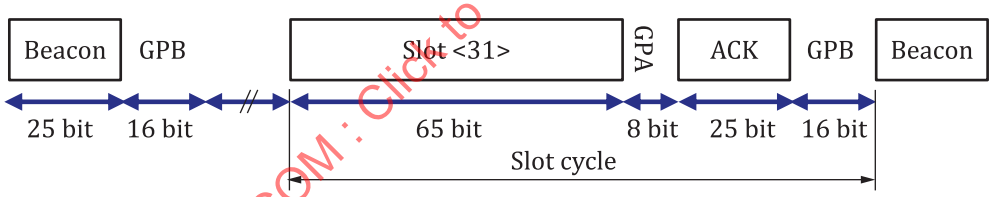


Figure C.13 — Description of format

C.2.5.3.6 Description of field

Table C.9 describes the parameters in the frame described in Figure C.10.

Table C.9 — Description of field

Field	bit	Description	mode
sync	7	Preamble pattern 1110011	fixed
GD1	1	Guard bit. reserved (always: 0, Beacon:1)	reserved (set to 0)
tp	2	Type field bit[1:0] 00:Reserved 01:ACK 10:beacon 11:DATA	
Parity1	1	parity1: Type field (ty) odd parity	
GD2	1	Guard bit. reserved (always: 0, Broadest:1)	reserved (set to 0)
DA	5	Destination Address	user area
Parity2	1	parity2: GD2 + DA odd parity	

Table C.9 *(continued)*

Field	bit	Description	mode
GD3	1	Guard bit. reserved (0)	reserved (set to 0)
SA	5	Source address (Self address): generate automatically	
Parity3	1	parity3: GD3 + SA odd parity	
data	32	Data field, ACK/Beacon frame is not include Data field.	user area
FCS	8	Frame Check Sequence. CRC-8-ATM, Error detection after Parity1.	

C.2.5.4 Data and waveform

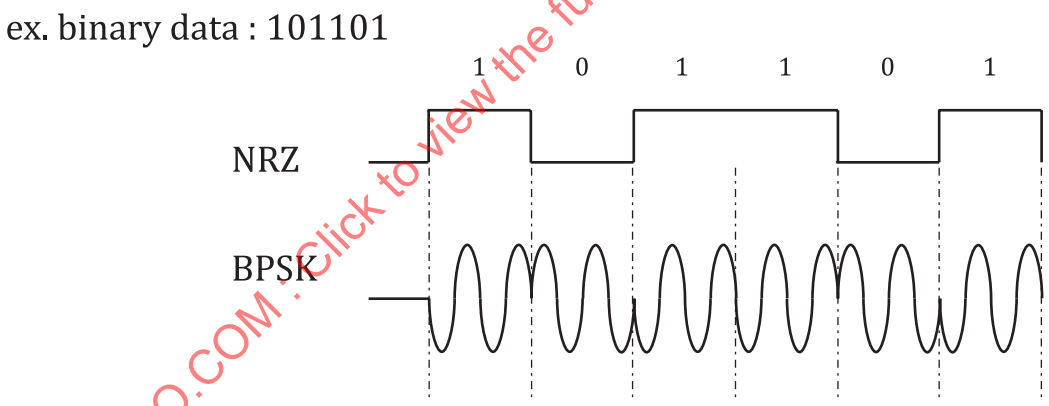
C.2.5.4.1 General

Describe the modulation method for data transmission. The data to be transmitted is BPSK (Biphase shift keying) modulated and sent on the transmission line.

C.2.5.4.2 BPSK

This BPSK modulated data shall be transmitted as one modulation unit for each waveform of two periods. Change in phase is informed by inverting the phase at two places, 0° and 180°, on the sine wave.

An example of BPSK modulation used in this communication method is shown in Figure C.14. The input data is expressed as "101101", and it is represented by NRZ (non-return-to-zero) and BPSK.



Key

BPSK: One data code is produced by two wave length cycle.
BPSK signal can change at every 0° or 180° of wave.
NRZ non-return-to-zero

Figure C.14 — Data and waveform

C.2.6 Communication protocols

C.2.6.1 Information of communication for charging

C.2.6.1.1 General

In order to monitor and control the charging status of the non-proprietary system, communication between EPACs and non-proprietary charger shall be implemented. There are basic information as a minimum function and optional information as additional information.

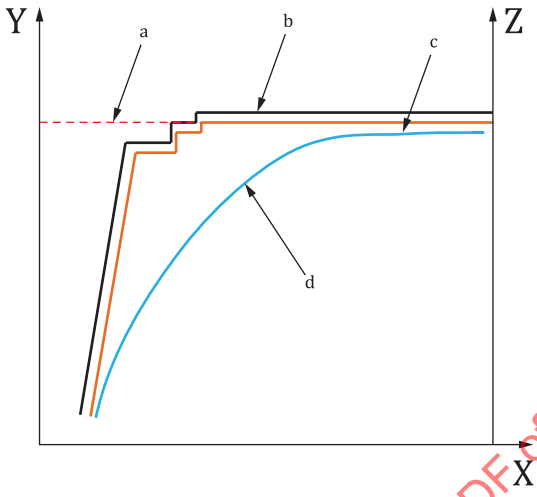
a) Controller (Master) is EPAC (or Battery).

b) The battery charger is always a slave during communication.

c) EPAC measures voltage, current and temperature.

d) EPAC requires voltage and current to the battery charger.

Charger can be controlled by command of EPAC. Figure C.15 shows an example of voltage or current adjustment of the charger.



Key

X time
Y voltage/current
Z energy [%]
a Target.
b Charger.
c EPAC.
d Energy.

Figure C.15 — Voltage, current and energy

With regard to the information display displayed on the charger as well, optional information can also be used based on basic information.

C.2.6.1.2 Set charge mode

This sample shows an example of setting the charge mode.

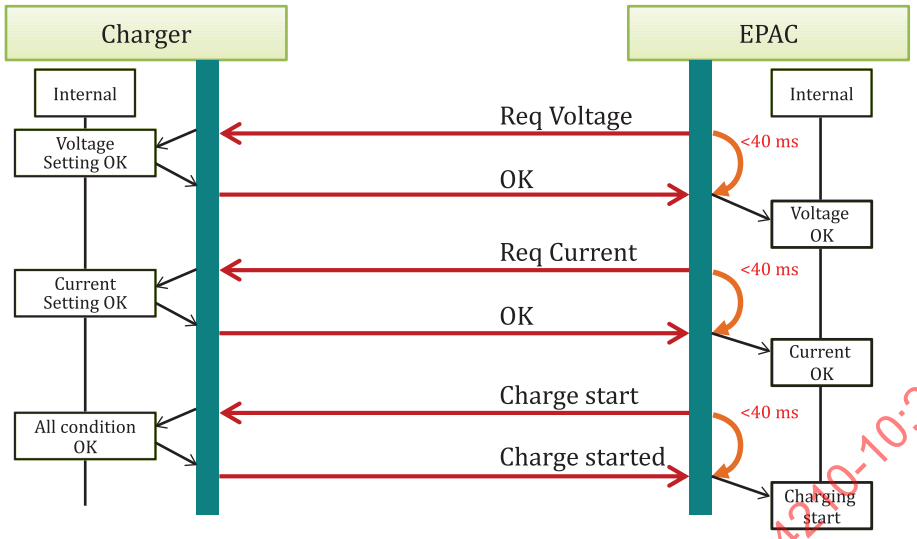


Figure C.16 — Set charge mode

C.2.6.1.3 Operating information of EPAC

The non-proprietary system charger shall be designed to interpret this command and to supply electric power (voltage, current) which meets to the required values from EPAC. If the charger cannot supply power required values, it shall return the error code to EPAC and shall stop to supply power.

The operating information of EPAC is shown in Table C.10.

Table C.10 — Communication information

Operating information (Information page 1)	
Information of charging the batteries	Request voltage for CV
	Request current for CC
	Error
	Network device number (NDN)
Information for indication to charger	Voltage of charging
	Current of charging
NOTE CV means constant voltage mode, CC means constant current mode.	

Information to charge EPAC

Request voltage for CV: "Request voltage for CV" means voltage which supplied from charger.

Request current for CC: "Request current for CC" means current which supplied from charger.

Error: If the communication between EPAC and non-proprietary system charger and the connection of the charger connector and charger inlet is not satisfied, the accident of incomplete communication and Time Out are notified mutually.

Network device number: "Network device number (NDN)" means unique number which assigned by the non-proprietary system charger if two or more EPACs are connected to it. It consists of alphanumeric characters or symbols in the range of 6 B to 10 B. Right justified.

Information for indication to charger

Voltage of charging: “Voltage of charging” means present charging voltage.

Current of charging: “Current of charging” means present charging current.

C.2.6.1.4 Operating Information

The format of each information is described in Table C.11.

Size is described in units of Byte. Type indicates the type of data, and ASCII indicates ASCII code.

Table C.11 — Form of operating information (Information page 1)

Item	Size B	Type	specimen	ref
Request voltage for CV	3	Hex	360 res 100 mV	00 03 61: 36,1 V
Request current for CC	3	Hex	150 res 100 mA	00 01 50: 15 A
Error	2	Hex	04 00	ref. error code list
EPAC NDN	10	ASCII	The last 6 B are used for authentication.	Use for authentication
Voltage of charging	2	Hex	24 V to 260 V res 100 mV	26 00: 260 V
Current of charging	2	Hex	1 A to 30 A res 100 mA	03 21: 32,1 A

Request voltage for CV: “Request voltage for CV” shall be used as 100 mV d.c. resolution. For specimen, this parameter is given as “360” (decimal) for 36 V d.c.

Request current for CC: “Request current for CC” shall be used as 100 mA resolution. For specimen, this parameter is given as “150” (decimal) for 15 A

Voltage of charging: “Voltage of charging” shall be used as 100 mV d.c. resolution.

Current of charging: “Current of charging” shall be used as 100 mA resolution.

Error: “Error” shall be used in accordance with Error code table when an error occurs.

C.2.6.1.5 Optional information

The information described in Table C.12 is necessary for rapid charging and other control information. There are "information page 1" which is required mainly for rapid charging and "information page 2" which is necessary as control information. For other information, the Table may be expanded and added.

Table C.12 — Operating information page list

	Information page 2
1	reserved
2	Maximum current of EPAC
3	Present temperature of EPAC
4	Maximum temperature of EPAC
5	Minimum temperature of EPAC
6	Battery energy (Wh)
7	Times of connecting to charger
8	Rating voltage

Page 2 describes the information group required for quick charge for EPAC.

Maximum current of EPAC: Maximum allowable current of battery. When a current exceeding this value flows, the charger cuts off the output.

Present temperature of EPAC: Present temperature of EPAC

Maximum temperature of EPAC: Upper limit of charging temperature of EPAC

Minimum temperature of EPAC: Lower limit of charging temperature of EPAC

Battery energy (Wh): Battery energy that can be outputted when the battery is fully charged

Times of connecting to charger: Indicates the number of times of connecting charger physically

Rated voltage: Rated voltage information

C.2.6.1.6 Operating information page 2

The format of each information is described in Table C.13. Size is described in units of Byte. Type indicates the type of data, and ASCII indicates ASCII code.

Table C.13 — Information page 2

	Item	Size B	Type	Data	Resolution
1	reserved	1	Hex	1 B	
2	Maximum current of EPAC	1	Hex	1 A to 30 A	1 A
3	Present temperature of EPAC	2	2's	–30 °C to 100 °C	0,1 °C
4	Maximum temperature of EPAC	2	2's	–30 °C to 100 °C	0,1 °C
5	Minimum temperature of EPAC	2	2's	–30 °C to 100 °C	0,1 °C
6	Battery energy (Wh)	2	Hex	1 Wh to 10 000 Wh	1 Wh
7	Times of charging cycles	2	Hex	0 times to 10 000 times	1
8	Rated voltage	1	Hex	0 V to 48 V	1 V

Maximum current of EPAC: Maximum current determined by battery

Present temperature of EPAC: Present temperature of battery

Maximum temperature of EPAC: Maximum temperature determined by battery

Minimum temperature of EPAC: Minimum temperature determined by battery

Battery energy (Wh): Battery energy in Wh

Times of charging cycles: Indicates the number of times the battery has been charged

Rated voltage: Rated voltage information

C.2.6.1.7 Information of communication for charger

In order to safely charge the EPAC with the non-proprietary system, it specify the information that the charger holds as identification information. The EPAC or battery can get information from the charger if (it is) necessary. This information can be used for charging history, trouble log management, etc.

C.2.6.1.8 Operating information of charger

When charging with a non-proprietary system charger, the minimum information that is essential for charging is described in this chapter. The charger interprets this command and supplies the output (voltage, current) meeting the required conditions to the EPAC or battery. If it cannot be supplied under the required conditions, return error code to the EPAC or battery and abort charging.

Table C.14 shows information of charging the batteries.

Table C.14 — Charger information

Information page 0	Item	
Information of charging the batteries	Charger Info 1	Country
		State
		Installation No.
		Company (Service)
	Charger Info 2	Company (Product)
		Type of products
		Serial No.
		Date of product
	Device type	
	Voltage of charging	
	Current of charging	
	Error	
	Device Info	

Information of charging the batteries

Charger Info 1: Information on the supplier who manages and operates the charger

Charger Info 2: Information on the vendor who manufactured the charger

Error: Generate and notify of Error

Device Info: Unique number of the charger. Serial number, product number etc.

C.2.6.1.9 Operating information of charger:

The format of each information is described in the table below. Size is described in units of Byte. Type indicates the type of data, and ASCII indicates ASCII code.

Table C.15 shows a format of battery charger and Table C.16 shows a device type of charger.

Table C.15 — Form of charger information

Item		Size B	Type	Example	Reference
Charger Info 1	Country	20	ASCII	JAPAN	
	State	20	ASCII	TOKYO	
	Installation No.	10	ASCII	0000000012	
	Company (service)	20	ASCII	COMPANY NAME	
Charger Info 2	Company (Product)	20	ASCII	COMPANY NAME	
	Type of products	20	ASCII	CHARGER	
	Serial No.	20	ASCII	0123456789ABCDEFGHIJ	
	Date of product	10	ASCII	0020180411	
Device type		2	ASCII	01	charger
Voltage of charging		2	HEX	24 V ~ 260 V res 100 mV	
Current of charging		2	HEX	1 A ~ 30 A res 100 mA	
Error		2	HEX	04 00(h)	ref. error code list
Device info		10	ASCII	ABCDEFGHIJ	temporary

Charger Info 1 is a data string of 20 + 20 + 10 + 20 = 70 B.

Charger Info 2 is a data string of 20 + 20 + 20 + 10 = 70 B.

Device type: This is a code of device type. Non-proprietary charger code is 01.

Table C.16 — Device type

code	Device
00	
01	Non-proprietary charger
02	Proprietary charger

Voltage of charging: "Voltage of charging" shall be used as 100 mV d.c. resolution.

Current of charging: "Current of charging" shall be used as 100 mA resolution.

Error: When an error occurs, refer to Error code table and transmit the generated error information.

Device Info: This information is an identify information to be included to a history of the charger. When an error or the like occurs, it is possible to grasp what type of error occurred with which charger.

C.2.6.1.10 Page code

Table C.17 shows information of page code, which is used in C.2.6.5.10.

Table C.17 — Page code information

Page	Description
00	Device information
01	Basic Information
02	Optional information 1
03	Optional information 2

C.2.6.2 Plug and play (PnP) command

C.2.6.2.1 General

PLC shall be supplied with electric power at all times. EPAC shall send the commands to the non-proprietary system charger after detecting the connection via interrupting by PLC. EPAC which connects to the non-proprietary system charger first shall be designed to manage the network address.

C.2.6.2.2 Plug and play command table

Table C.18 — Plug and play command

Code	Type	Command	Destination	CST[a]	Description (Return)
101b	00b	Address Request1	Master	U	If connection is complete, LU send this command for address request1.
111b	00b	Address Request2	Master	U	address request 2.
011b	00b	Address Ack	Master	B	
101b	00b	Address Set	LU[b]	U	
111b	00b	Address No.	LU	U	
011b	00b	Address Request Reception	LU	B	

[a] CST U: Unicast
B: Broadcast

[b] LU: logical unit

The commands which required for communication after detection the connection are listed in Table C.18. By using these six kinds of commands to complete the negotiation in the procedure described in Figure C.18, it is possible to perform the communication for charging.

C.2.6.3 Plug and play (PnP) command descriptor block

C.2.6.3.1 Command descriptor block (CDB) format for PnP

Command descriptor block format is described in Table C.19.

Table C.19 — Command descriptor block format

	7	6	5	4	3	2	1	0
0	code			parameter				
1	DATA1							
2	DATA2							
3	DATA3							
4	Cast	Type field(00b)		Target Address				

PnP command

Type field is a parameter set in tp of Table C.9.

Type field (Type, tp): 00b

If it uses PnP command, Type field shall be set by “00b”.

Cast:

0: Unicast

1: Broadcast

parameter: The parameter field has an individual meaning for each command.

ex. checksum, temp slot No., Fixed slot No.

Set it to 0 unless otherwise specified.

Target Address: The target address indicates the destination address.

When sending by Broadcast, set 1Fh for Target address and Cast to 1.

The target address indicates the destination address.

C.2.6.3.2 Address request reception (Code: 011b)

Table C.20 shows the address request reception command descriptor block.

When master unit received request from logical unit to which a network address isn't granted, the temporary address (temporally slot number) is given to logical unit concerned in broadcast. Temporally slot number is the optional value. Half of the ID (LUID1: 3 B) to logical unit which was put on data, when logical unit sent a request to DATA1-3, is unique (Total 6 B).

Table C.20 — Address request reception (Code: 011b) command descriptor block

	7	6	5	4		3	2	1	0
0	0	1	1	parameter					
1	DATA1 (ID 1st)								
2	DATA2 (ID 3rd)								
3	DATA3 (ID 5th)								
4	1	00b		1Fh					

PnP command

Code: 011

Parameter: Temporally Slot Number1

DATA1-3: The data sent from logical unit (LUID1) is returned just as it is.

Cast: 1 (Broadcast)

Type: 00h (PnP only)

C.2.6.3.3 Address No(Code: 111b) command

Table C.21 shows the address No command descriptor block.

This command is executed in the final step of PnP. In the PnP process, communication between the master unit and the logical unit is performed to determine the address on the network. The logical unit is recognized from the master unit, and finally it will receive the Fixed slot number as an official network address and the logical unit will set that number as own address.

Table C.21 — Address request 2(Code: 111b) command descriptor block

	7	6	5	4	3	2	1	0
0	1	1	1	Fixed slot No.				
1	00h							
2	00h							
3	00h							
4	0	00b		Target address				

PnP command

Code: 111

Parameter: Fixed slot No.

DATA1-3: 00h

Cast: 0 (Unicast)

Type: 00h (PnP only)

Target address: Set the temporary address that was set last.

C.2.6.3.4 Address set (Code: 101b)

Table C.22 shows the address set command descriptor block.

Master unit receives the 2nd time of address request command from logical unit to which a network address isn't granted (Address Request2) and gives the 2nd temporary address (Temporally Slot Number2) in Unicast to logical unit concerned. Temporally Slot Number is the optional value. Remaining half of the ID to which logical unit put on data is unique when logical unit sent the 2nd time of request to DATA1-3, (Total 6 B) (LUID2: 3 B).

Table C.22 — Address set (Code: 101b) command descriptor block

	7	6	5	4	3	2	1	0
0	1	0	1	parameter				
1	DATA1 (ID 2nd)							
2	DATA2 (ID 4th)							
3	DATA3 (ID 6th)							
4	0	00b		00h				

PnP command

Code: 101

Parameter: Temporally Slot Number2

DATA1-3: The data sent from logical unit (LUID2) is returned just as it is.

Cast: 0 (Unicast)

Type: 00h (PnP only)

C.2.6.3.5 Address request1(Code: 101b) command

Table C.23 shows the address request1 command descriptor block.

When finding master unit on network in the state to which the address on the network isn't given by logical unit yet, logical unit demands address giving to master unit. Peculiar ID 6 B of logical unit is divided into 1 B as data, odd part-time work is picked out and it's sent out to master unit in that case.

Table C.23 — Address request 1(Code: 101b) command descriptor block

	7	6	5	4	3	2	1	0
0	1	0	1	checksum				
1	DATA1 (ID 1st)							
2	DATA2 (ID 3rd)							
3	DATA3 (ID 5th)							
4	0	00b		00h				

PnP command

Code: 101

Parameter: checksum

checksum products:

ach ID(ID1a or ID1b) (100 - (1st byte + 2nd byte + 3rd byte)) & 1F

for specimen. DATA1-3: 00 00 FF then

checksum = (100 – (00 + 00 + FF)) & 1F = 01 (hex)

DATA1-3: 00h

for specimen. Logical unit has 6 B ID “00 00 00 FF FF FF (hex)”.

ID 1st: 00 ID 3rd : 00 ID 5th: FF

DATA1-3: 00 00 FF

Cast: 0 (Unicast)

Type: 00h (PnP only)

Target Address:00h (Master)

C.2.6.3.6 Address request2(Code: 111b) command

Table C.24 shows the address request2 command descriptor block.

When after sending address request1 in the state to which the address on the network isn't given by logical unit yet, the address of that case received address request reception command, and was identical with the address one sent, logical unit demands the 2nd time of address giving to master unit. Peculiar ID 6 B of logical unit is divided into 1 B as data, even numbered bytes are picked out and it's sent out to master unit in that case.

Table C.24 — Address request 2(Code: 111b) command descriptor block

	7	6	5	4	3	2	1	0
0	1	1	1	temp slot No.				
1	DATA1 (ID 2nd)							
2	DATA2 (ID 4th)							
3	DATA3 (ID 6th)							
4	0	00b		00h				

PnP command

Code: 111

Parameter: temp slot No.

: The latest address sent from master unit.

DATA1-3: 00h

for example. Logical unit has 6 B ID “00 00 00 FF FF FF (hex)”.

ID 2nd : 00 ID 4th : FF ID 6th: FF

DATA1-3: 00 FF FF

Cast: 0 (Unicast)

Type: 00h (PnP only)

Target Address:00h (Master)

C.2.6.3.7 Address acknowledge (Code: 011b) command

Table C.25 shows the address acknowledge command descriptor block.

When LUID2 sent by the address set command from master unit was parallel with LUID2 one sent, slot number in the 2nd temporary address sent by the address set command (Temporally Slot Number2) (Network address) is set as its address with parameter as its slot number. Next LUID2 is set as DATA1-3 and it's sent to master unit.

After that, logical unit is set to 2nd temporary address (Temporary Slot Number2) by master unit while the logical unit maintains the first temporary address (Temporary Slot Number1). Its reason is to avoid false recognition of communication that occurs when the master unit sends a command. After 30 ms, the logical unit shall set the first address (Temporary Slot Number1) immediately.

Table C.25 — Address acknowledge command descriptor block

	7	6	5	4	3	2	1	0
0	0	1	1	parameter				
1	Reserved							
2	Reserved							
3	Reserved							
4	0	00b		00h				

PnP command

Code: 011

Parameter: Set address which sent in the phase of address request2

DATA1-3: 00h

Cast: 0 (Unicast)

Type: 00h (PnP only)

Target address:00h (Master)

C.2.6.4 Standard command

C.2.6.4.1 Standard command list

Table C.26 shows a list of standard command.

Table C.26 — Standard command

Code	Command	CST	Description	Return
80h	Test unit ready	U	Request that report of logical unit status	c/c[a]
81h	Inquiry	U	Requests that information regarding parameters of the logical unit	c/c
89h	Device detection	B	It's sent by a broadcast because a partner is unclear.	
8Ah	Request sense	B/U	Unit information request	
92h	START/STOP charging	U	START/STOP command for charging control	c/c
98h	Request data	U	Data request	
99h	Send data	U	send data	
9Ah	Stop data	U	stop data sending	
9Bh	MODE SENSE	U	setting procedure of profile, and readout	Data
9Ch	Access Direct	U	Command over PLC	Ack
9Dh	MODE SELECT	U	Set conditions for MODE SENSE command	
A0h	Error Report	U	Report error information	no
A9h	Send data large	U	Send large size of data (more than 4 B)	c/c
Exh			From E0h to FFh: Vender unique area	
Fxh				

[a] c/c: check condition.

The vendor unique command area (Exh - Fxh) is a vendor's freely usable area. There is no regulation of compatibility and it cannot be used in the market. Prohibit accepting commands so that malfunction will not occur even if this command is received.

C.2.6.5 Standard command descriptor block

C.2.6.5.1 Command descriptor block (CDB) format

Table C.27 shows the command descriptor block format.

Set necessary data of 5 B in the CDB and transmit it.

Table C.27 — Command descriptor block format

	7	6	5	4	3	2	1	0
0	Operation code							
1	Page or Sub Operation Code							
2	DATA							
3	DATA							
4	Cast	Type field(11b)		Target Address				

This is a format of command description block.

return: Good/No good/Error code (Command A0h) CHECK CONDITION

1st byte of this format is operational code area. Every Units interpret this area and execute each actions.

2nd byte of this format is operational code or data. It depends on the command in 1st line for this meaning.

From 3rd byte to 4th byte of this format is data area.

5th byte of this format means as follows,

Cast:

0: Unicast

1: Broadcast

Type field:

Type field shall be set to 11b. It is reserved.

Target Address

Target address means the unit which becomes the partner who communicates. When it send data or control another unit, set the target address in that location.

C.2.6.5.2 TEST UNIT READY command descriptor block

Table C.28 shows the TEST UNIT READY command descriptor block.

The TEST UNIT READY command is used when a master unit polls if any logical unit is ready, without allocating any space for returned data. When logical units receive the TEST UNIT READY command, the logical units shall respond promptly with the current status.

The command shall be terminated with GOOD status.

If TEST UNIT READY command is issued to check the charging connectors, the command shall be terminated with GOOD status.

When preparations of a logical unit aren't complete, Busy status (CDB: A0 01 02 00 xx) is returned. Or when it's some error status, Error codes as well as Error status are returned.

Table C.28 — The TEST UNIT READY command descriptor block

	7	6	5	4	3	2	1	0
0	Operation code (80h)							
1	Reserved							
2	Reserved							
3	Reserved							
4	0	11b		Target Address				

Normal command

return: Good/No good/Error code (Command A0h) CHECK CONDITION

Type field: 11b

Reserved DATA1-3: set to 00h

Cast: 0 (Unicast)

Type: 00h (PnP only)

NOTE The field that filled by Reserved should be set to zero. The logical unit can ignore this field.

C.2.6.5.3 INQUIRY command

Table C.29 shows the INQUIRY command descriptor block.

The INQUIRY command requests that information regarding parameters of the logical unit be sent to the master unit. Options allow the master unit to request additional information about the logical unit.

If error has occurred, logical unit returns message to master unit by using command A0.

Table C.29 — INQUIRY command descriptor block

	7	6	5	4	3	2	1	0
0	Operation code (81h)							
1	Reserved							
2	Reserved							
3	Reserved							
4	0	11b		Target Address				

return: Good/No good/Error code (Command A0h) CHECK CONDITION

Type field: 11b

Table C.29 describes errors that may occur during the operation of the command or which may cause a CHECK CONDITION status to be reported.

C.2.6.5.4 DEVICE DETECTION Command

The DEVICE DETECTION command confirms whether equipment is on the network.

The following Table C.30 shows the DEVICE DETECTION command descriptor block.

If logical unit receive this command, it shall send Address Request1 of the PnP command (Code:101b) to the master unit and wait for a reply from master unit.

Table C.30 — DEVICE DETECTION command descriptor block

	7	6	5	4	3	2	1	0
0	Operation code (89h)							
1	Reserved							
2	Reserved							
3	Reserved							
4	1	11b		Target Address				

return: Good / No good / Error code (Command A0h) CHECK CONDITION

Type field: 11b

C.2.6.5.5 REQUEST SENSE command

The REQUEST SENSE command requests that the logical unit sends a sense data to the master unit.

The following Table C.31 shows the REQUEST SENSE command descriptor block.

Table C.31 — REQUEST SENSE command descriptor block

	7	6	5	4	3	2	1	0
0	Operation code (8Ah)							
1	Reserved							
2	Allocation length							
3	Reserved							
4	0	11b		Target Address				

return: Good/No good/Error code (Command A0h) CHECK CONDITION

Type field: 11b

The sense data:

1. shall be available if an error condition (CHECK CONDITION) had previously been reported to the master unit;
2. shall be available if other information is available in any field.

If the logical unit has no other sense data available to return, it shall return a Sense Key of NO SENSE and an additional sense code of NO ADDITIONAL SENSE INFORMATION.

No further CHECK CONDITION status shall be generated.

If a recovered error occurs during the execution of the REQUEST SENSE command, the logical unit shall return the sense data with GOOD status. If a logical unit returns CHECK CONDITION status for a REQUEST SENSE command, the sense data may be invalid.

Master unit is able to determine how much sense data has been returned by examining the allocation length parameter in the Command Packet and the additional sense length in the sense data.

C.2.6.5.6 START/STOP command

The START/STOP command requests that the logical unit supplies it and makes them stop operations.

Table C.32 shows the START/STOP command descriptor block.

Table C.32 — START/STOP command descriptor block

	7	6	5	4	3	2	1	0
0	Operation code (92h)							
1	Reserved						Charger Control	
2	Reserved							
3	Reserved							
4	0	11b		Target Address				

return: Good/No good/Error code (Command A0h) CHECK CONDITION

Type field: 11b

Charger Control[1:0]

00b: reserved

01b: Stop charging

10b: Start charging

11b: reserved

C.2.6.5.7 REQUEST DATA Command

C.2.6.5.7.1 General

The REQUEST DATA command requests the data from logical unit.

The following Table C.33 shows the REQUEST DATA command descriptor block. Table C.34 shows the Sub Operation code in the Table C.33.

Table C.33 — REQUEST DATA command descriptor block

	7	6	5	4	3	2	1	0
0	Operation code (98h)							
1	Mode	Sub operation code (SOPC)						
2	Type of request							
3	Transfer Length							
4	0	11b		Target Address				

return: Good/No good/Error code (Command A0h) CHECK CONDITION

Mode:

0: Normal data request

1: Re-send request

Sub Operation code (SOPC)

The meaning of the Sub Operation code varies depending on the parameter of mode.

See Table C.34 for the Sub Operation code.

During the SEND LARGE DATA command is occurred, many packets send from master to logical unit. If one or any packet is missing, the logical unit requests to send the missing packet again.

A request for missing packet Re-send is made using this command.

Table C.34 — Sub operation code column

Mode	Sub operation code column	Comment
0	SOPC changes parameter of Request data	
1	Number of Packet	

C.2.6.5.7.2 Type of request

The following Table C.35 shows a Type of request (ToR).

Sub Operation code (SOPC): 00h

Table C.35 — Type of request column

ToR	DATA	SOPC	comment
00h	Reserved	00h	Reserved
01h	Voltage	00h	present voltage Table C.11
02h	Current	00h	Table C.11
03h	Temperature	00h	present temperature Table C.12-3
04h	Times of charge	00h	Table C.12-7
05h	Level of battery	00h	Battery remaining
06h	Electric energy	00h	Table C.12-6
07h	Rating voltage	00h	Table C.12-8
08h	Last Error	00h	Table C.14
09h		00h	
0Ah		00h	
0Bh		00h	
NOTE All codes not shown are reserved.			

Data format is shown in Table C.13 and Table C.15.

C.2.6.5.7.3 Sub operation code

Table C.36 shows the Sub operation code that shows the attribute of the REQUEST DATA command.

Table C.36 — Sub operation code (Attribute)

SOPC	Description	Comment
00h	Battery and charger category	Device: battery
01h	Reserved	
02h	Reserved	
NOTE All codes not shown are reserved.		

The Transfer Length field specifies the number of contiguous logical blocks of data that shall be transferred. A Transfer Length of zero indicates that no logical blocks shall be transferred. This

condition shall not be considered an error. Any other value indicates the number of logical blocks that shall be transferred.

Maximum length of data packet is 128 B.

Data transmission shall be less than 256 B with one command.

C.2.6.5.7.4 Command relation table

Table C.37 shows the command relation.

Table C.37 — Command relation

	Command	Return CMD	Return value
1	Test unit ready	Error Report	check condition
2	Inquiry	Basic Information Mode Sense Page 0	
3	Device Detection	Request AD1	
4	Request Sense	Error Report	check condition
5	START/STOP charging	Error Report	check condition
6	Request data	return sense data	
7	Send data	Error Report	check condition
8	Stop data	Error Report	check condition
9	MODE SENSE	return mode information	
10	Access Direct		
11	MODE SELECT	Error Report	check condition
12	Error Report	no return	
13	Send data large	Error Report	check condition
14			
15			
16			
17			
18			
19			
20			
21			

C.2.6.5.8 SEND DATA Command

Table C.38 shows the SEND DATA command descriptor block.

The SEND DATA command requests that the data sends to logical unit less than 3 B.

When requesting data by the Request DATA command, data is sent using this command.

Table C.38 — SEND DATA command descriptor block

	7	6	5	4	3	2	1	0
0	Operation code (99h)							
1	DATA1							
2	DATA2							
3	DATA3							
4	0	11b		Target Address				

return: Good/No good/Error code (Command A0h) CHECK CONDITION

Type field: 11b

Sub operation field (Byte1) change to DATA field.

DATA1-3: Send data (less than 3 B)

C.2.6.5.9 STOP DATA command

Table C.39 shows the STOP DATA command descriptor block.

Table C.39 — STOP DATA command descriptor block

	7	6	5	4	3	2	1	0
0	Operation code (9Ah)							
1	Reserved							
2	Reserved							
3	Reserved							
4	0	11b		Target Address				

return: Good/No good/Error code (Command A0h) CHECK CONDITION

C.2.6.5.10 MODE SENSE command

C.2.6.5.10.1 General

The MODE SENSE command provides a means for a logical unit to report parameters to the master unit.

Table C.40 shows the MODE SENSE command descriptor block.

Table C.40 — MODE SENSE command descriptor block

	7	6	5	4	3	2	1	0
0	Operation code (9Bh)							
1	Page control(PC)			Page code				
2	Subpage code (Reserved)							
3	Reserved							
4	0	11b		Target Address				

return: Good/No good/Error code (Command A0h) CHECK CONDITION

The Subpage code field should be set to zero. The logical unit can ignore this field.

C.2.6.5.10.2 Page control (PC)

Table C.41 shows the detail of Page Control description in the Table C.40.

Table C.41 — Page control

Page code	Type of parameter	Reference
000b	Present Value	
001b	Reserved	
010b	Reserved	
011b-111b	Reserved	

Present Values

A PC field value of 0h requests that the logical unit returns the present values of the mode parameters. The present values returned are:

a) the present values of the mode parameters established by last successful MODE SELECT command.

b) the saved values of the mode parameters if a MODE SELECT command has not successfully completed since the last power-on, hard RESET condition.

c) the default values of the mode parameters, if saved values are not available or not supported.

C.2.6.5.10.3 Page code

The following Table C.42 shows the detail of Page code field description in the Table C.40.

Table C.42 — Page code field

Page code	Type of parameter	Reference
00h	Operating Information Page 1	C.2.6.1.4
01h	Operating Information Page 2	C.2.6.1.6
02h	Operating Information page 3	Reserved
03h-0Fh	Reserved	
10h	00h (Reserved)	
11h-1Fh	Reserved	

The logical unit sends necessary data to the master unit with A9 command (SEND DATA LARGE) in response to the request.

A master unit may request any one or all of the supported mode pages from a logical unit. If a master unit issues a MODE SENSE command with a Page Code value not implemented by the logical unit, the logical unit shall return CHECK CONDITION status, 02/24 INVALID FIELD IN CDB.

C.2.6.5.11 ACCESS DIRECT command

Table C.43 shows the ACCESS DIRECT command descriptor block.

The ACCESS DIRECT command provides a means for a logical unit to report parameters to the master unit.

Table C.43 — ACCESS DIRECT command descriptor block

	7	6	5	4	3	2	1	0
0	Operation code (9Ch)							
1	cnt	Page or Sub Operation Code						
2	DATA							
3	DATA							
4	0	11b		Target Address				

return: Good/No good/Error code (Command A0h) CHECK CONDITION

cnt: sign of sequential data

0: sequential data

1: packet size

If cnt set zero,

DATA1-2: transfer data

Packet number: Number of sequential data

This command can packetize data to be transmitted.

The received data is expanded and reexecuted on the logical unit.

In the first process, the transmission data is needed to send after setting it as following:

— cnt is set to 0,

— the data size (number of packets) is set to size of parameter "Packet number", and

— DATA1 and DATA2 are set to 00.

Subsequently, the process shifts to actual data transmission.

Set 1 to cnt, set the value to “Packet number” which clearly indicates the order of data, and set the data to be transmitted to the following DATA1 and DATA2.

Maximum length of data packet is 128 B.

C.2.6.5.12 MODE SELECT command

The MODE SELECT command provides a means for the master unit to specify logical unit parameters to the logical unit. Master unit should issue a MODE SENSE command prior to each MODE SELECT command to determine supported Pages and other parameters.

Table C.44 shows the MODE SELECT command descriptor block.

Table C.44 — MODE SELECT command descriptor block

	7	6	5	4	3	2	1	0
0	Operation code (9Dh)							
1	Reserved							SP
2	Reserved							
3	Reserved							
4	0	11b		Target Address				

return: Good/No good/Error code (Command A0h) CHECK CONDITION

Type field: 11b

A Save Pages (SP) bit of zero indicates the logical unit shall perform the specified MODE SELECT operation, and shall not save any Pages. An SP bit of one indicates that the logical unit shall perform the specified MODE SELECT operation, and shall save to a non-volatile vendor-specific location all the saveable Pages. If a logical unit supports saved Pages, it shall save only one copy of the Page.

The SP bit is optional, even when mode pages are supported by the logical unit. Pages that are saved are identified by the parameter saveable (PS) bit that is returned in the Page Header by the MODE SENSE command.

If the PS bit is set in the MODE SENSE data then the Page shall be saveable by issuing a MODE SELECT command with the SP bit set. If the logical unit does not implement saved Pages and the SP bit is set to one, the command shall be terminated with CHECK CONDITION status, 02/24 INVALID FIELD IN CDB.

C.2.6.5.13 ERROR REPORT command

Table C.45 shows the ERROR REPORT command descriptor block.

Table C.45 — ERROR REPORT command descriptor block

	7	6	5	4	3	2	1	0
0	Operation code (A0h)							
1	Type of report							
2	DATA1 (error code S1)							
3	DATA2 (error code S2)							
4	0	11b		Target Address				

Type field: 11b

When accepting with no problem to the received command, Type of report:00h is returned, and when some's Error occurred, the Type of report:01h as well as the cord to which the error which occurred is relevant (CHECK CONDITION status) are returned.

Type of report

00h: Good/Good status (No error)

DATA1: 00h

DATA2: 00h

01h: CHECK CONDITION

DATA1: error code S1

DATA2: error code S2

03h: detail error report

DATA1 ,2: VENDOR SPECIFIC

When the logical unit to which Error Report was sent, received Type of report:10h, details of Error will be reported.

10h: request detail of errors

DATA1: error code S1

DATA2: error code S2

When requesting details of Error, 10h is set as Type of report and it's sent to a logical unit concerned.

C.2.6.5.14 The SEND DATA LARGE command

Table C.46 shows the SEND DATA LARGE command descriptor block.

The SEND DATA LARGE command requests that the data is sent from master unit to logical unit between 4 B to 128 B.

First the size of the sent data (packet size) is sent and the amount of data declared with the packet size each 2 B continuously is sent.

To prevent a sent packet being lost, when assigning the packet number, sending and doing packet loss, a terminal for receiving side does a re-transmission request, and perfect data is received.

Table C.46 — SEND DATA LARGE command descriptor block

	7	6	5	4	3	2	1	0
0	Operation code (A9h)							
1	cnt	Packet number						
2	DATA1							
3	DATA2							
4	0	11b		Target Address				

return: Good/No good/Error code (Command A0h) CHECK CONDITION

cnt: sign of sequential data

0: sequential data

1: packet size

If cnt set zero,

DATA1-2: transfer data

Packet number: Number of sequential data

When starting transmission, first set cnt to 0 and set the data size (number of packets) to be transmitted to parameter “Packet number”. At that time, 00 is set for DATA1 and DATA2.

Subsequently, the process shifts to actual data transmission.

Set 1 to cnt, set the value to “Packet number” which clearly indicates the order of data, and set the data to be transmitted to the following DATA1 and DATA2.

Data transmission shall be less than 256 B with one command.

C.2.6.6 Sequence

C.2.6.6.1 Heart beat

During charging, always communicate between EPAC and charger in order to constantly monitor communication disconnection including disconnection and abnormal situation.

Figure C.17 shows the transaction example of Heart beat.

In order to instantaneously grasp abnormal situations, voltage information, current information, and temperature information are transmitted at intervals of 10 ms.

When transmission / reception is not completed three times in succession or when stopped for 40 ms or more, it is regarded as an abnormality detection state, and the charger cuts off the power supply.

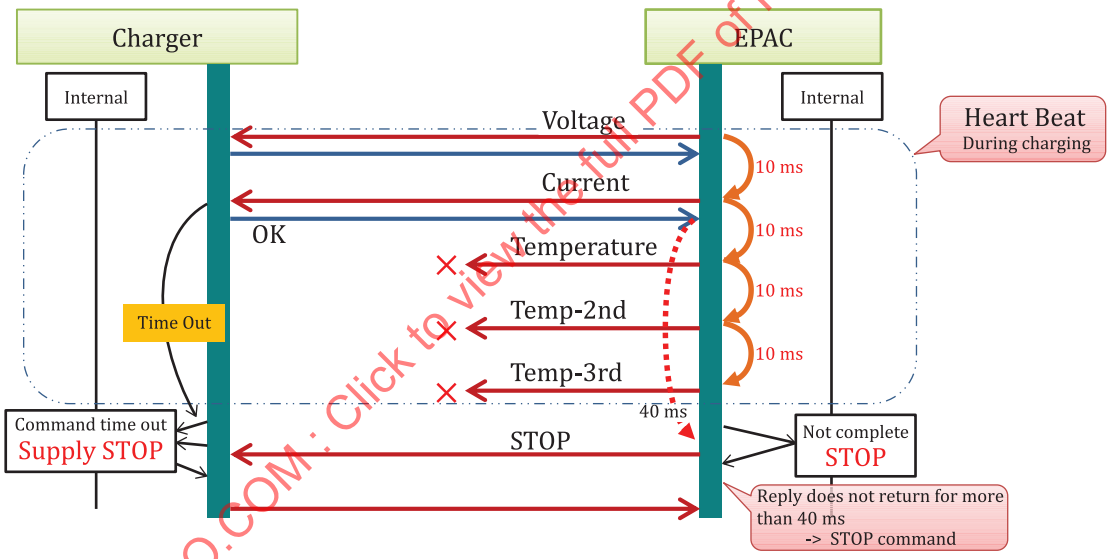


Figure C.17 — Heart beat

C.2.6.6.2 Sequence of devices detection

Figure C.18 shows the transaction example of device detection.

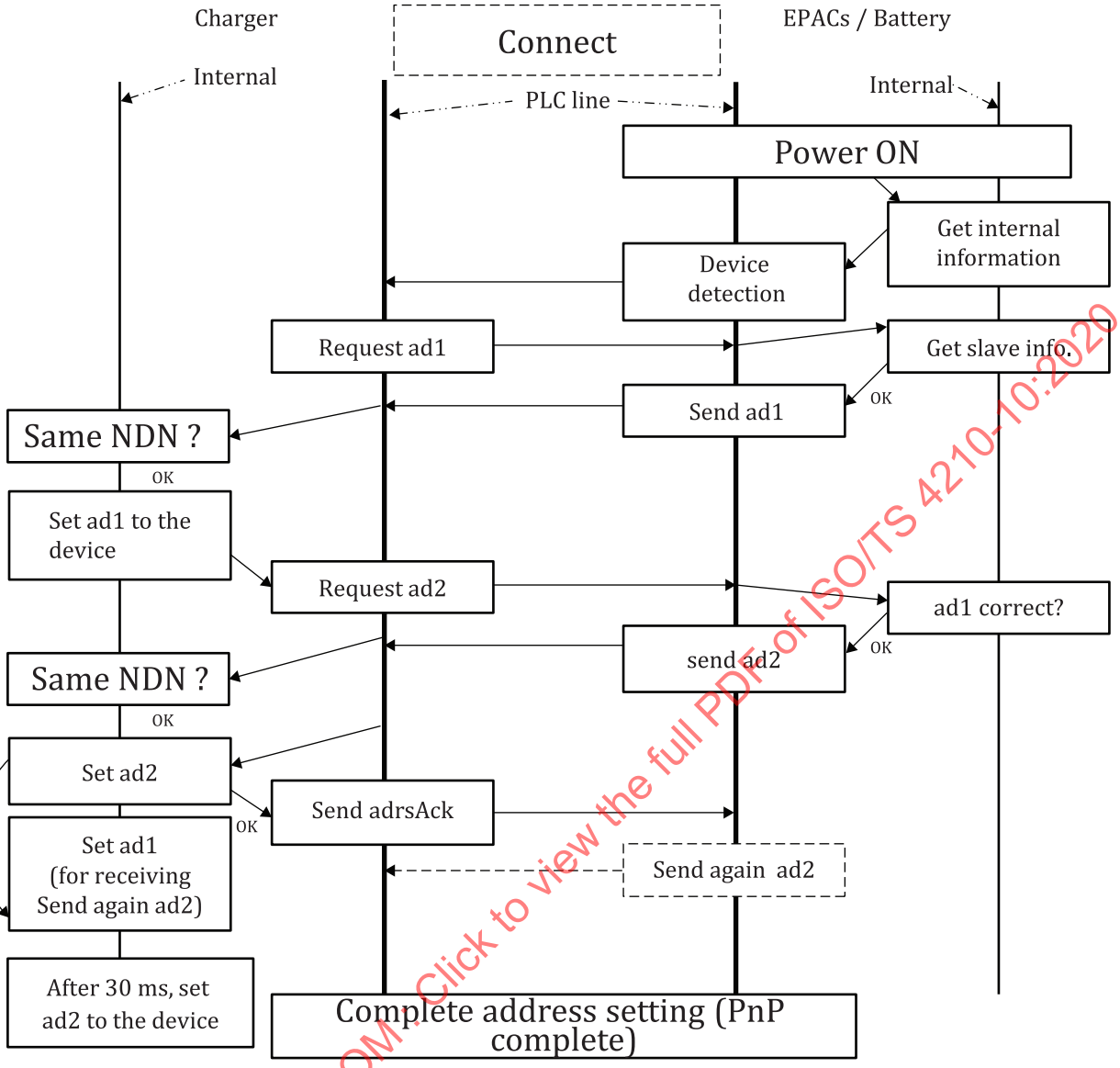


Figure C.18 — Plug and play sequence

C.2.6.6.3 Communication Sequence

Figure C.19 shows the transaction example of communication.

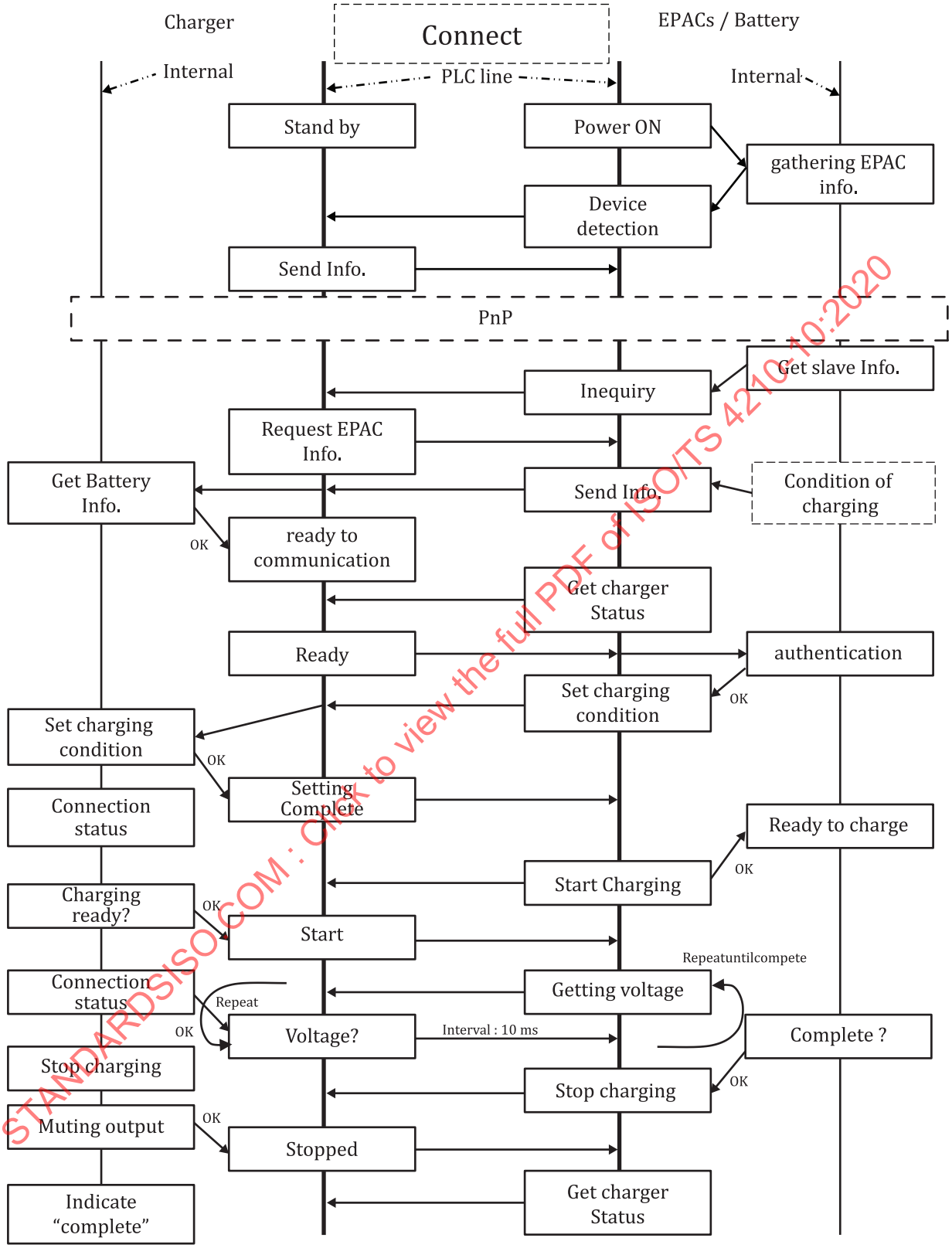


Figure C.19 — Communication sequence

C.3 System B

C.3.1 System configuration

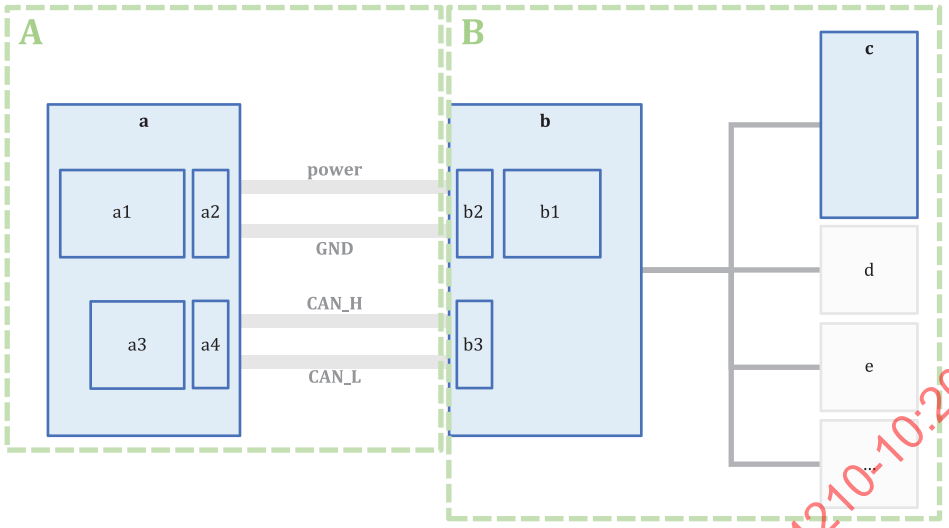
C.3.1.1 System diagram

Figure C.20 gives the system diagram for standardized non-proprietary system. Communication shall be based on CAN bus. Charger shall be able to provide up to 60V d.c. and 40 A. The charging voltage is variable and is adjusted in accordance with the request of the EPAC.

EPAC and charger shall be connected via a 4 pins connector: two pins for the CAN communication and two pins to supply the EPAC with electric power.

The charger shall consist of AC/DC converter, charger connector, CAN transceiver, circuit protection and EPAC detection. The AC/DC converter converts the grid power to the power that is needed to charge the EPAC. The charger connector connects the charger with the EPAC. The CAN transceiver enables the communication with the EPAC. The circuit protection shall detect EPAC and charger against over voltage as well as over current. The EPAC detection shall detect if the EPAC is connected to the charger and if the communication can start.

The manufacturer adapter shall build the interface between EPAC and charger with circuit protection and charge controller.



Key

A battery charger for non-proprietary system
B EPAC
a1 current / voltage controller AC/DC converter
a2 circuit protection
a3 EPAC detection
a4 CAN
b1 charging controller
b2 circuit protection
b3 CAN
[a] Charger.
[b] Manufacturer adapter.
[c] Battery.
[d] Motor.
[e] HMI.

Figure C.20 — Non-proprietary system diagram

C.3.1.2 Multi-Master CAN network and data exchange principle

Due to the system architecture, each CAN communication always only exists between EPAC and charger. The CAN network therefore only exists of two nodes.

Charger is allowed to have multiple charger connector with separated networks.

CAN is a message based multi-master serial bus, therefore both nodes, EPAC and charger are allowed to initiate a communication at any time. Bus conflicts are resolved with CSMA/CR where a message with the highest priority is allowed to continue transmission in case of a conflict.

C.3.2 Functions

C.3.2.1 Dynamic attach and detach

The act of plugging or unplugging charger connector and charger inlet shall not affect the functionality of another device on other segments of the network. Unplugging charger connector and charger inlet shall stop any transactions in progress between the EPAC and the charger. EPAC may be disconnected while the power is ON (hot plugging) if this is permitted by the system. If not connected, no communication

between EPAC and charger may be possible. The charger connector shall be de-energized until by communication the charging was permitted.

C.3.3 Operating Condition

C.3.3.1 General

The operating and storage conditions of this communication system shall be guaranteed normal operation under the conditions described in Table C.47.

Table C.47 — Operating and storage condition(environment)

	Conditions	Units	Min.		Max.
Temperature	Operating	°C	−10		+50
	Storage	°C	−30		+50
Humidity (no condensation)	Operating	%	30		80
	Storage	%	15		90

C.3.3.2 CAN frame timeout monitoring

Important cyclic CAN frames shall be monitored by the receiving node. E.g. the charger shall monitor the frequent reception of the EPAC heartbeat.

C.3.4 Specification(mechanical/electrical)

C.3.4.1 Charger inlet and charger connector

Charger connector, charger inlet, and the pin arrangement are shown in Figure C.21 and Figure C.23. Two of the four pins shall be used for the CAN communication (CAN high and CAN low). The other two pins are used to supply the EPAC with electric power (power and GND).

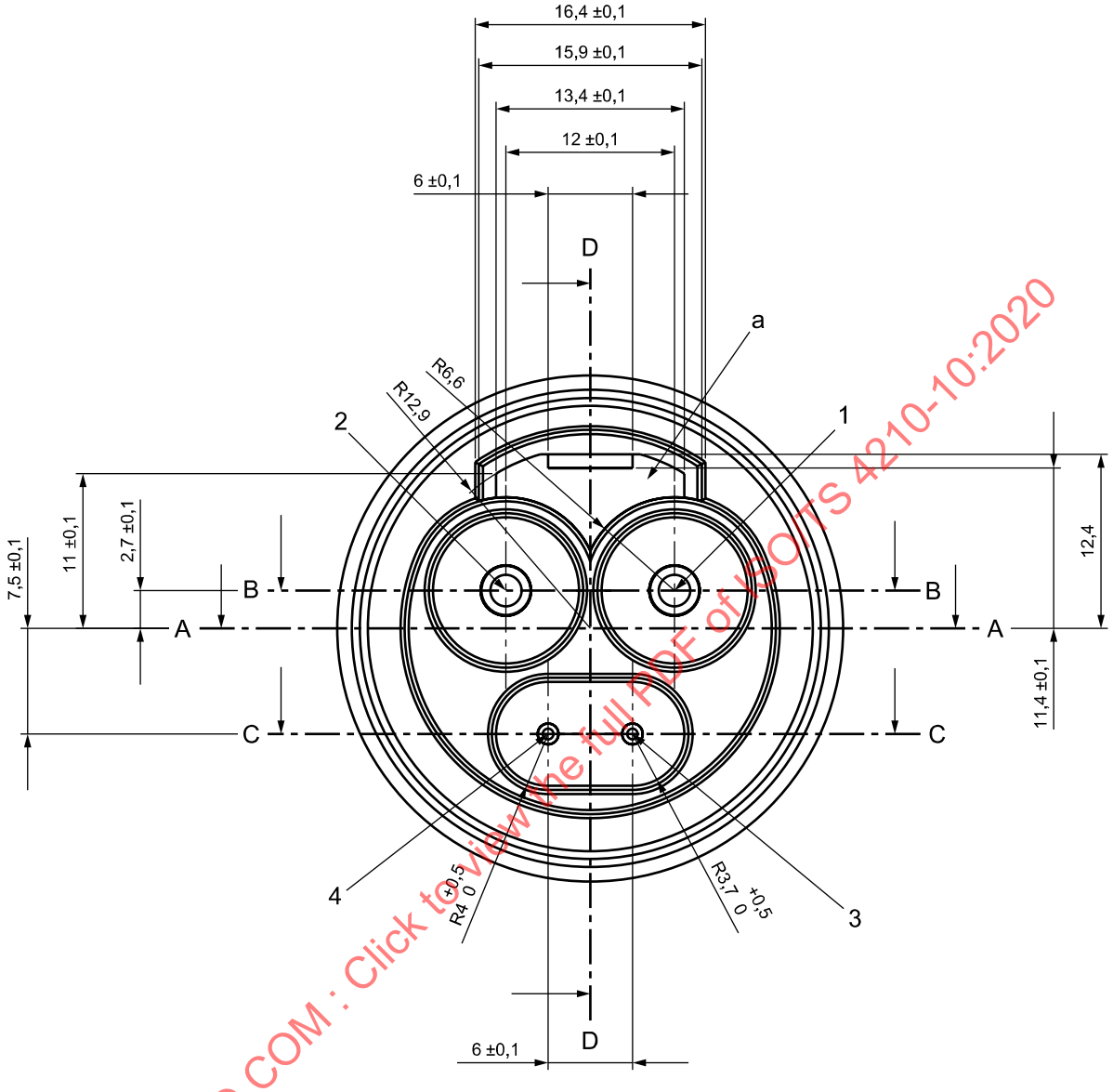
The DC pins shall be capable of carrying at least 40 A without exceeding maximum charger connector temperature.

Charger connector shall have a durability of insertion and removable of 10 000 times or more. Charger inlet shall have the durability of insertion and removable of 3 000 times or more.

Charger connector and charger inlet shall have a structure to prevent miss-insertion.

The corresponding cross sections of charger connector and charger inlet are shown in Figure C.22 and Figure C.24.

Dimensions in millimetres

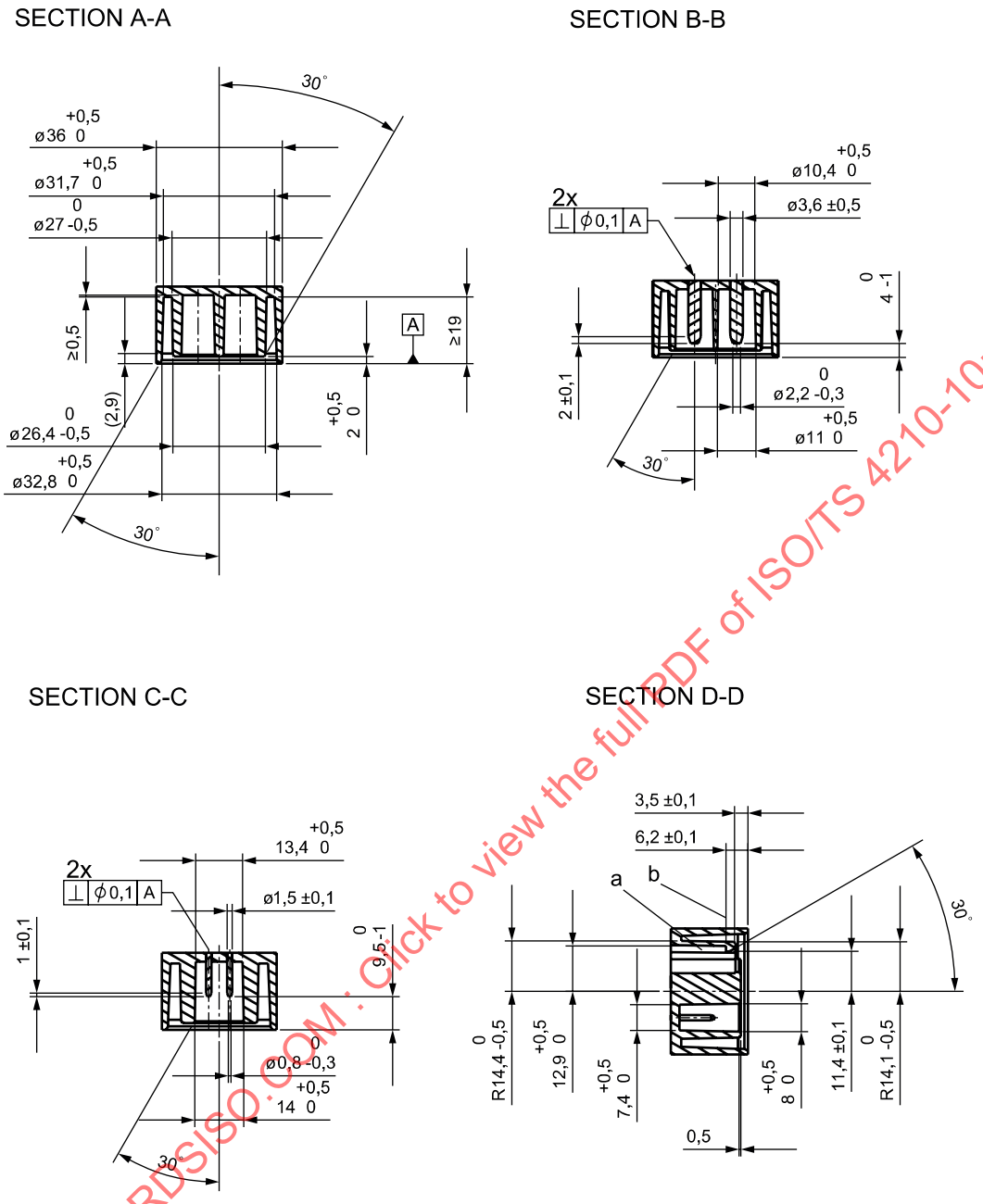


Pin connections	
Position/Pin	**Functions**
1	DC +60 V
2	DC 0 V
3	CAN high (Hi)
4	CAN low (Lo)

b Opening for locking / latching mechanism.

Figure C.21 — Charger inlet (on EPAC side)

Dimensions in millimetres

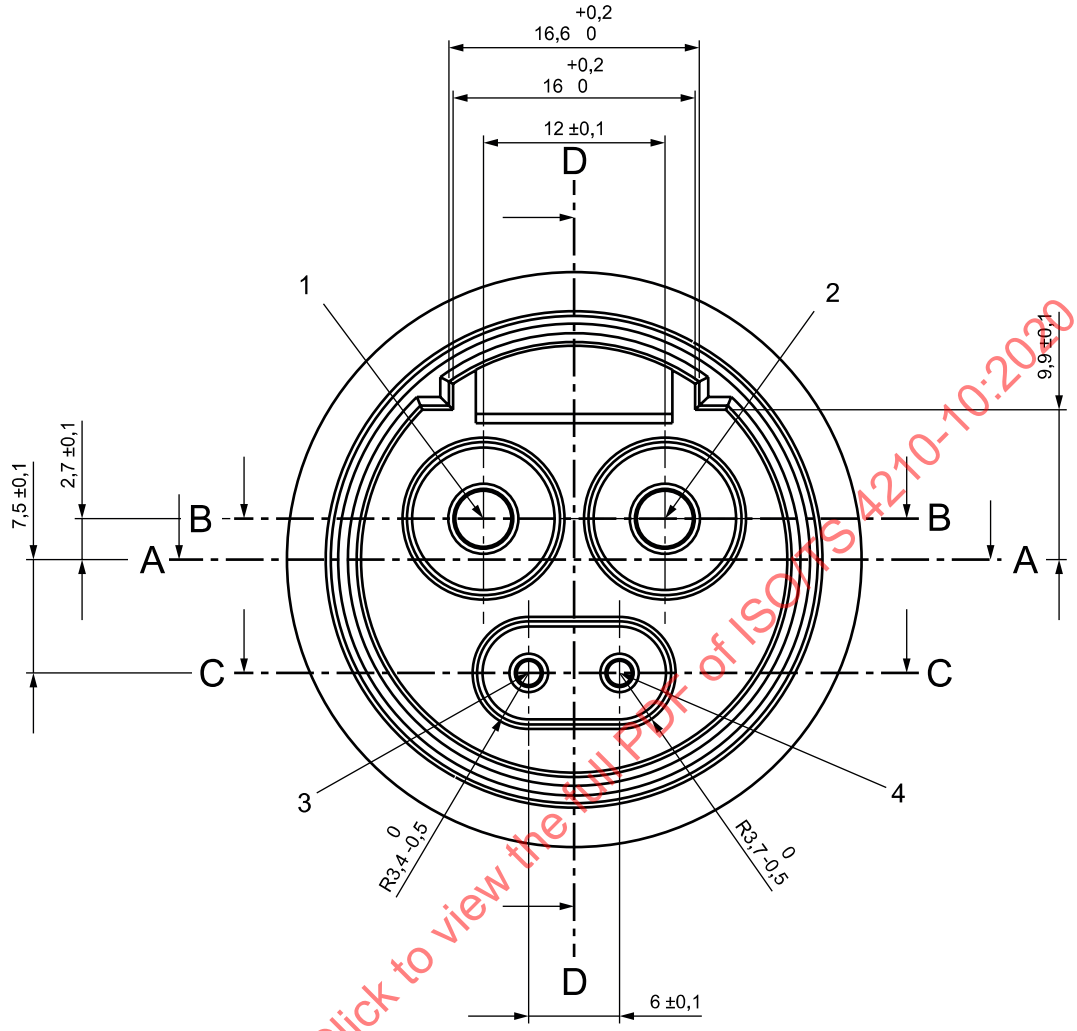


b Opening for locking / latching mechanism.

c Latching area.

Figure C.22 — Cross sections of charger inlet (on EPAC side)

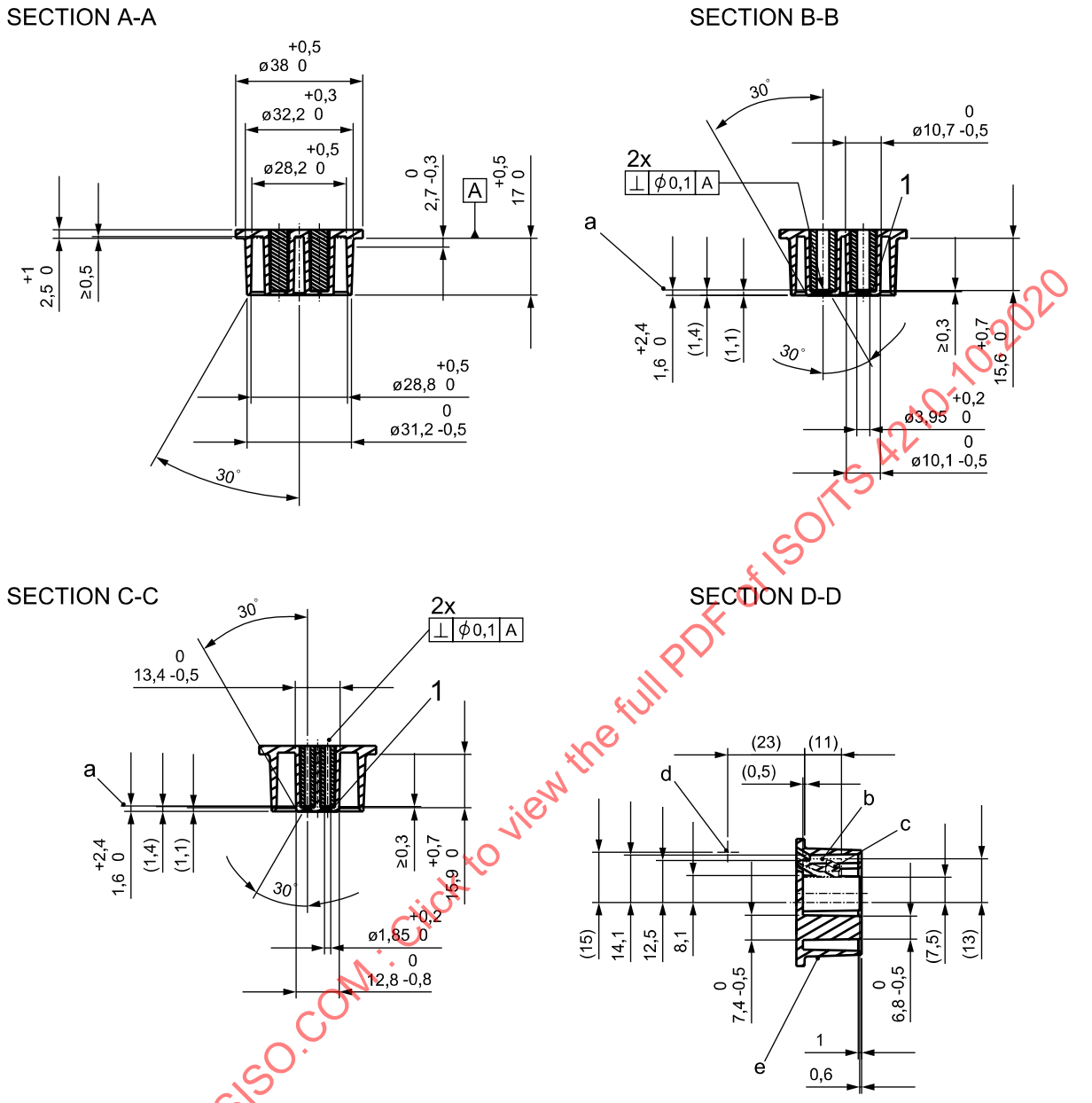
Dimensions in millimetres



Pin connections	
Position/Pin	**Functions**
1	DC +60 V
2	DC 0 V
3	CAN high (Hi)
4	CAN low (Lo)

Figure C.23 — Charger connector (on charger side)

Dimensions in millimetres



Key

1 chamfered for easy insertion

a Contact point/area.

d Latch area.

e Latching mechanism, construction to customer's decision.

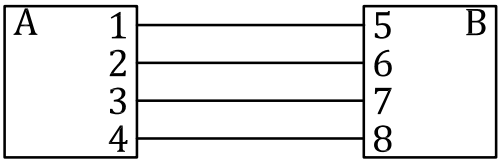
f Pivot point, construction to customer's decision.

g Sealing surface free of flaws.

Figure C.24 — Cross sections of charger connector (on charger side)

C.3.4.2 Cable characteristics

Figure C.25 shows examples of non-proprietary systems. Note that the figure does not depict all allowed configurations.



Key

1 CAN high
2 CAN low
3 DC +
4 DC 0 V
5 CAN high
6 CAN low
7 DC +
8 DC 0 V
A charger
B EPAC

Figure C.25 — Implementation example

C.3.5 Communication media

C.3.5.1 Communication — Physical layer specification

The communication between EPAC and non-proprietary charger shall be High Speed Classical CAN in accordance with ISO 11898-2.

NOTE To ensure sustainability, it is highly recommended to use CAN controllers on EPAC and charger side, that already support or at least tolerate CAN flexible data rate communication.

C.3.6 Communication protocol

C.3.6.1 General

The communication between EPAC and charger shall be implemented by a CAN bus, in accordance with ISO 11898-1, where the CAN bus network between the charger inlet and the charger shall be separated from the EPAC internal communication (see Figure C.26). Each charger connector of the charger shall have a dedicated CAN controller. High Speed CAN with a data rate of 250 kbit/s shall be used. In the example (see Figure C.26) the charger consists of charger1 and charger2. The number of chargers in the non-proprietary charger can be adapted.

All signals communicated on the network shall be interpreted with Motorola byte order. All CAN frame identifiers shall be standard format (11 bit). Reserved areas shall be kept undefined for future use and shall be set to 0x00.

NOTE The communication protocol can be extended for customer specific applications.

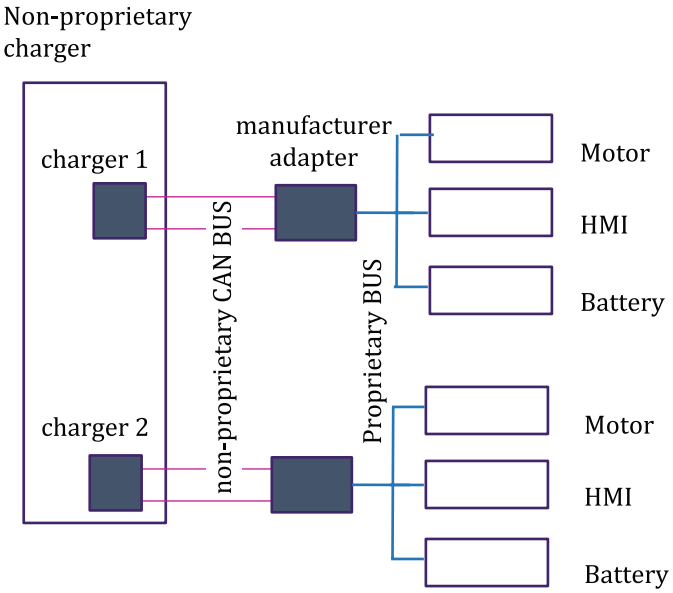


Figure C.26 — EPAC internal communication is separated from the CAN bus network between charger inlet and charger

C.3.6.2 CAN frames send by charger

C.3.6.2.1 Chrg_ErrorCode

CAN ID = 0x250 DLC = 8

Transmit behavior: Once on event of error

Transmitter: Charger

Receiver: EPAC

Byte/bit index	7	6	5	4	3	2	1	0
0	Chrg_ErrorCode							
1								
2								
3								
4								
5								
6								
7								

Message is *optional* for future use

Signals:

— Chrg_ErrorCode
  — Length = 64 bit
  — Value: to be defined

C.3.6.2.2 Chrg_Heartbeat

CAN ID = 0x200 DLC = 1

Transmit behavior: Each 100 ms

Transmitter: Charger

Receiver: EPAC

Byte/bit index	7	6	5	4	3	2	1	0
0	ChrgHeartbeatSignal							

Main purpose of this message is to allow a presence detection of the Charger.

Signals:

— ChrgHeartbeatSignal

  — Length = 8 bit

  — Value: always 0x00

C.3.6.2.3 Chrg_Measure

CAN ID = 0x225 DLC = 8

Transmit behavior: Each 100 ms

Transmitter: Charger

Receiver: EPAC

Byte/bit index	7	6	5	4	3	2	1	0
0	ChrgMeasuredOutputCurrent							
1								
2	ChrgMeasuredOutputVoltage							
3								
4	reserved							
5								
6								
7								

Message is *optional*. Charger transmits measured output voltage and output current. EPAC may validate requested current/voltage against values measured by charger, and transmit adjusted current/voltage.

Signals:

— ChrgMeasuredOutputCurrent:

  — Length: 16 bit

  — Unit: Ampere

  — Unsigned integer

- Conversion formula:
  - Factor: 0,01
  - Offset: 0

- ChrgMeasuredOutputVoltage
  - Unit: Volts
  - Unsigned integer
  - Conversion formula:
    - Factor: 0,01
    - Offset: 0

C.3.6.2.4 Chrg_NetworkManagement

CAN ID = 0x20 DLC = 8

Transmit behavior: Once during shutdown

Transmitter: Charger

Receiver: EPAC

Byte/bit index	7	6	5	4	3	2	1	0
0	ChrgNM_control							
1	ChrgNM_state							
2	reserved							
3								
4								
5								
6								
7								

Message is sent either if charger wants to shut down or as response to a shutdown request from the EPAC. One participant may request the shutdown by set NM_Control to “shutdown request”, but always shall wait, until the other participant transmits the Network Management (NM) message with NM_state = “shutdown_acknowledge”.

Signals:

- ChrgNM_Control:
  - Length: 8 bit
  - Conversion table:
    - 0x00 = no action
    - 0x01 = shutdown request
- ChrgNM_state:
  - Length: 8 bit

— Conversion table:
  — 0x00 = standby
  — 0x01 = shutdown_acknowledge

C.3.6.2.5 Chrg_PropertiesAdmin

CAN ID = 0x210 DLC = 8

Transmit behavior: On EPAC request via EPAC_ReqProperties

Transmitter: Charger

Receiver: EPAC

Byte/bit index	7	6	5	4	3	2	1	0
0	ChrgProp_PropVersionMajor							
1	ChrgProp_PropVersionMinor							
2	ChrgProp_ProtocolVersionMajor							
3	ChrgProp_ProtocolVersionMinor							
4	reserved							
5								
6								
7								

This message is sent during property exchange on startup and transmits information about the protocol version and the property exchange mechanism version.

Signals:

— ChrgProp_PropVersionMajor
  — Length: 8 bit
  — Data type Unsigned integer
  — Default value: 0x01
— ChrgProp_PropVersionMinor
  — Length: 8 bit
  — Data type Unsigned integer
  — Default value: 0x00
— ChrgProp_ProtocolVersionMajor
  — Length: 8 bit
  — Data type Unsigned integer
  — Default value: 0x01
— ChrgProp_ProtocolVersionMinor
  — Length: 8 bit
  — Data type Unsigned integer