PUBLICLY AVAILABLE SPECIFICATION

ISO/PAS 19363

First edition
2017-01

Electrically propelled road vehicles — Magnetic field wireless power transfer — Safety and interoperability requirements

Véhicules routiers électriques — Transmission d'énergie sans fil par champ magnétique — Exigences de sécurité et d'interopérabilité

Reference number
ISO/PAS 19363:2017(E)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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 on 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 the following URL: www.iso.org/iso/foreword.html.

ISO PAS 19363:2017 was prepared by Technical Committee ISO/TC 22, *Road vehicles,* SC 37, *Electrically propelled vehicles*, in collaboration with IEC/TC 69 *Electric road vehicles and electric industrial trucks,* in accordance with ISO/IEC mode of cooperation 4.

Introduction

This document is an intermediate specification, published prior to the development of a full International Standard. This document prescribes the usage of the wireless power transfer technology to charge electrically propelled road vehicles. Even if the technology itself is well known, the implementation in a vehicle is new and demands to meet the very specific requirements of the automotive industry. The main purpose of this document is to respond to the upcoming market needs starting with determination of basic safety requirements and documentation for the first findings for vehicle usage.

This document will be transformed into an International Standard as soon as consolidated technical experiences are available. When transferring this document into an IS, technical changes are possible to adopt the document to the latest level of knowledge.

Electrically propelled road vehicles — Magnetic field wireless power transfer — Safety and interoperability requirements

1 Scope

This document defines the requirements and operation of the on-board vehicle equipment that enables magnetic field wireless power transfer (MF-WPT) for traction battery charging of electric vehicles. It is intended to be used for passenger cars and light duty vehicles.

This document addresses the following aspects for an EV device:

— transferred power;

— ground clearance;

— interoperability requirements among differently classified EV devices and associated off-vehicle systems;

— performance requirements under various conditions, including among different manufacturers and classifications;

— safety requirements;

— test procedures.

EV devices according to this document are intended to operate with off-board systems currently under development in the IEC 61980 series.

NOTE 1 This edition covers stationary applications.

NOTE 2 Bidirectional power transfer is not considered in this edition.

2 Normative references

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

ISO 6469-3, *Electrically propelled road vehicles — Safety specifications — Part 3: Protection of persons against electric shock*

ISO 14117, *Active implantable medical devices — Electromagnetic compatibility — EMC test protocols for implantable cardiac pacemakers, implantable cardioverter defibrillators and cardiac resynchronization devices*

ISO 15118-8, *Road vehicles — Vehicle to grid communication interface — Part 8: Physical layer and data link layer requirements for wireless communication*

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

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

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

IEC 61786-1, *Measurement of DC magnetic, AC magnetic and AC electric fields from 1 Hz to 100 kHz with regard to exposure of human beings - Part 1: Requirements for measuring instruments*

ICNIRP 2010, *Guidelines for limiting exposure to time varying electric and magnetic fields (1 HZ – 100 kHZ)*

ICNIRP 1998, *Guidelines for limiting exposure to time varying electric and magnetic fields (up to 300 kHZ)*

3 Terms and definitions

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

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

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

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

3.1
alignment
relative position of primary to *secondary device* (3.27)

3.2
alignment check
confirmation that the primary and *secondary devices* (3.27) are properly positioned relative to each other

Note 1 to entry: Proper positioning is done to assure sufficient system functionality [e.g. *system efficiency* (3.35), EMF/EMC limits, safety requirements, etc.].

3.3
basic insulation
insulation of hazardous-live-parts which provides basic protection

3.4
battery system
(battery) energy storage device that includes cells or cell assemblies or battery pack(s), as well as electrical circuits and electronics

EXAMPLE BCU, contactors.

3.5
double insulation
insulation comprising both *basic insulation* (3.3) and *supplementary insulation* (3.30)

3.6
electric shock
physiological effect resulting from an electric current through a human body

3.7
electric vehicle/electric road vehicle
EV
any vehicle propelled by an electric motor drawing current from a *battery system* (3.4) intended primarily for use on public roads

3.8
EV communication controller
EVCC
embedded system, within the vehicle, that implements the communication between the vehicle and the SECC in order to support specific functions

Note 1 to entry: Such specific functions could be, for example, controlling input and output channels, encryption, or data transfer between vehicle and SECC.

3.9
EV device
on-board component assembly, comprising the *secondary device* (3.27), the *EV power electronics* (3.12) and the *EV communication controller* (3.8), as well as the mechanical connections between the components necessary for wireless power transfer

3.10
EV power circuit
EVPC
electrical component assembly that includes the *secondary device* (3.27) and *EV power electronics* (3.12), as well as the mechanical connections between the components

Note 1 to entry: EVPC is here defined specifically for *MF-WPT systems* (3.19).

3.11
EVPC power class
power class of an EVPC defined according to the *MF-WPT input power class* (3.18) of the supply device it is designed to operate

Note 1 to entry: The power delivered to the *EV device* (3.9) will be less than that maximum MF-WPT input power to the *MF-WPT system* (3.19) due to losses, for example, in the *supply power electronics* (3.34) and eddy currents in the MF-WPT shield or the vehicle underbody.

3.12
EV power electronics
on-board electronics, including all housings and covers, that convert the AC power from the *secondary device* (3.27) to DC power having suitable voltages and currents provided to the *battery system* (3.4) or the traction-battery

EXAMPLE Impedance matching network (IMN), filter, rectifier, impedance converter.

3.13
fine positioning
relative movement of the *secondary device* (3.27) in relation to the *primary device* (3.23) with the goal of reaching *optimal alignment* (3.20)

3.14
foreign object
object that is not an attached part of the vehicle or the *MF-WPT system* (3.19)

3.15
grid
electric power source that is not part of the vehicle for supplying electric energy to an EV using a *supply power circuit* (3.33)

3.16
Magnetic Field Wireless Power Transfer
MF-WPT
wireless transfer of energy from a power source to an electrical load via a magnetic field

3.17
message
data in a specified format

EXAMPLE A message contains data in a specified format that describes for example, a request or a reply.

Note 1 to entry: A message contains zero or more parameters.

3.18
MF-WPT input power class
power class of a supply device of *MF-WPT systems* (3.19) defined from the perspective of the maximum power drawn from the *grid* (3.15) in order to drive the supply device

Note 1 to entry: IEC 61980-3 will specify the MF-WPT input power classes, current status of discussions: for MF-WPT1 the maximum input power is ≤3,7 kW, for MF-WPT2 the maximum input power is >3,7 kW and ≤7,7 kW, for MF-WPT3 the maximum input power is >7,7 kW and ≤11 kW, for MF-WPT4 the maximum input power is >11 kW and ≤22 kW, for MF-WPT5 the maximum input power is >22 kW. For this document, MF-WPT1 to MF-WPT4 are under consideration.

3.19
MF-WPT system
system consisting of *primary device* (3.23), *supply power electronics* (3.34), *supply equipment communication controller* (3.32), (the supply device), *secondary device* (3.27), *EV power electronics* (3.12) and electric vehicle communication controller [the *EV device* (3.9)], including wiring, housing and covers used to transfer energy using magnetic fields

Note 1 to entry: See also Figure 1.

3.20
optimal alignment
alignment (3.1) with the most efficient power transfer

3.21
pairing
process by which an EV is correlated with the unique dedicated *primary device* (3.23) at which it is located and from which power will be transferred

3.22
power saver mode
mode in which the EV either turns *EV device* (3.9) components off or into a mode with reduced power consumption

3.23
primary device
device external to the EV that is the source of the MF-WPT, including all housings and covers

Note 1 to entry: When the EV is receiving power, the primary device acts as the source of the power to be transferred.

3.24
protection area
volume in and around the vehicle that has homogeneous protection target requirements

3.25
reference level
levels of field strength or power density derived from the basic restrictions using worst case assumptions about exposure

Note 1 to entry: If the reference levels are met, then the basic restrictions will be complied with, but if the reference levels are exceeded, that does not necessarily mean that the basic restriction will not be met.

3.26
reinforced insulation
insulation of hazardous live parts which provides a degree of protection against *electric shock* (3.6) equivalent to *double insulation* (3.5)

Note 1 to entry: Reinforced insulation may comprise several layers which cannot be tested singly as *basic insulation* (3.3) or *supplementary insulation* (3.30).

3.27
secondary device
device mounted on the EV, including all housings and covers, that captures the magnetic field sourced by the *primary device* (3.23)

Note 1 to entry: When the EV is receiving power, the *secondary device* (3.28) transfers the power from the primary to the EV.

3.28
secondary device ground clearance
vertical distance between the ground surface and the lowest point of the *secondary device* (3.28)

Note 1 to entry: The lower surface may not be planar and may not be parallel to the ground surface.

3.29
steady state
state of a system at which all state and output variables remain constant in time while all input variables are constant

3.30
supplementary insulation
independent insulation applied in addition to *basic insulation* (3.3) for fault protection

3.31
supply device
off-board component assembly comprising the *primary device* (3.23), the *supply power electronics* (3.34) and the supply device communication controller, as well as the mechanical connections between the components necessary for wireless power transfer

3.32
supply equipment communication controller
SECC
entity which implements the communication to one or multiple *EVCCs* (3.8)

Note 1 to entry: Functions of an SECC control input and output channels, data encryption, or data transfer between vehicle and SECC.

3.33
supply power circuit
off-board component assembly comprising the *supply power electronics* (3.34) and *primary device* (3.23), as well as the mechanical connections between the components

3.34
supply power electronics
off-board electronics, including all housings and covers, that supply the electric power to the *primary device* (3.23)

EXAMPLE PFC converter, DC-AC inverter, filter, impedance matching network.

3.35
system efficiency
efficiency from AC or DC power supply (input of the supply device) to the output of the *EV device* (3.9)

Note 1 to entry: It is of no importance whether the output is connected to a device or directly to a battery.

3.36
voltage class B
classification of an electric component or circuit with a maximum working voltage of >30 V and ≤1,000 V AC (rms) or >60 V DC and ≤1,500 V DC, respectively

4 Environmental conditions

Potential environmental stresses and related tests and requirements for electronic systems/components mounted in specific locations on/in the vehicle are described in ISO 16750.

The environmental requirements applicable to a particular EV device shall be identified and agreed between the customer and supplier and the compliance testing for these requirements shall be performed in accordance with the following ISO standards:

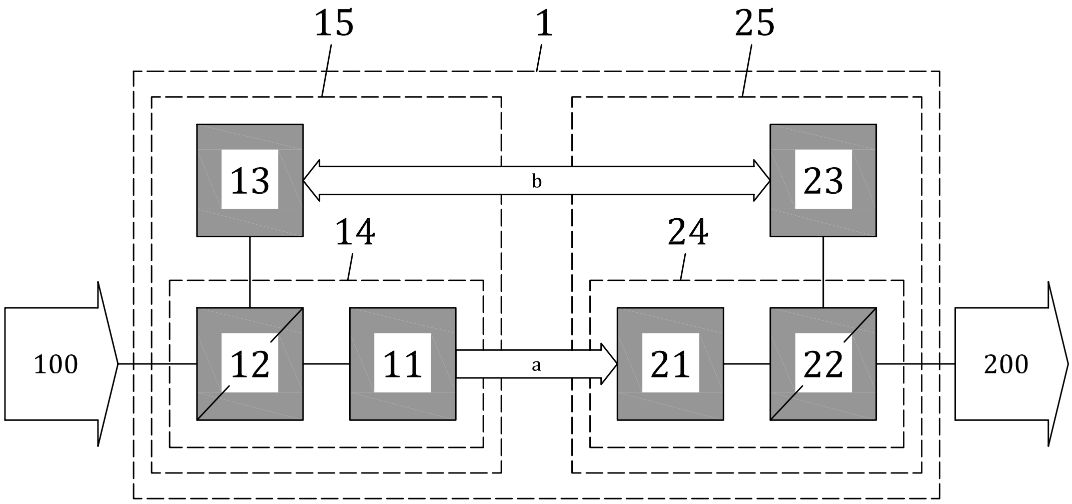
— mechanical loads according to ISO 16750-3, test procedure type VI, vehicle body;

— climate loads according to ISO 16750-4;

— chemical loads according to ISO 16750-5.

5 System description

Figure 1 shows an example for the structure of an MF-WPT system.



Key

1 MF-WPT system
11 primary device
12 supply power electronics
13 supply equipment communication controller (SECC)
14 supply power circuit
15 supply device
100 grid
21 secondary device
22 EV power electronics
23 EV communication controller (EVCC)
24 EV power circuit (EVPC)
25 EV device
200 battery
a Wireless power flow.
b Communication.

NOTE The numbering convention adopted is based on system blocks being assigned a number with the supply device blocks having numbers of the form “1X” and the EV device blocks of the form “2X”. The second digit identifies equivalent functionality in the supply and EV sub-systems.

Figure 1 — MF-WPT system

6 MF-WPT interoperability

6.1 General

Interoperability refers to the capability of the supply device and the EV device being able to transfer power wirelessly in a safe and efficient manner, based on compliance with the requirements in this document.

In order to determine interoperability, an EV device shall be tested according to 6.6 with the reference supply devices for which it is designed to operate.

NOTE 1 IEC 61980-3 will specify the reference supply devices. A supply device is designed so that it is operable with the relevant reference EV devices, specified in this document. In order to determine interoperability, a supply device is tested with the relevant reference EV devices specified in this document. This allows EV devices and supply devices to be sourced independently.

NOTE 2 The interoperability of the functions and communication is specified in Clause 7 and Clause 8.

6.2 Classification of EV power circuits

6.2.1 General

The reference EV devices are classified by MF-WPT class and Z class.

NOTE For this document, it is assumed that supply devices are designed to serve all Z classes.

6.2.2 MF-WPT classes

An EVPC shall be classified for one or more MF-WPT classes.

The maximum power of an EVPC shall be specified.

A reference EV device is classified for one MF-WPT class.

Reference EV devices are verified to meet the performance requirements (see 6.3) up to the maximum power of the MF-WPT class it is assigned to.

MF-WPT class interoperability requirements between the supply device and an EVPC are shown in Table 1.

Table 1 — MF-WPT Class Interoperability Requirements

		Supply device MF-WPT input power class			
		MF-WPT1	**MF-WPT2**	**MF-WPT3**	**MF-WPT4**
EVPC MF-WPT class	MF-WPT1	Required	Required[a]	[a]	[a]
	MF-WPT2	Required[a]	Required	[a]	[a]
	MF-WPT3	[a]	[a]	Required	[a]
	MF-WPT4	[a]	[a]	[a]	Required

[a] Under consideration.

MF-WPT class interoperability implies that the EV device shall be able to request adaptation of output power of the supply device.

6.2.3 Z classes

The Z classes as specified in Table 2 are based on the secondary device ground clearance.

Table 2 — Z classes

Z class	Secondary device ground clearance mm
Z1	100 to 150
Z2	140 to 210
Z3	170 to 250
NOTE Alternative for Z3 as 200 mm to 250 mm is under discussion.	

A reference EV device is verified to meet the performance requirements (see 6.3) within the entire Z class for which it is specified.

The secondary device ground clearance range for which an EVPC is designed shall be specified.

An EVPC shall meet the performance requirements (see 6.3) within the secondary device ground clearance range for which it is specified when tested with the reference supply device(s).

6.3 Performance requirements

6.3.1 General

An EVPC shall meet the performance requirements within the secondary device ground clearance range and within the power range as specified by the manufacturer when tested with the corresponding reference supply device.

6.3.2 Alignment tolerance requirements

The reference EV device are verified to meet the power transfer requirements as in 6.3.3 and the system efficiency requirements as in 6.3.4 over its entire Z class and the alignment tolerances in x and y direction (see Table 4).

An EVPC shall meet the requirements as in 6.3.3 and 6.3.4 over its entire secondary device ground clearance range and the alignment tolerances in x and y direction (see Table 3).

NOTE 1 Compliance is verified by including the maximum misalignment point within the test plan. The test conditions are defined in the test procedure.

NOTE 2 The alignment tolerances are defined with respect to the optimal alignment.

Table 3 — x and y alignment tolerance requirements

Axis	Alignment tolerance (mm)
x	±75
y	±100

The EV may have the capability to assist the driver in aligning the vehicle for proper coupling between the primary and secondary device. This functionality may require some support from the supply power circuit and standardization of this mechanism may be desired. The definition of such a mechanism does not preclude the use of alternate mechanisms by the EV.

6.3.3 Power transfer requirements

A reference EV device shall deliver the requested power under steady-state condition up to maximum power of the MF-WPT class for which it is specified.

An EVPC shall deliver the requested power under steady-state condition up to the power for which it is specified by the vehicle manufacturer.

A requested change in power delivery shall not cause a DC output voltage overshoot of an EVPC by more than ±250 V/ms with the peak voltage not higher than 10 % of the nominal DC output voltage. The DC output voltage ripple amplitude of an EVPC shall not exceed ±8 V.

6.3.4 System efficiency requirements

The minimum system efficiency shall be according to Table 4.

Table 4 — Minimum efficiency

Alignment	Minimum system efficiency
Optimal alignment	85 %
Within alignment tolerance	80 %

If auxiliary loads (e.g. thermal management or foreign object detection) are mandatory for a system specific application (e.g. higher power classes or higher flux), their power consumption shall also be included in the system efficiency calculation.

If auxiliary loads are not mandatory and partial load is not applicable for a system specific application, this shall be confirmed in a clear statement as part of the measurement procedure and type certification documents.

6.4 Frequency

To ensure interoperability, the power transfer shall be operated within the system frequency range respectively at the nominal frequency, according to Table 5.

Table 5 — Frequency

Description	**Frequency** (kHz)
System frequency range	81,38 to 90,00
Nominal frequency	85 ± 0,1

A fixed-frequency system shall transfer the power at the nominal frequency.

For frequency-tuneable systems, the nominal frequency is typically observed under optimal alignment and while the system is in a steady-state. Frequency-tuneable systems may transfer power at any frequency within the system frequency range.

NOTE To optimize the system efficiency, the MF-WPT system (or the supply power circuit) can tune the frequency within the system frequency range.

6.5 Reference EV devices

Reference EV devices for MF-WPT1 and MF-WPT2 are described in Annex A to Annex D.

NOTE Annex A to Annex D reflect the state-of-the-art proposals for reference EV devices that are under discussion. Technical investigations are ongoing to specify the reference EV devices and interoperability requirements.

6.6 Test procedure

Power transfer and system efficiency requirements shall be tested with the following setup:

— the EV device is connected to a battery or a simulated DC load.

Power transfer and system efficiency requirements shall be tested under the following conditions:

— ambient temperature of 25 °C ± 5 °C;

— the system is in steady-state;

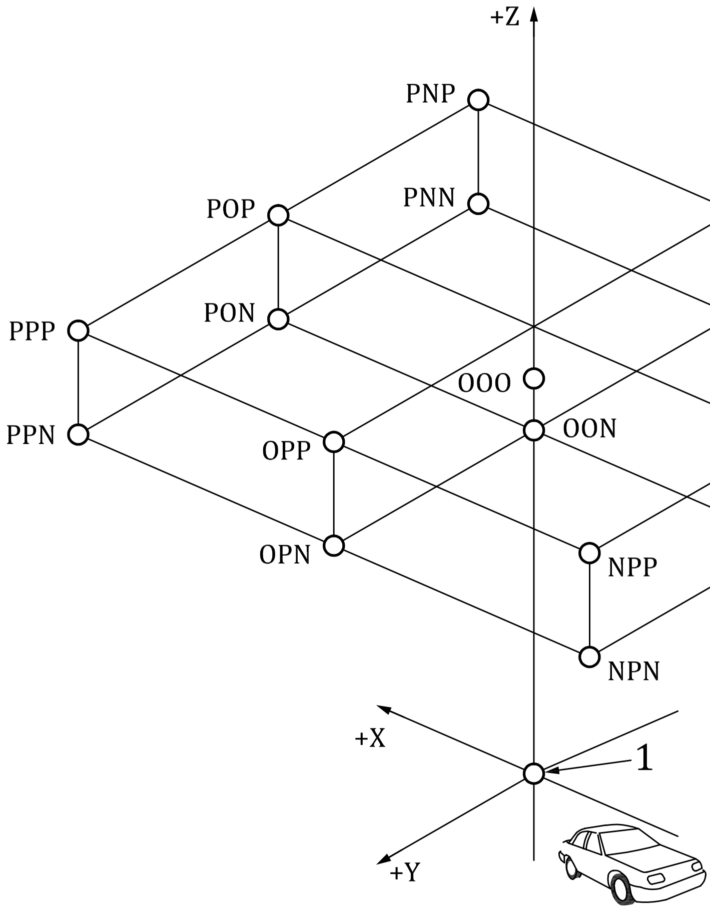
— output voltage of the EV device of 280 V, 350 V and 420 V;

— maximum output power of the EV device. The maximum output power of the EV device is specified by the manufacturer.

NOTE 1 According to Figure 1, “output power of the EV device” means the power which the EV device is able to provide to the battery.

NOTE 2 Other output voltage can be selected in the future application.

Power transfer and system efficiency requirements shall be tested in the positions as specified in Figure 2.



Key

1 optimal alignment

NOTE The coordinate system complies with ISO 4130.

Figure 2 — Measurement positions

The values of the measurement position in Figure 2 are given in Table 6.

Table 6 — Measurement positions

Point X Y Z	Coordinate value (mm)				
	X	Y	Secondary device ground clearance (Z)		
			Z1 class	Z2 class	Z3 class
P P P	+75	+100	150	210	250
P P N			100	140	170
P 0 P		0	150	210	250
P 0 N			100	140	170
P N P		−100	150	210	250
P N N			100	140	170
0 P P	0	+100	150	210	250
0 P N			100	140	170
0 0 0		0	125	175	210
0 0 N			100	140	170
0 N P		−100	150	210	250
0 N N			100	140	170
N P P	-75	+100	150	210	250
N P N			100	140	170
N 0 P		0	150	210	250
N 0 N			100	140	170
N N P		−100	150	210	250
N N N			100	140	170

The values for the secondary device ground clearance shown in Table 6 are used for measuring reference EV devices. For testing EV devices, the maximal and minimal secondary device ground clearance shall be according to the specification by the manufacturer.

7 Functions

7.1 Communication setup

Communication setup shall be initiated by the EVCC. The EVCC shall be able to verify communication is properly established.

7.2 Service selection

7.2.1 General

The EVCC shall request available services and possible power transfer options from the SECC.

In order to be able to serve multiple EVs with different EVPC power classes or other different MF-WPT system characteristics, a supply site may be organized to offer different options for WPT at different supply power circuits which are all using one SECC in common for communication. This function will allow the EVCC and SECC to determine what fine positioning and pairing methods to use. This function may increase comfort in terms of a pre-selection of valid WPT options and optimization of guidance functionality. The SECC may provide the same information as in the final compatibility check, as well as information about the methods for fine positioning, pairing and initial alignment check. The situation of a home garage with a SECC serving only one primary device maybe treated as a special case of the situation sketched above.

7.2.2 Parameters to be exchanged for interoperability

The EVCC shall send the following parameters for service selection:

— EVPC power class;

— maximum receivable power;

— maximum secondary device ground clearance;

— minimum secondary device ground clearance;

— minimum operating frequency;

— maximum operating frequency;

— type of geometry of the secondary device;

— circuit topology;

— fine positioning methods;

— pairing methods;

— initial alignment check methods;

— manufacturer ID;

— manufacturer specific data container;

— specific Service Provider (optional).

NOTE The EVCC expects corresponding information from the SECC according to IEC 61980–2 (under development).

7.3 Fine positioning

Fine positioning begins when the EV is entering the chosen WPT spot and guidance is provided to the driver. The goal is to reach an alignment within the alignment tolerance requirements (see 6.3.2). The method for fine positioning shall be chosen during service selection.

7.4 Pairing

The EV shall initiate the pairing process by sending a pairing request to the SECC.

The method for pairing is chosen during service selection. The EVCC shall be able to confirm pairing.

7.5 Final compatibility check

The compatibility of the primary and the secondary device shall be checked after pairing and prior to power transfer.

The EVCC shall confirm compatibility with the SECC.

7.6 Initial alignment check

The EV shall request the initial alignment check to be performed by the supply device using the method that was chosen during service selection.

The initial alignment check ensures that alignment is within the alignment tolerance requirements (see 6.3.2) before the power transfer starts.

NOTE The function is performed by the supply device according to IEC 61980-2 (under development).

7.7 Start power transfer

Power transfer shall be initiated by request of the EV.

The EV shall request power transfer only when safety monitoring and diagnostic functions according to 7.12 are active.

7.8 Power saver mode

7.8.1 Start power saver mode

To start power saver mode, the EVCC shall inform the SECC that power saver mode will be turned on, and provides the duration for the power saver mode.

In case the SECC agrees, then the EV may go into power saver mode.

SECC and EVCC may negotiate an extension to the power saver mode.

7.8.2 Terminate power saver mode

Once the negotiated time has expired, the EV terminates power saver mode.

The EV may terminate power saver mode at any time.

NOTE Further actions after termination of power saver mode are under consideration.

7.9 Perform power transfer

Transfer of the power from the primary device to the secondary device shall be in accordance with the power request of the vehicle. The EV shall be able to request a specific amount of power, with the power to be specified in watts.

The EV shall not request more power than the supply device has indicated being able to transfer.

If the EV needs less power than the lower limit of the supply device, the EV shall request zero power.

The EV may also be able to request zero power in order to pause power transfer.

NOTE 1 The maximum power the supply device is able to deliver can change during the power transfer process.

NOTE 2 If the supply device is not able to deliver the amount of power which is requested by the EV, the supply device will indicate that it is unable to service the request and will continue to transfer power at the same rate.

NOTE 3 Timing of exchange of power transfer parameters between supply device and EV device under development.

7.10 Stop power transfer

When the EV wants to terminate power transfer, the EVCC shall send a message to the SECC indicating to stop power transfer.

NOTE This does not terminate communication.

7.11 User initiated stop power transfer

The EV may be equipped with a means for user initiated termination of power transfer.

7.12 Safety monitoring and diagnostics

7.12.1 General

The EV device shall detect the violation of limits or thresholds given within this document and shall request termination of power transfer within 2 s after occurrence, if not otherwise specified.

Power transfer shall only occur when safety monitoring and diagnostic functions are active.

7.12.2 Alignment monitoring

If the EV monitors alignment, the EVCC device shall request power transfer termination in case alignment is no longer within the alignment tolerance.

NOTE Either the EV or supply device monitors the alignment.

7.12.3 Power transfer monitoring

The EV shall provide means to verify that the actual input power does not differ from the expected input power. If the difference exceeds a device specific limit, the EV shall request to stop power transfer.

The EV shall monitor the power transfer to ensure that the received power at the secondary device does not exceed the capabilities of the secondary device.

7.12.4 Communication link monitoring

If the time between valid messages from the SECC exceeds 2,5 s, the EVCC shall request power transfer termination.

7.13 Terminate communication

The communication shall be terminated by an exchange of termination messages.

7.14 Terminate safety monitoring and diagnostics

The EV shall wait for the termination confirmation from the SECC and shall check that no power is transferred before deactivating safety monitoring and diagnostics.

7.15 Wake up after power outage

Wake up after power outage is under consideration.

7.16 Test procedure

Test requirements for the described functions are under development.

8 Sequence and communication

8.1 General

The message sequence and the communication are defined in ISO 15118-2.

8.2 Sequence of functions

8.2.1 Protocol flow stages and associated messages

For power transfer, the following steps apply:

— communication setup;

— service selection;

— fine positioning;

— pairing;

— prepare for power transfer;

— initial alignment check;

— perform power transfer;

— stop power transfer;

— terminate communication.

These steps ensure that prior to power transfer,

— proper/secure communication is established,

— billing/services are agreed upon, and

— alignment check/pairing has taken place.

8.2.2 Basic definitions for error handling

The basic error handling shall be according to ISO 15118-2.

8.3 Communication

WPT requires a wireless communication between the supply device and the EV device.

The communication PHY/MAC shall comply with ISO 15118-8.

9 EMC requirements

EMC requirements are under consideration. The device shall be compliant with the EMC requirements outlined by CISPR/D.

NOTE MF-WPT EMC requirements are currently under development in CISPR/D.

10 Safety requirements

10.1 Protection in case of unintended power transfer

Unintended power transfer is the transfer of power in excess of the power requested by the EV or transfer of power after the termination request by the EV.

In case of unintended power transfer, the EVPC shall interrupt communication with the supply device within 10 s.

NOTE In the absence of communication capability, power transfer is not allowed.

An EVPC shall withstand the maximum power of the MF-WPT input power class it is interoperable with for a minimum of 15 s.

Test to be agreed between supplier and vehicle manufacturer.

10.2 Protection against electrical shock

This subclause applies only to voltage class B electric circuits of an EV device.

Design and testing for protection against electric shock shall be in accordance with ISO 6469-3.

The isolation for the secondary coil shall have at least double or reinforced insulation.

NOTE Requirements on post-crash electrical safety are specified in ISO 6469-4.

10.3 Protection against overcurrent

10.3.1 Overload protection

Overload protection shall be provided for live conductors of a voltage class B electric circuit according to their cross sectional area.

Compliance is checked by inspection.

10.3.2 Short-circuit protection

The following requirements shall be fulfilled for short-circuit protection:

a) the cross sectional area of the live conductors of the voltage class B electric circuit shall have a short-circuit current withstand rating (I^2t) according to the maximum short-circuit current of an electric power source;

b) overcurrent protection shall be provided for live conductors of a voltage class B electric circuit according to their cross-sectional area.

The design of conductors and protection devices shall take into account that the short-circuit current may be fed from a source outside the EV device. One example of such a source is the battery.

Compliance is checked by inspection.

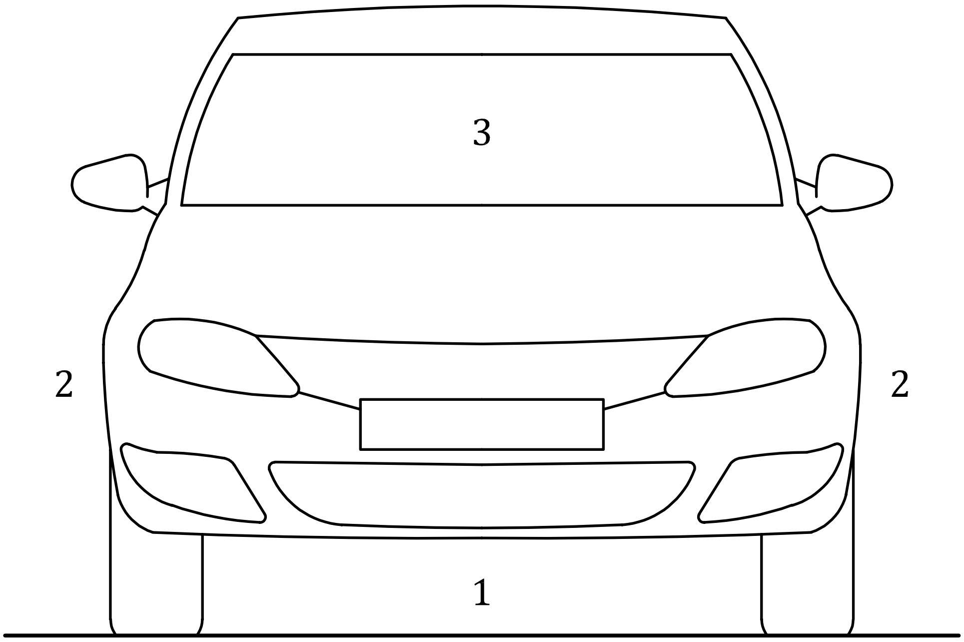
10.4 Protection of humans against electromagnetic effects

10.4.1 General

The requirements in this subclause are specified to protect humans against electromagnetic effects. This covers the protection against negative effects of exposure to electromagnetic fields and the protection of the functionality of AIMDs. The conformance to the specified requirements shall be proved by testing an EV device with a reference supply device according to 10.4.5.

10.4.2 Protection areas

The space inside, under and around the vehicle is divided into three protection areas according to Figure 3.



Key

1 protection area 1: area underneath the vehicle delimited by area 2

2 protection area 2: area surrounding the vehicle; public area to the side, front, rear and top of the vehicle (area around the chassis silhouette of the vehicle)

3 protection area 3: vehicle interior (vehicle cabin)

Figure 3 — Protection areas

10.4.3 Requirements for protection against exposure to hazardous electromagnetic fields

In protection area 2 and 3, the exposure at the worst case alignment (or alignments, if there is more than one alignment with identical emission values) shall meet the applicable limits from ICNIRP Guideline 2010 or ICNIRP 1998 if required by regional regulations.

NOTE 1 There are no requirements for protection against exposure to hazardous electromagnetic fields for the EV device in protection area 1.

NOTE 2 Temporarily, the numbering of the protection areas differs between this document and IEC 61980–1.

In accordance with ICNIRP Guideline 2010, the compliance requirement is to meet the basic restrictions as shown in Table 8. As a convenient method for assessing compliance to basic restrictions, also reference levels may be used as shown in Table 7.

Table 7 — ICNIRP 2010 reference levels

Quantity	Unit	ICNIRP 1998	ICNIRP 2010
		RMS	RMS
Magnetic field	µT	6,25	27
	A/m	5	21
Electric field	V/m	87	83
Contact current	mA	0,2 × f	0,2 × f
NOTE f in kHz.			

Table 8 — ICNIRP 2010 basic restrictions

Quantity	ICNIRP 2010		
	RMS	Peak	Peak exposure index
Internal electric field	1,35 × 10−4 × f(Hz) = 11,0 V/m at 81,38 kHz	1,91 × 10−4 × f (Hz) = 15,5 V/m at 81,38 kHz	1 (as ratio) or 100 %

10.4.4 Requirements to protect functionality of active implantable medical devices (AIMDs)

Protection requirements for AIMDs in protection area 2 and 3 are based on pacemaker immunity levels according to ISO 14117-1. Therefore, protection area 2 is divided into an area below and above 70 cm from the ground. The magnetic field strength shall comply with the limits shown in Table 9.

NOTE There are no requirements to protect the functionality of active implantable medical devices (AIMDs) for the EV device in protection area 1.

Table 9 — Limits for AIMD protection

Protection area	Magnetic field limits	
	RMS (information only)	Peak (normative)
3, 2 (>70 cm)	15 µT or 11,9 A/m (for 81,38 kHz to 90 kHz)	21,2 µT or 16,9 A/m (for 81,38 kHz to 90 kHz)
2 (<70 cm)	29,4 µT or 23,4 A/m (at 85 kHz) 27,8 µT or 22,1 A/m (at 90 kHz)	41,6 µT or 33,1 A/m (at 85 kHz) 39,3 µT or 31,3 A/m (at 90 kHz)

10.4.5 Test procedures

10.4.5.1 Basic restrictions

Compliance of the EV device is established by using a combination of simulations and experimental validation together with a reference supply device to prove that basic restrictions from ICNIRP 2010 are met.

10.4.5.2 Reference levels

10.4.5.2.1 General

Compliance of the EV device may also be demonstrated together with a reference supply device based on assessment to reference levels. If reference levels are used to demonstrate compliance, a presumption of compliance with the basic restrictions is established by showing that the reference level value is not exceeded at any location.

10.4.5.2.2 Compliance demonstration for protection area 3

The test shall be conducted with an EV device together with a reference supply device. During the test the EV device shall be operated at its maximum output power (battery in charging mode). The offset and the air-gap between primary and secondary device shall be set to the configuration which generates the highest emissions in protection area 3.

For determining these worst case position(s), the following procedure shall be applied:

Scan with the field-probe according to IEC 61786-1 (isotropic 3 cm^2 probe or 100 cm^2 probe) over the complete surface of a virtual vertical plane which is located in 20 cm distance and parallel to each of the four sides of the vehicle. The 20 cm distance shall be measured from the most outstanding point of the vehicle surface, excluding the rear mirrors. The plane shall be limited by the size of the vehicle (sides, top) and the ground floor. The probe shall be centred in that virtual surface. The centre of the measurement probe shall be kept at least in the middle of the distance between ground floor and the vehicle underbody during this scan measurement. From a height of 50 cm above the height of the vehicle, no measurement is necessary. Once the hot spot area is identified, a scan with a finer step needs to be performed in the identified localized area to determine the maximum emission value. That value read at the point of highest emissions over the four sides of the vehicle shall be extrapolated to the value which would have been read at the vehicle perimeter (i.e. at the point which is 20 cm closer to the vehicle) using an appropriate extrapolation technique. The extrapolated value shall be considered as worst case emission at the worst case position. It shall be recorded in the test report and fulfil the requirement given in 10.4.3 and 10.4.4.

10.4.5.2.3 Compliance demonstration for protection area 3

During the test, the EV device shall be operated at its maximum output power (battery in charging mode). The offset and the air-gap between primary and secondary device shall be set to the configuration which generates the highest emissions in protection area 3.

The compliance shall be demonstrated in positions (a) to (d) according to Figure 4.

If seats are adjustable in their position, they shall be centre-positioned for testing; see Figure 5.

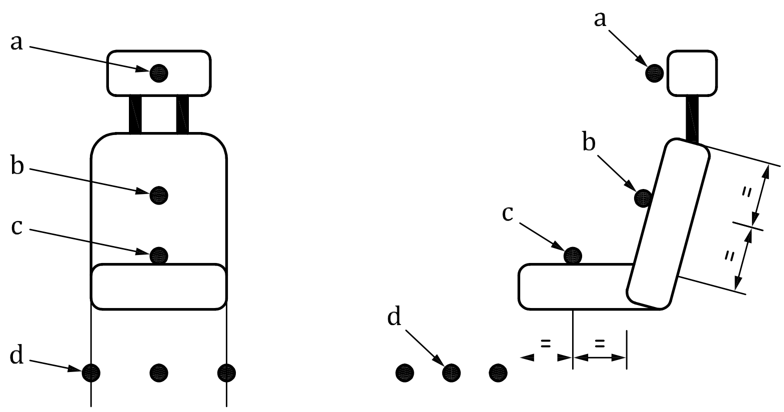


Figure 4 — Emission validation positions for area 4

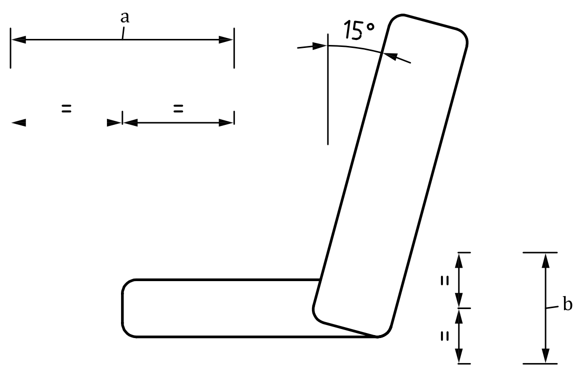


Figure 5 — Seat position adjustment

10.5 Temperature rise and protection against thermal incidents

10.5.1 General

This clause describes the requirements for the protection against foreign objects in the air space between primary and secondary device from exceeding temperatures which could become a touch hazard.

10.5.2 Protection against burns from heating of foreign objects

Protection is provided by the supply device according to IEC 61980-1.

11 Owner's manual and marking

11.1 Owner's manual

The following information shall be included in the owner's manual:

a) description of the MF-WPT system operation and location of the secondary device on the vehicle;

b) functional operations to be performed by the user;

c) position of the HMI elements (command and display) provided on board for these operations;

d) any special precautions required by operators wearing implantable medical devices.

Special attention shall be given in the owner's manual to aspects specific to the vehicle. At least the following indication shall be given to the user:

— instruction for proper alignment of the EV to wireless supply device;

— information about the EVPC power class(es) and interoperability with MF-WPT input power class(es);

— information about how to start and stop wireless power transfer;

— information about the need of a proper installation of the fixed electrical installation.

11.2 Marking

Marking of voltage class B components and wiring shall be in accordance with ISO 6469-3.

Annex A
(informative)

Circular reference EV device proposals for MF-WPT1

A.1 Circular reference EV device proposal for MF-WPT1

A.1.1 General

This annex describes reference EV device proposals for MF-WPT class MF-WPT1 and z classes Z1 and Z2. The reference supply devices as specified in E.2 and E.3 in combination with the reference EV devices specified in this annex fulfil the performance requirements as described in Clause 6.

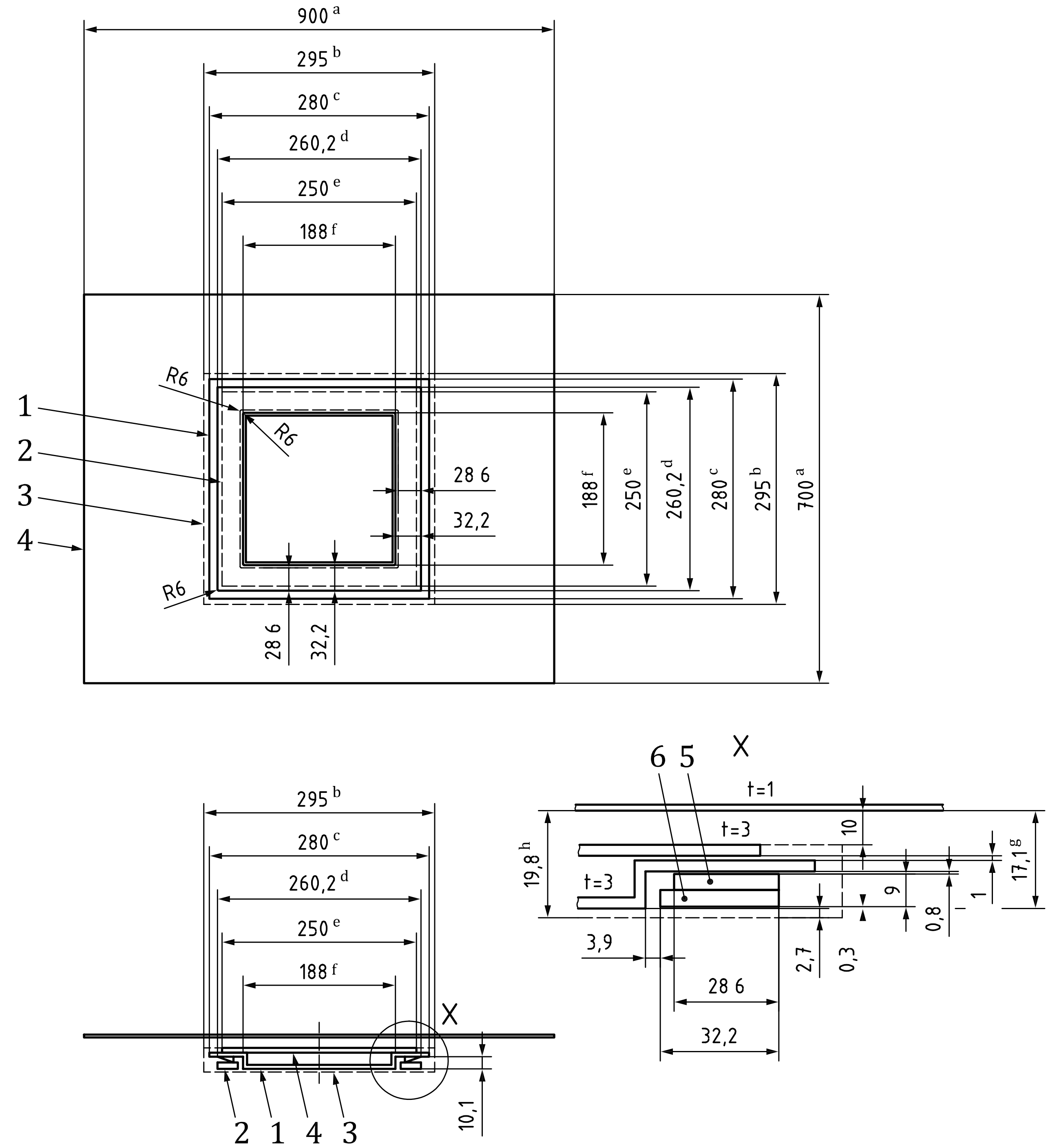
A.1.2 Frequency

Distance variation and misalignment between the supply device and EV device cause variation of inductance and coupling factor. In order to meet the minimum resonance condition, and to achieve higher system efficiency, the EV devices expect a frequency variation within the system frequency range according to Table 5.

A.2 Circular reference EV device proposal for MF-WPT1/Z1

A.2.1 Magnetic interface

Figure A.1 shows the mechanical dimensions of the MF-WPT1/Z1 circular reference EV device.



Key

1	ferrite	a	Aluminium shield dimension.
2	coil	b	Outer case dimension.
3	outer case (for reference)	c	Outer core dimension.
4	aluminium shield	d	Coil dimension.
5	8 upper turns	e	Shielding dimension.
6	9 lower turns	f	Inner core dimension.
		g	Core to shielding distance.
		h	Assy dimension.

Figure A.1 — Mechanical dimensions of the MF-WPT1/Z1 circular reference EV device

The coupling factor of this reference EV device when used in combination with the reference supply device as specified in E.3 is shown in Table A.1.

Table A.1 — Range of coupling factors

Minimum coupling factor	0,109
Maximum coupling factor	0,290

The coil accepts the current according to Table A.2.

Table A.2 — Coil current

Maximum coil current	17 A rms

A.2.2 Schematics of power electronics

Figure A.2 shows the schematics of the power electronics for the reference EV device as described in A.2.1.

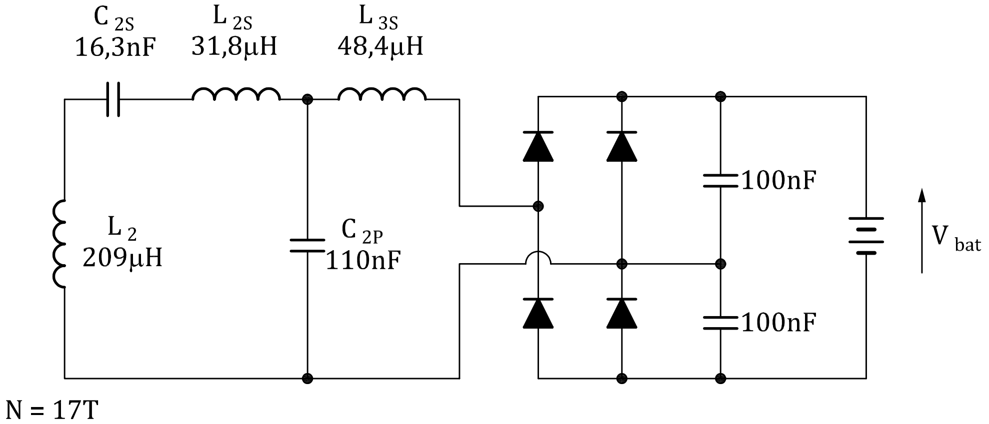
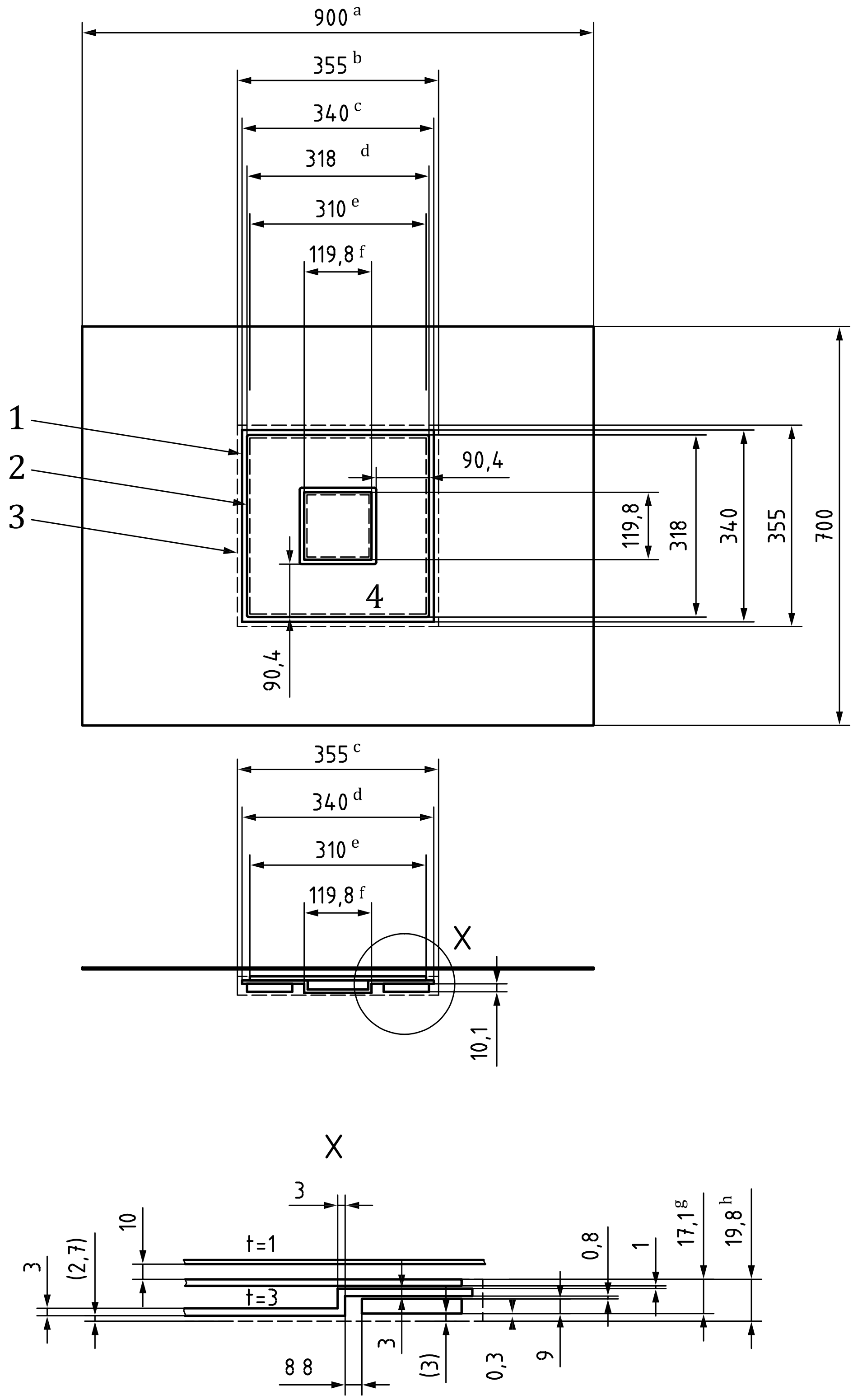


Figure A.2 — Schematics of power electronics for the MF-WPT1/Z1 circular reference EV device

A.3 Circular reference EV device proposal for MF-WPT1/Z2

A.3.1 Magnetic interface

Figure A.3 shows the mechanical dimensions of the MF-WPT1/Z2 circular reference EV device.



Key

1 ferrite

2 coil

3 outer case (for reference)

4 20 turns

a Aluminium shield dimension.

b Outer case dimension.

c Outer core dimension.

d Coil dimension.

e Shielding dimension.

f Inner core dimension.

g Core to shielding distance.

h Assy dimension.

Figure A.3 — Mechanical dimensions of the MF-WPT1/Z2 circular reference EV device

The coupling factor of this reference EV device when used in combination with the reference supply device as specified in E.3 is shown in Table A.3.

Table A.3 — Range of coupling factors

Minimum coupling factor	0,082
Maximum coupling factor	0,215

The coil accepts the current according to Table A.4.

Table A.4 — Coil current

Maximum coil current	18 A rms

A.3.2 Schematics of power electronics

Figure A.4 shows the schematics of the power electronics for the reference EV device as described in A.3.1.

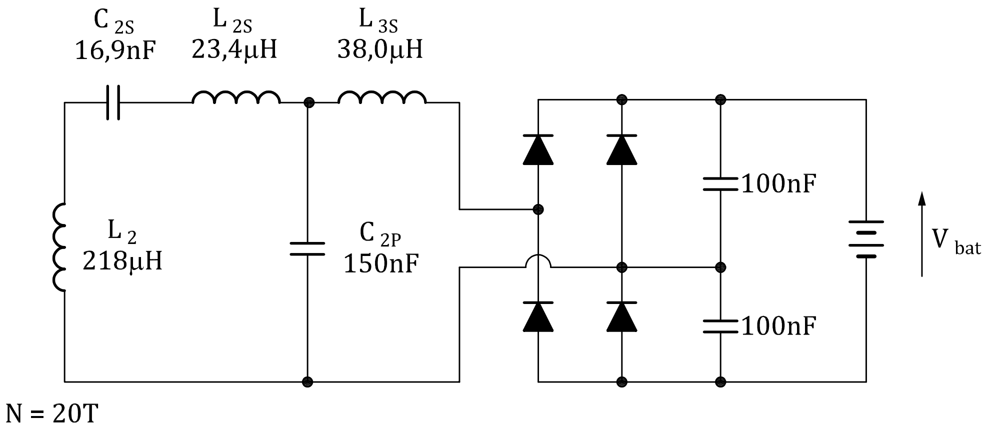


Figure A.4 — Schematics of power electronics for the MF-WPT1/Z2 circular reference EV device

Annex B
(informative)

DD reference EV device proposals for MF-WPT1

B.1 DD reference EV device proposal for MF-WPT1

B.1.1 General

This annex describes reference EV device proposals for MF-WPT class MF-WPT1 and z classes Z1 and Z2. The reference supply device as specified in E.1 in combination with the reference EV devices as specified in this annex fulfil the performance requirements as described in Clause 6.

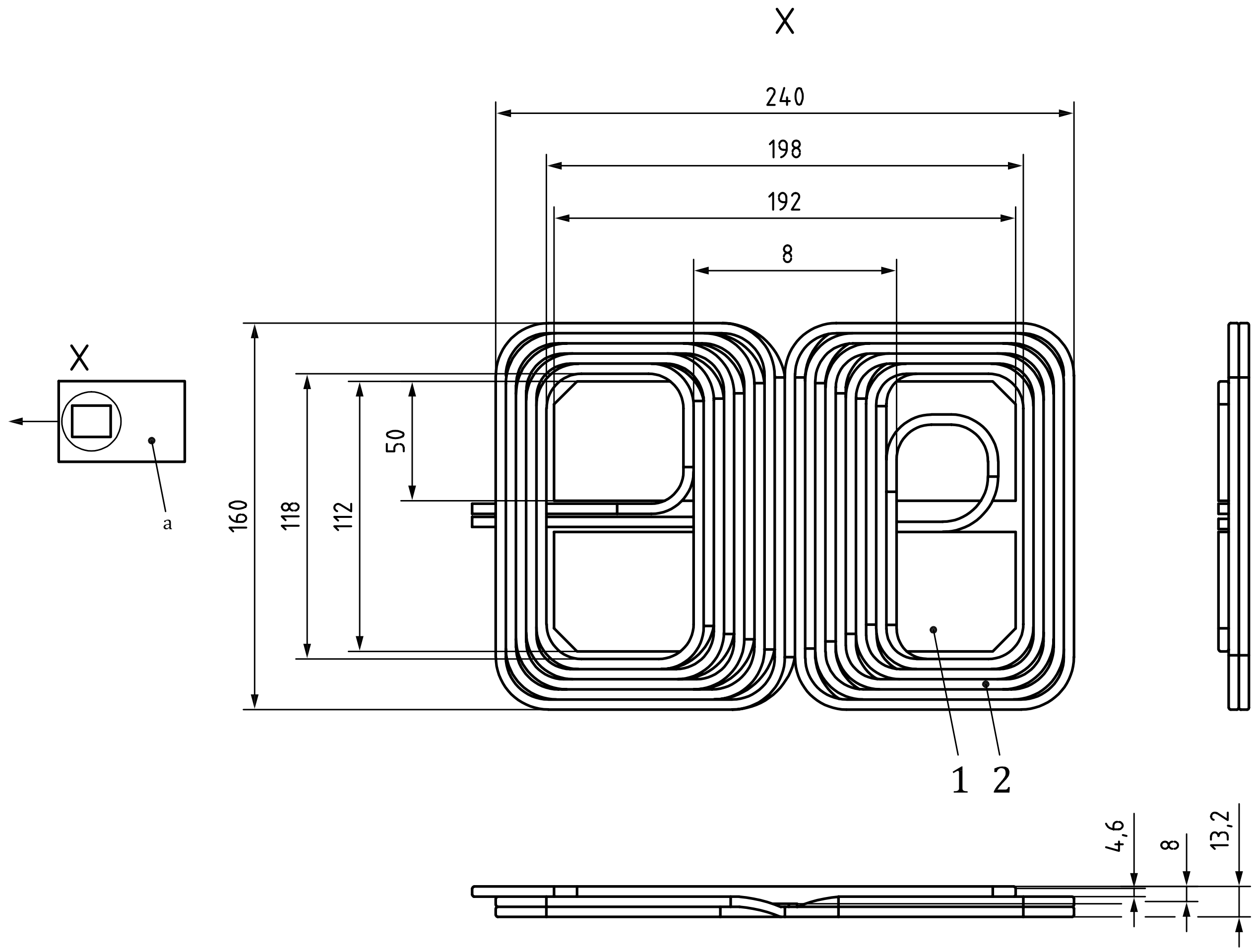
B.1.2 Frequency

The system is tuned for a fixed frequency operation at 85 kHz. Frequency tuning to compensate, for example, for height and alignment variation is not required.

B.2 DD reference EV device proposal for MF-WPT1/Z1

B.2.1 Magnetic interface

Figure B.1 shows the mechanical dimensions of the ferrite and the coil for the MF-WPT1/Z1 DD reference EV device. For clarity, the housing is not shown. The reference EV device orientation on the vehicle is indicated by the icon on the left.



Key

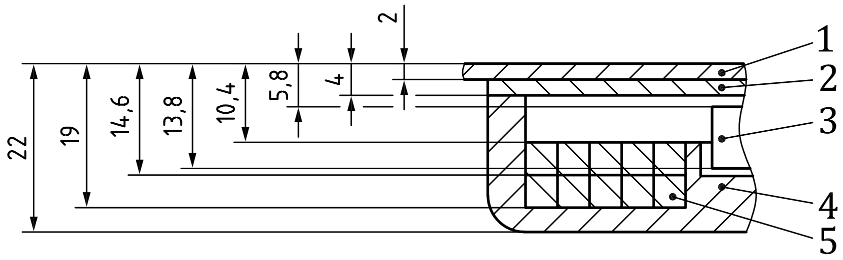
1 ferrite

2 coil

a Pad orientation on the vehicle (driving direction indicated by arrow).

Figure B.1 — Mechanical dimensions of the MF-WPT1/Z1 DD reference EV device

Figure B.2 shows a detailed cross-section view of the MF-WPT1/Z1 reference EV device (including housing and an assumed vehicle shield thickness of 2 mm).



Key

1 aluminium shield

2 aluminium backplate

3 ferrite

4 plastic cover

5 litz wire coil

Figure B.2 — Detailed cross-section view of the MF-WPT1/Z1 DD reference EV device

Table B.1 shows the mechanical dimensions of the MF-WPT1/Z1 reference EV device.

Table B.1 — Mechanical dimensions of the MF-WPT1/Z1 reference EV device

	Coil + ferrite only	**Housing (w/o vehicle shield)**
$L \times W \times H$ (mm)	240 × 160 × 13,2	250 × 170 × 20

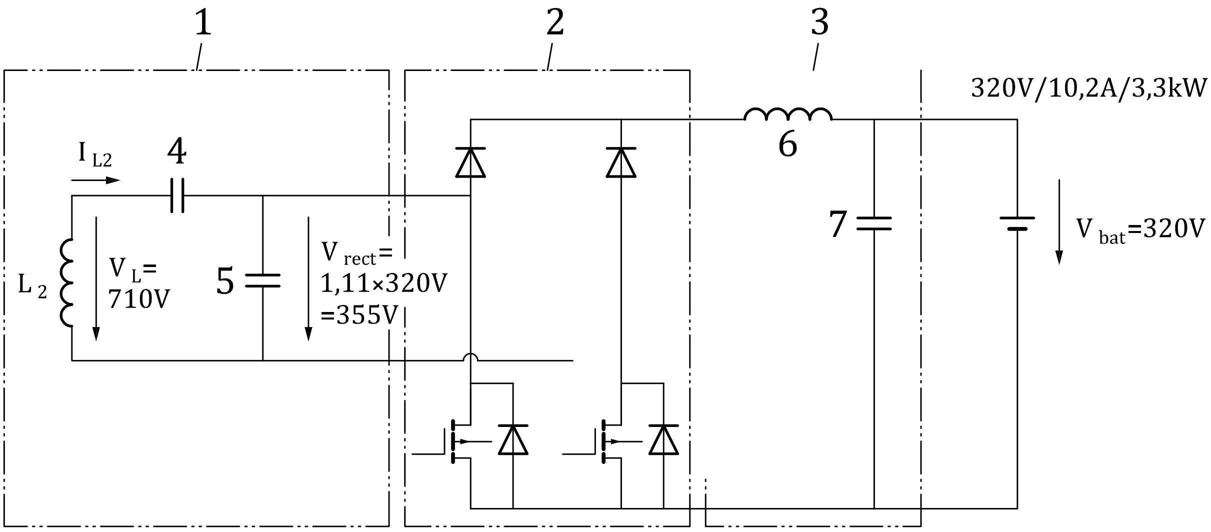
The coupling factor of this reference EV device when used in combination with the reference supply device as specified in E.1 is shown in Table B.2.

Table B.2 — Range of coupling factors

Minimum coupling factor	0,113
Maximum coupling factor	0,222

11.2.1 Schematics of power electronics

Figure B.3 shows the tuning topology for the reference EV device as described in B.2.1. Typical currents and voltages for the MF-WPT class MF-WPT1 are indicated in the diagram.



Key

1 parallel tuned receiver coil including reactance matching
2 rectifier with clamping capability
3 output filter
4 reactance matching capacitor
5 parallel tuning capacitor
6 filter inductance ca. 50 µH
7 filter capacitor ca. 20 µH

Figure B.3 — Schematics of power electronics for the MF-WPT1/Z1 DD reference EV device

The value of the secondary coil inductance L2 varies depending on the secondary device ground clearance. Minimum and maximum values for z class Z1 are given in Table B.3.

Table B.3 — Value of the secondary coil inductance L2 depending on the secondary device ground clearance

Z class	**L_Min** (µH)	**L_Max** (µH)
Z1	62,8	67,3

The values of the secondary tuning capacitors vary depending on the z class. Values for z class Z1 are given in Table B.4.

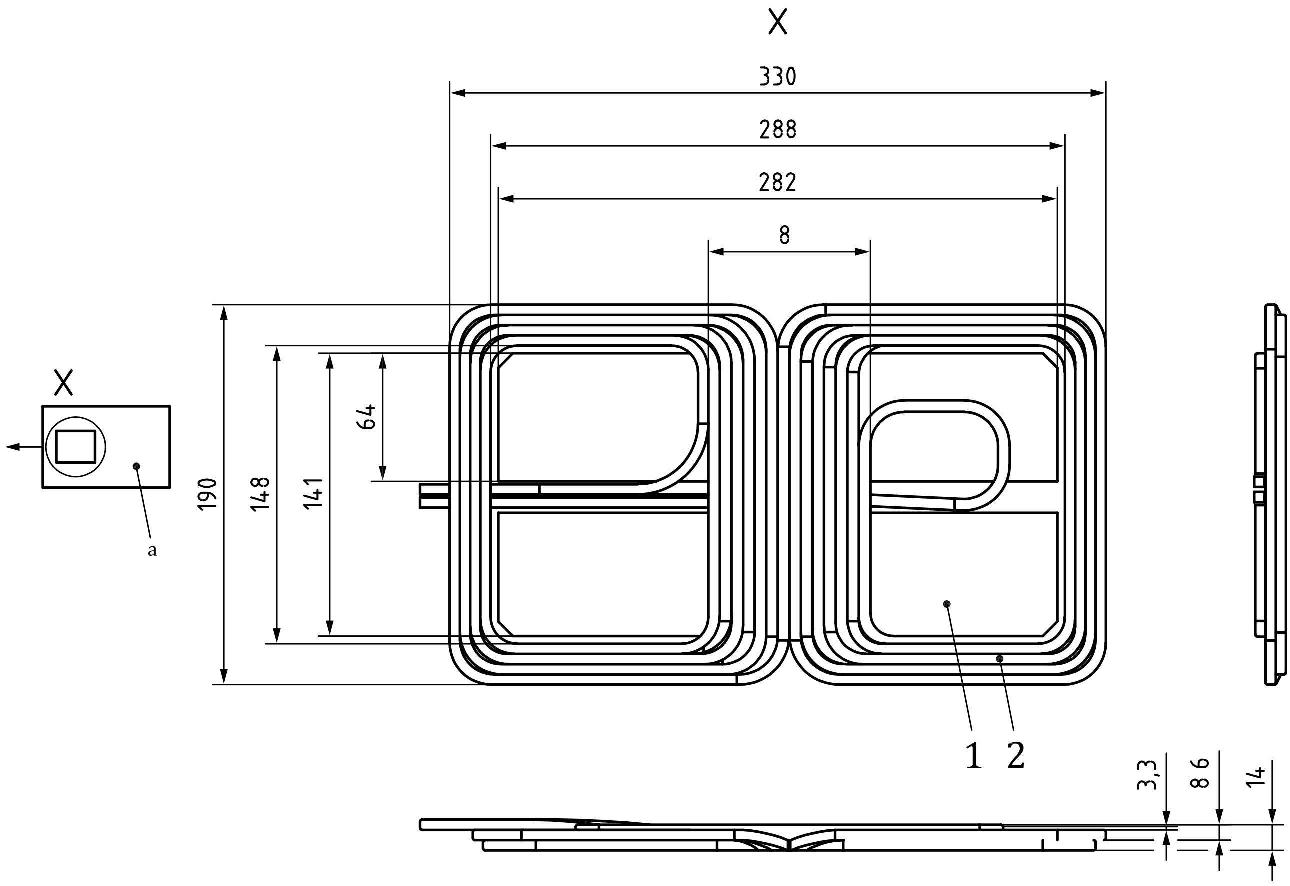
Table B.4 — Values of the secondary tuning capacitors

z class	**C_Parallel** (nF)	**C_Reactance** (nF)
Z1	78,4	172,3

B.3 DD reference EV device proposal for MF-WPT1/Z2

B.3.1 Magnetic interface

Figure B.4 shows the mechanical dimensions of the ferrite and the coil for the MF-WPT1/Z2 DD reference EV device. For clarity, the housing is not shown. The reference EV device orientation on the vehicle is indicated by the icon on the left.



Key

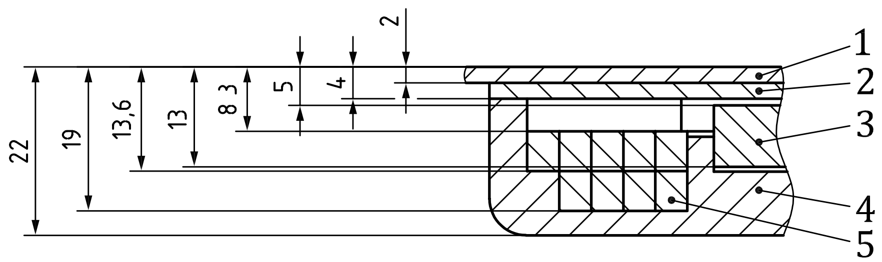
1 ferrite

2 coil

a Pad orientation on the vehicle (driving direction indicated by arrow).

Figure B.4 — Mechanical dimensions of the MF-WPT1/Z2 DD reference EV device

Figure B.5 shows a detailed cross-section view of the MF-WPT1/Z2 reference EV device (including housing and an assumed vehicle shield thickness of 2 mm).



Key

1 aluminium shield

2 aluminium backplate

3 ferrite

4 plastic cover

5 litz wire coil

Figure B.5 — Detailed cross-section view of the MF-WPT1/Z2 DD reference EV device

Table B.5 shows the mechanical dimensions of the MF-WPT1/Z2 reference EV device.

Table B.5 — Mechanical dimensions of the MF-WPT1/Z2 reference EV device

	Coil + ferrite only	Housing (w/o vehicle shield)
L × *W* × *H* (mm)	330 × 190 × 14	340 × 200 × 20

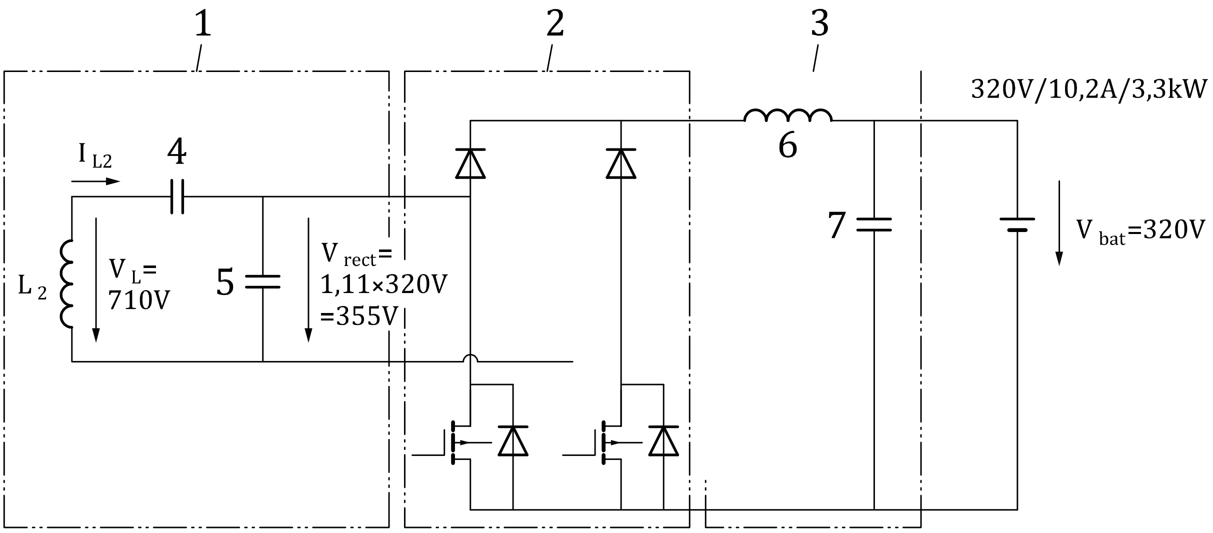
The coupling factor of this reference EV device when used in combination with the reference supply device as specified in E.1 is shown in Table B.6.

Table B.6 — Range of coupling factors

Minimum coupling factor	0,102
Maximum coupling factor	0,215

B.3.2 Schematics of power electronics

Figure B.6 shows the tuning topology for the reference EV device as described in B.3.1. Typical currents and voltages for the MF-WPT class MF-WPT1 are indicated in the diagram.



Key

1 parallel tuned receiver coil including reactance matching
2 rectifier with clamping capability
3 output filter
4 reactance matching capacitor
5 parallel tuning capacitor
6 filter inductance ca. 50 µH
7 filter capacitor ca. 20 µH

Figure B.6 — Schematics of power electronics for the MF-WPT1/Z2 DD reference EV device

The value of the secondary coil inductance L2 varies depending on the secondary device ground clearance. Minimum and maximum values for z class Z2 are given in Table B.7.

Table B.7 — Value of the secondary coil inductance L2 depending on the secondary device ground

Z class	**L_Min** (µH)	**L_Max** (µH)
Z2	47,4	48,8

The values of the secondary tuning capacitors vary depending on the z class. Values for z class Z2 are given in Table B.8.

Table B.8 — Values of the secondary tuning capacitors

z class	**C_Parallel** (nF)	**C_Reactance** (nF)
Z2	103,7	245,5

Annex C
(informative)

Circular reference EV device proposals for MF-WPT2

C.1 Circular reference EV device proposal for MF-WPT2

C.1.1 General

This annex describes reference EV device proposals for MF-WPT class MF-WPT2 and z classes Z1, Z2 and Z3. The reference supply device as specified in E.2 in combination with the reference EV devices as specified in this annex fulfil the performance requirements as described in Clause 6.

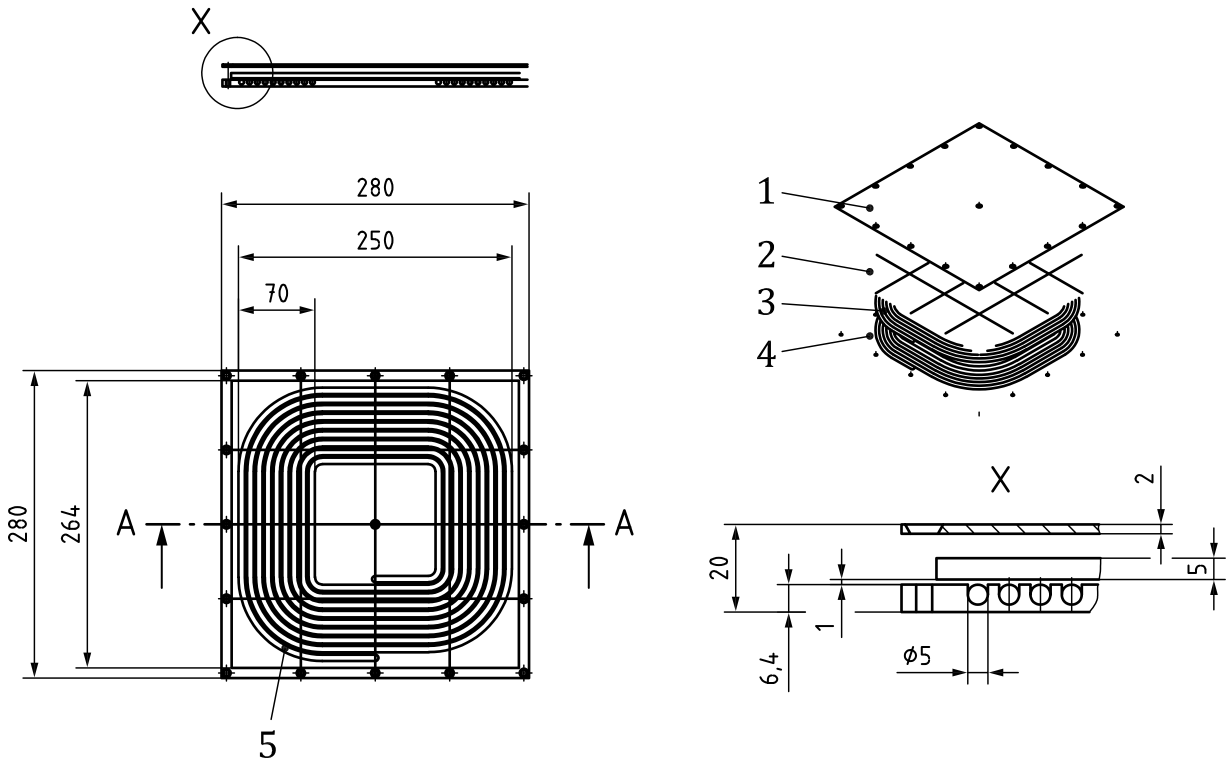
C.1.2 Frequency

Distance variation and misalignment between the supply device and EV device cause variation of inductance and coupling factor. In order to meet the minimum resonance condition, and to achieve higher system efficiency, the EV devices expect a frequency variation within the system frequency range according to Table 5.

C.2 Circular reference EV device proposal for MF-WPT2/Z1

C.2.1 Magnetic interface

Figure C.1 shows the mechanical dimensions of the MF-WPT2/Z1 circular reference EV device.



Key

1 aluminium plate

2 ferrite tiles

3 litz wire

4 litz tray

5 10 turns

Figure C.1 — Mechanical dimensions of the MF-WPT2/Z1 circular reference EV device

The size of the aluminium shield is 800 mm in width and 800 mm in length (not shown in Figure C.1).

The coupling factor of this reference EV device when used in combination with the reference supply device as specified in E.2 is shown in Table C.1.

Table C.1 — Range of coupling factors

Minimum coupling factor	0,109
Maximum coupling factor	0,238

The coil accepts the current according to Table C.2.

Table C.2 — Coil current

Maximum coil current	50 A rms

C.2.2 Schematics of power electronics

Figure C.2 shows the schematics of the power electronics for the reference EV device as described in C.2.1.

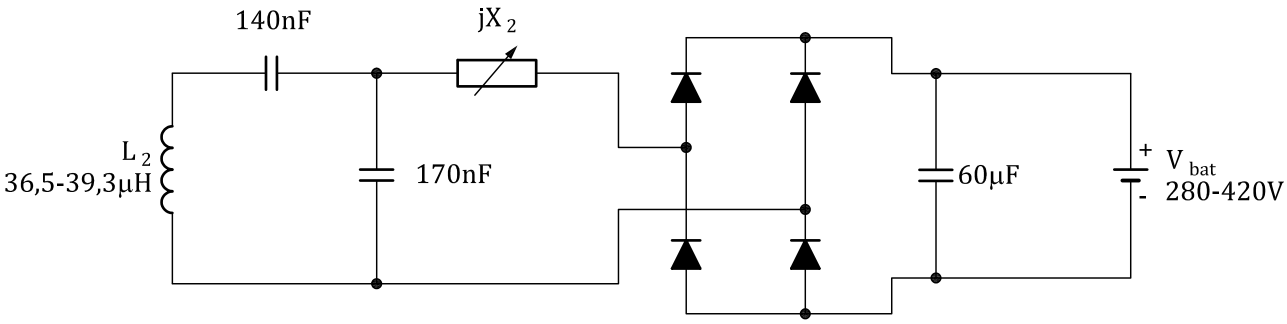


Figure C.2 — Schematics of power electronics for the MF-WPT2/Z1 circular reference EV device

Table C.3 shows the reactance range of the variable element jX_2 as shown in Figure C.2.

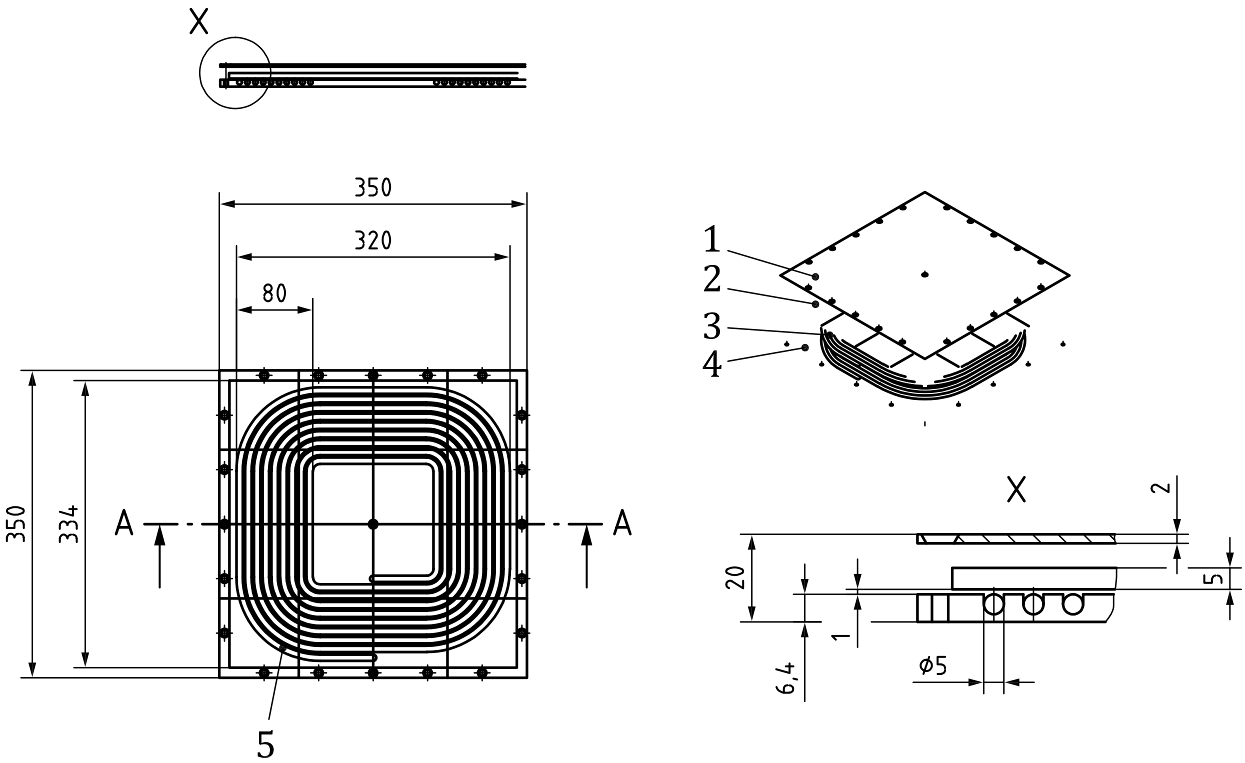
Table C.3 — Reactance range (jX_2) of MF-WPT2/Z1

Reactance range (Ω)	−14 to 12

C.3 Circular reference EV device proposal for MF-WPT2/Z2

C.3.1 Magnetic interface

Figure C.3 shows the mechanical dimensions of the MF-WPT2/Z2 circular reference EV device.



Key

1 aluminium plate
2 ferrite tiles
3 litz wire
4 litz tray
5 9 turns

Figure C.3 — Mechanical dimensions of the MF-WPT2/Z2 circular reference EV device

The size of the aluminium shield is 800 mm in width and 800 mm in length (not shown in Figure C.3).

The coupling factor of this reference EV device when used in combination with the reference supply device as specified in E.2 is shown in Table C.4.

Table C.4 — Range of coupling factors

Minimum coupling factor	0,094
Maximum coupling factor	0,244

The coil accepts the current according to Table C.5.

Table C.5 — Coil current

Maximum coil current	50 A rms

C.3.2 Schematics of power electronics

Figure C.4 shows the schematics of the power electronics for the reference EV device as described in C.3.1.

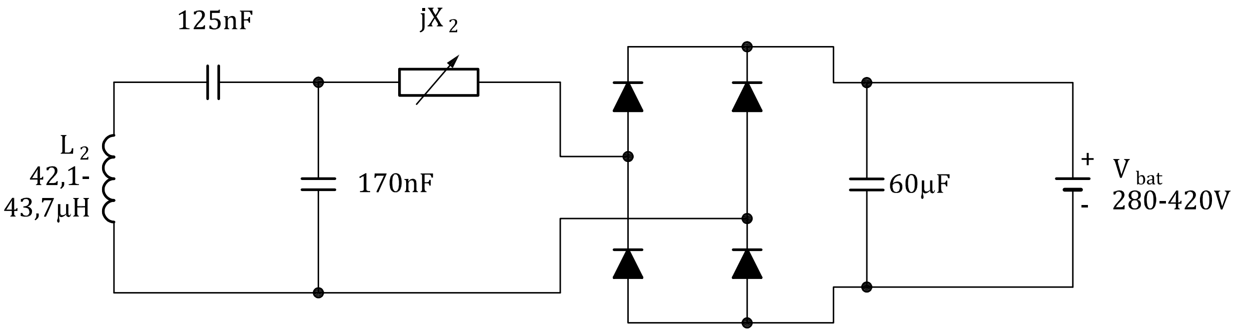


Figure C.4 — Schematics of power electronics for the MF-WPT2/Z2 circular reference EV device

Table C.6 shows the reactance range of the variable element jX_2 as shown in Figure C.4.

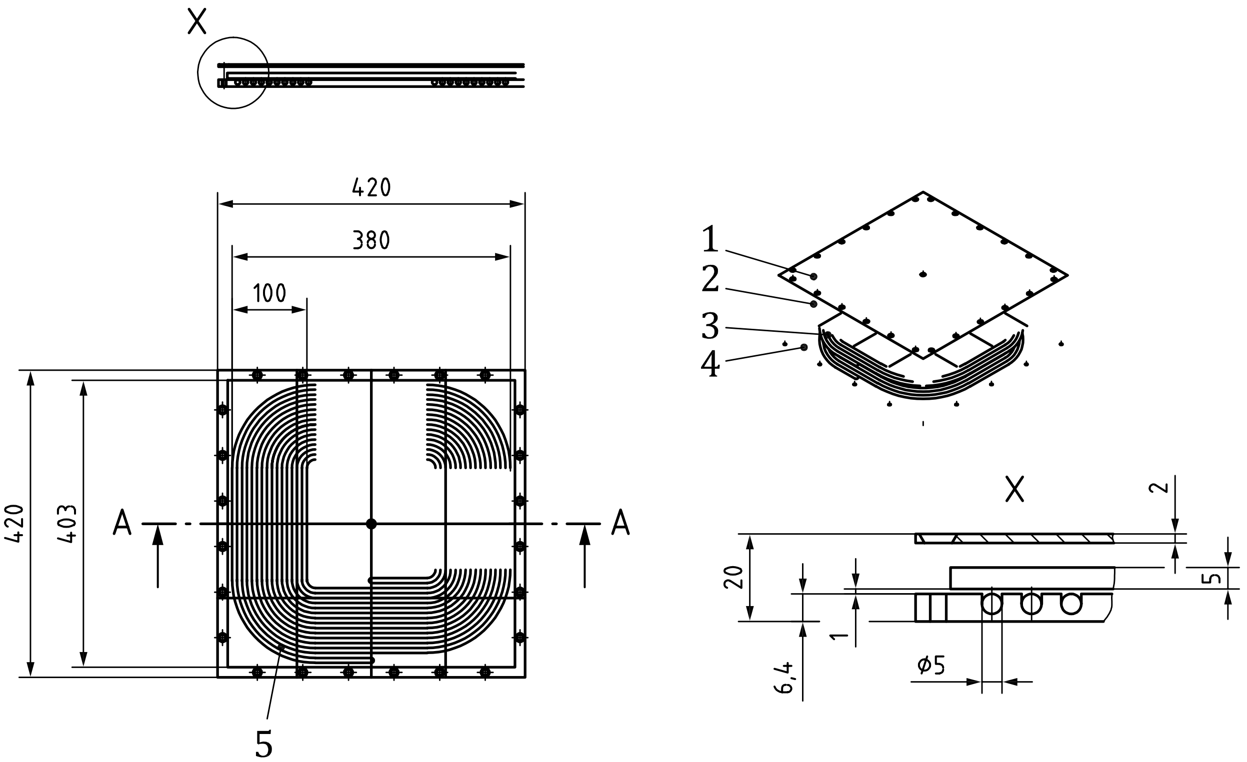
Table C.6 — Reactance range (jX2) of MF-WPT2/Z2

Reactance range (Ω)	−12 to 14

C.4 Circular reference EV device proposal for MF-WPT2/Z3

C.4.1 Magnetic interface

Figure C.5 shows the mechanical dimensions of the MF-WPT2/Z3 circular reference EV device.



Key

1 aluminium plate

2 ferrite tiles

3 litz wire

4 litz tray

5 8 turns

Figure C.5 — Mechanical dimensions of the MF-WPT2/Z3 circular reference EV device

The size of the aluminium shield is 800 mm in width and 800 mm in length (not shown in Figure C.5).

The coupling factor of this reference EV device when used in combination with the reference supply device as specified in E.2 is shown in Table C.7.

Table C.7 — Range of coupling factors

Minimum coupling factor	0,088
Maximum coupling factor	0,245

The coil accepts the current according to Table C.8.

Table C.8 — Coil current

Maximum coil current	50 A rms

C.4.2 Schematics of power electronics

Figure C.6 shows the schematics of the power electronics for the reference EV device as described in C.4.1.

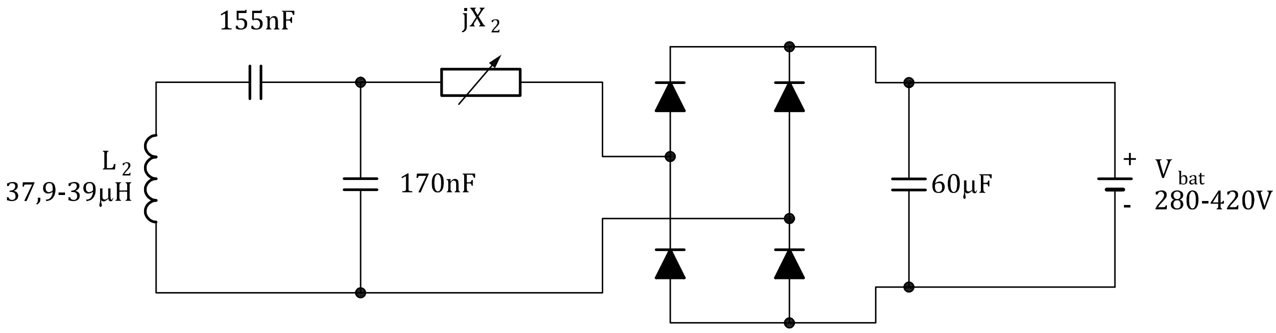


Figure C.6 — Schematics of power electronics for the MF-WPT2/Z3 circular reference EV device

Table C.9 shows the reactance range of the variable element jX_2 as shown in Figure C.6.

Table C.9 — Reactance range (jX_2) of MF-WPT2/Z3

Reactance range (Ω)	−14 to 12

Annex D
(informative)

DD reference EV device proposals for MF-WPT2

D.1 DD reference EV device proposal for MF-WPT2

D.1.1 General

This annex describes reference EV device proposals for MF-WPT class MF-WPT2 and z classes Z1, Z2 and Z3. The reference supply device as specified in E.1 in combination with the reference EV devices as specified in this annex fulfil the performance requirements as described in Clause 6.

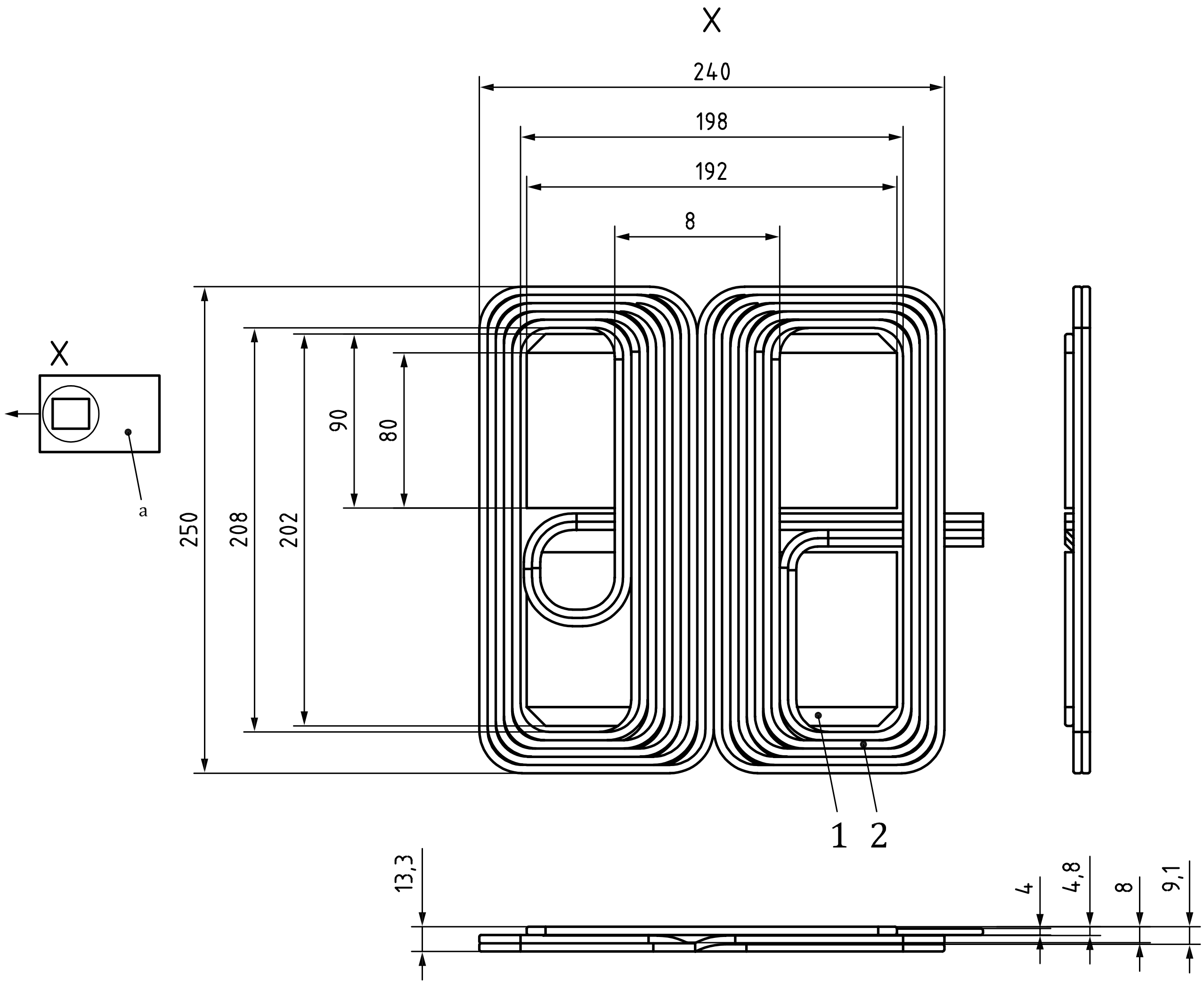
D.1.2 Frequency

The system is tuned for a fixed frequency operation at 85 kHz. Frequency tuning to compensate, for example, for height and alignment variation is not required.

D.2 DD reference EV device proposal for MF-WPT2/Z1

D.2.1 Magnetic interface

Figure D.1 shows the mechanical dimensions of the ferrite and the coil for the MF-WPT2/Z1 DD reference EV device. For clarity, the housing is not shown. The reference EV device orientation on the vehicle is indicated by the icon on the left.



Key

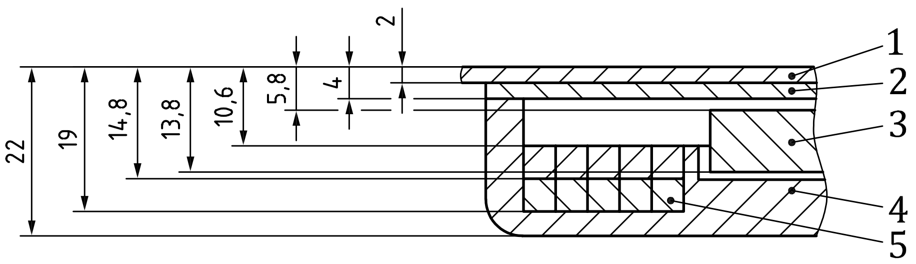
1 ferrite

2 coil

a Pad orientation on the vehicle (driving direction indicated by arrow).

Figure D.1 — Mechanical dimensions of the MF-WPT2/Z1 DD reference EV device

Figure D.2 shows a detailed cross-section view of the MF-WPT2/Z1 reference EV device (including housing and an assumed vehicle shield thickness of 2 mm).



Key

1 aluminium shield
2 aluminium backplate
3 ferrite
4 plastic cover
5 litz wire coil

Figure D.2 — Detailed cross-section view of the MF-WPT2/Z1 DD reference EV device

Table D.1 shows the mechanical dimensions of the MF-WPT2/Z1 reference EV device.

Table D.1 — Mechanical dimensions of the MF-WPT2/Z1 reference EV device

	Coil + ferrite only	Housing (w/o vehicle shield)
L × *W* × *H* (mm)	240 × 250 × 13,3	250 × 260 × 20

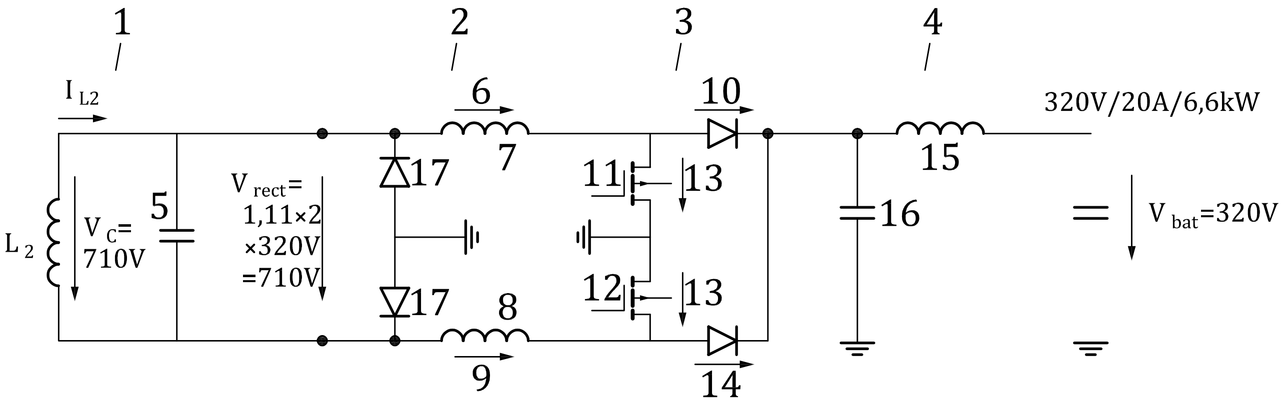
The coupling factor of this reference EV device when used in combination with the reference supply device as specified in E.1 is shown in Table D.2.

Table D.2 — Range of coupling factors

Minimum coupling factor	0,130
Maximum coupling factor	0,260

D.2.2 Schematics of power electronics

Figure D.3 shows the tuning topology for the reference EV device as described in D.2.1. Typical currents and voltages for the MF-WPT class MF-WPT2 are indicated in the diagram.



Key

1 parallel tuned receiver coil
2 current doubler
3 interleaved secondary control
4 output filter
5 parallel tuning capacitor
6 peak max. 17 A, average max. 12 A
7 DC inductor 250 µH
8 DC inductor 250 µH
9 peak max. 17 A, average max. 12 A
10 peak max. 17 A, average max. 12 A
11 650 V MOSFET
12 650 V MOSFET
13 peak max. 17 A
14 peak max. 17 A, average max. 12 A
15 lead inductance ca. 2 µH
16 filter capacitor 40 µF
17 1 200 V diode

Figure D.3 — Schematics of power electronics for the MF-WPT2/Z1 DD reference EV device

The value of the secondary coil inductance L2 varies depending on the secondary device ground clearance. Minimum and maximum values for z class Z1 are given in Table D.3.

Table D.3 — Value of the secondary coil inductance L2 depending on the secondary device ground clearance

Z class	**L_Min** (µH)	**L_Max** (µH)
Z1	21,5	23,3

The value of the parallel tuning capacitor varies depending on the z class. The value for z class Z1 is given in Table D.4.

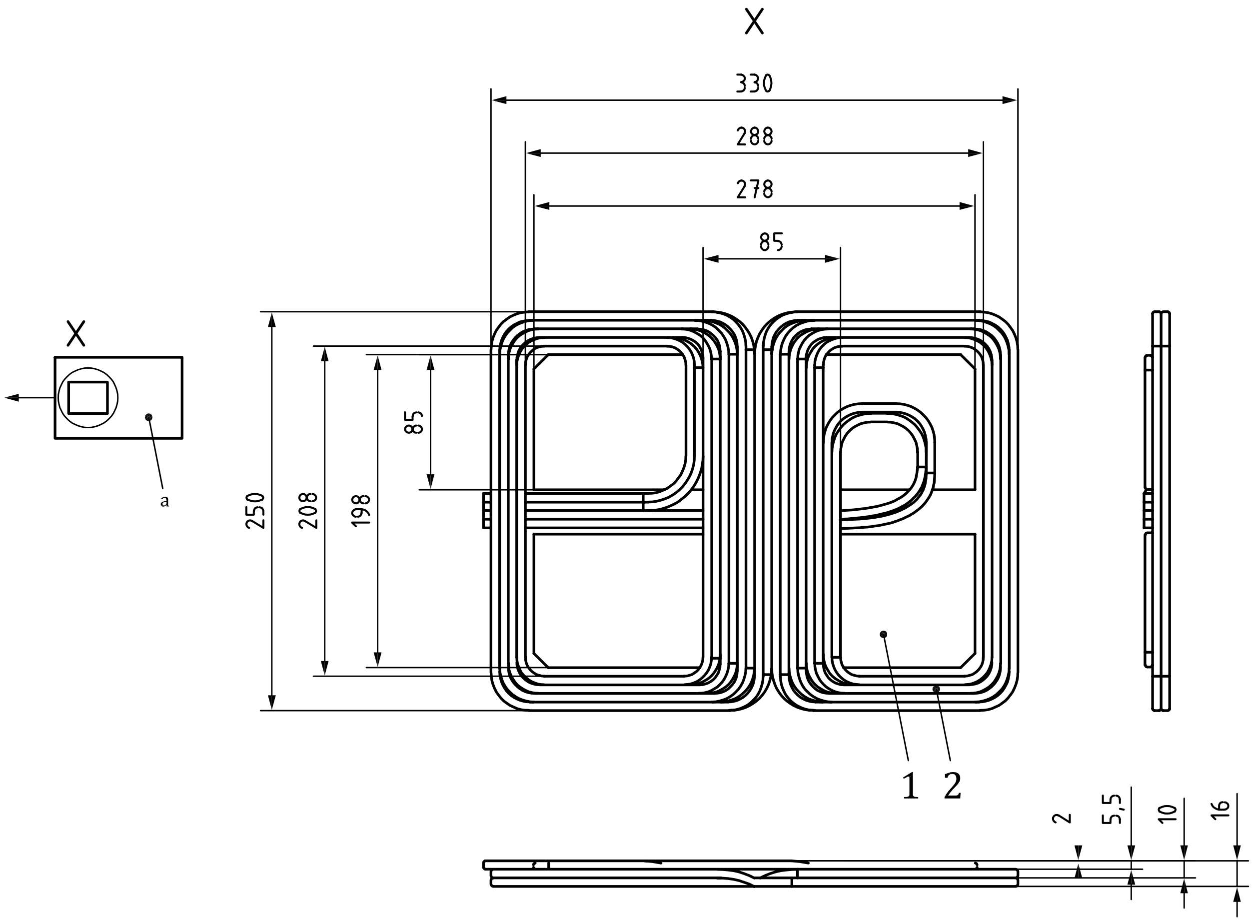
Table D.4 — Value of the secondary tuning capacitor

z class	**C** (nF)
Z1	150

D.3 DD reference EV device proposal for MF-WPT2/Z2

D.3.1 Magnetic interface

Figure D.4 shows the mechanical dimensions of the ferrite and the coil for the MF-WPT2/Z2 DD reference EV device. For clarity, the housing is not shown. The reference EV device orientation on the vehicle is indicated by the icon on the left.



Key

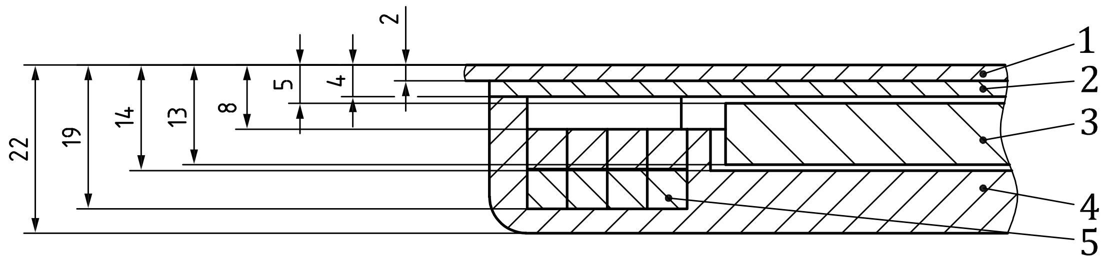
1 ferrite

2 coil

a Pad orientation on the vehicle (driving direction indicated by arrow).

Figure D.4 — Mechanical dimensions of the MF-WPT2/Z2 DD reference EV device

Figure D.5 shows a detailed cross-section view of the MF-WPT2/Z2 reference EV device (including housing and an assumed vehicle shield thickness of 2 mm).



Key

1 aluminium shield

2 aluminium backplate

3 ferrite

4 plastic cover

5 litz wire coil

Figure D.5 — Detailed cross-section view of the MF-WPT2/Z2 DD reference EV device

Table D.5 shows the mechanical dimensions of the MF-WPT2/Z2 reference EV device.

Table D.5 — Mechanical dimensions of the MF-WPT2/Z2 reference EV device

	Coil + ferrite only	Housing (w/o vehicle shield)
L × *W* × *H* (mm)	330 × 250 × 16	340 × 260 × 20

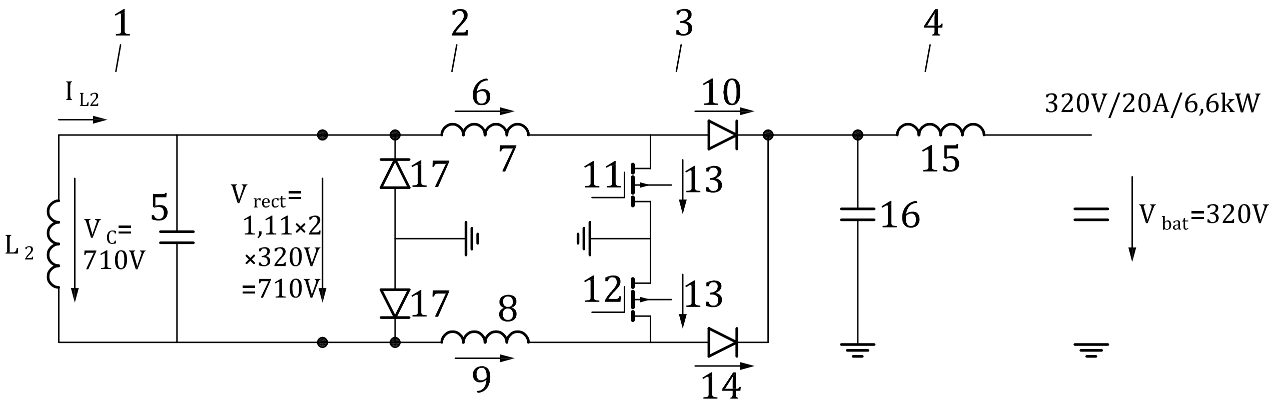
The coupling factor of this reference EV device when used in combination with the reference supply device as specified in E.1 is shown in Table D.6.

Table D.6 — Range of coupling factors

Minimum coupling factor	0,113
Maximum coupling factor	0,240

D.3.2 Schematics of power electronics

Figure D.6 shows the tuning topology for the reference EV device as described in D.3.1. Typical currents and voltages for the MF-WPT class MF-WPT2 are indicated in the diagram.



Key

1 parallel tuned receiver coil
2 current doubler
3 interleaved secondary control
4 output filter
5 parallel tuning capacitor
6 peak max. 17 A, average max. 12 A
7 DC inductor 250 μH
8 DC inductor 250 μH
9 peak max. 17 A, average max. 12 A
10 peak max. 17 A, average max. 12 A
11 650 V MOSFET
12 650 V MOSFET
13 peak max. 17 A
14 peak max. 17 A, average max. 12 A
15 lead inductance ca. 2 μH
16 filter capacitor 40 μF
17 1 200 V diode

Figure D.6 — Schematics of power electronics for the MF-WPT2/Z2 DD reference EV device

The value of the secondary coil inductance L2 varies depending on the secondary device ground clearance. Minimum and maximum values for z class Z2 are given in Table D.7.

Table D.7 — Value of the secondary coil inductance L2 depending on the secondary device ground clearance

Z class	**L_Min** (μH)	**L_Max** (μH)
Z2	19,8	20,5

The value of the parallel tuning capacitor varies depending on the z class. The value for z class Z2 is given in Table D.8.

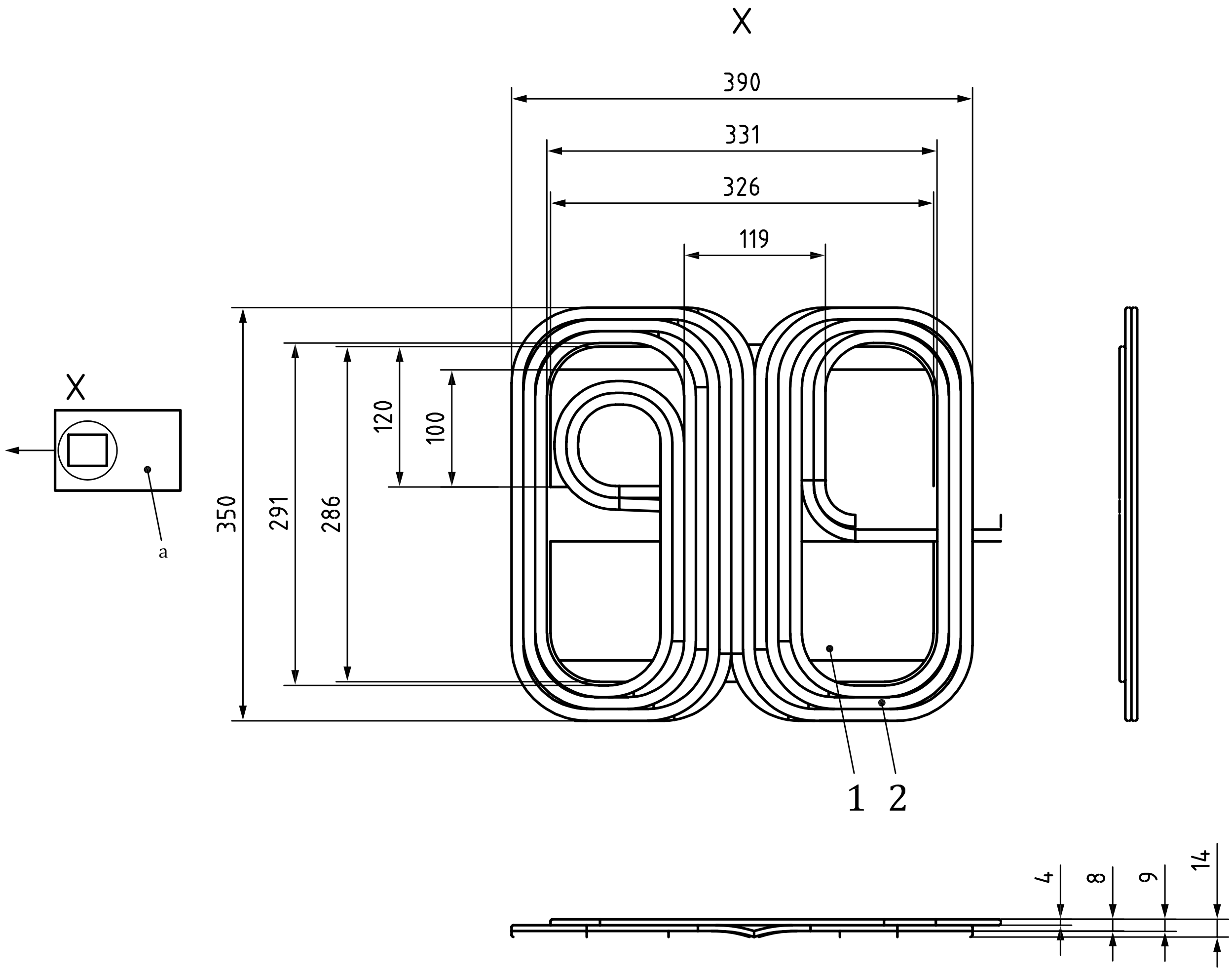
Table D.8 — Value of secondary tuning capacitor C

z class	**C** (nF)
Z2	175

D.4 DD reference EV device proposal for MF-WPT2/Z3

D.4.1 Magnetic interface

Figure D.7 shows the mechanical dimensions of the ferrite and the coil for the MF-WPT2/Z3 DD reference EV device. For clarity, the housing is not shown. The reference EV device orientation on the vehicle is indicated by the icon on the left.



Key

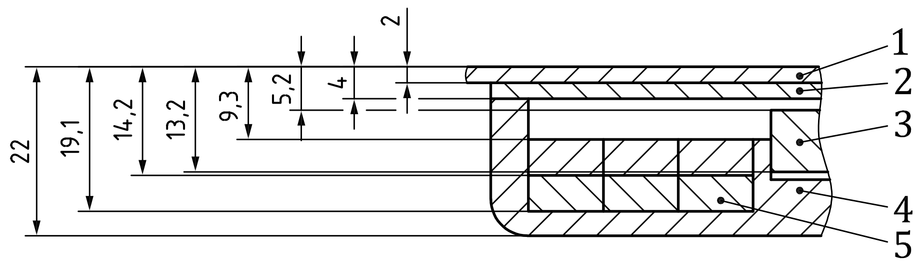
1 ferrite

2 coil

a Pad orientation on the vehicle (driving direction indicated by arrow).

Figure D.7 — Mechanical dimensions of the MF-WPT2/Z3 DD reference EV device

Figure D.8 shows a detailed cross-section view of the MF-WPT2/Z3 reference EV device (including housing and an assumed vehicle shield thickness of 2 mm).



Key

1 aluminium shield
2 aluminium backplate
3 ferrite
4 plastic cover
5 litz wire coil

Figure D.8 — Detailed cross-section view of the MF-WPT2/Z3 DD reference EV device

Table D.9 shows the mechanical dimensions of the MF-WPT2/Z3 reference EV device.

Table D.9 — Mechanical dimensions of the MF-WPT2/Z3 reference EV device

	Coil + ferrite only	Housing (w/o vehicle shield)
$L \times W \times H$ (mm)	390 × 350 × 14	400 × 360 × 20

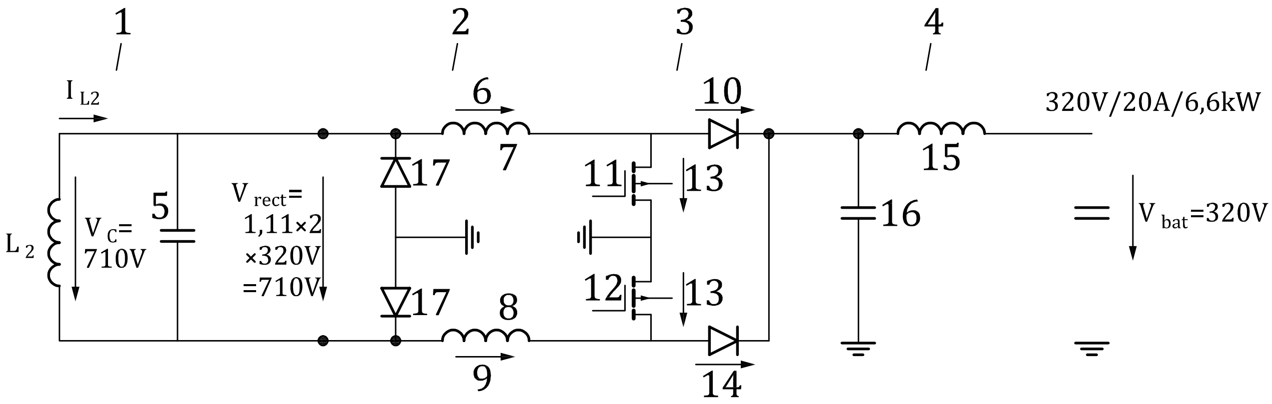
The coupling factor of this reference EV device when used in combination with the reference supply device as specified in E.1 is shown in Table D.10.

Table D.10 — Range of coupling factors

Minimum coupling factor	0,094
Maximum coupling factor	0,190

D.4.2 Schematics of power electronics

Figure D.9 shows the tuning topology for the reference EV device as described in D.4.1. Typical currents and voltages for the MF-WPT class MF-WPT2 are indicated in the diagram.



Key

1 parallel tuned receiver coil
2 current doubler
3 interleaved secondary control
4 output filter
5 parallel tuning capacitor
6 peak max. 17 A, average max. 12 A
7 DC inductor 250 μH
8 DC inductor 250 μH
9 peak max. 17 A, average max. 12 A
10 peak max. 17 A, average max. 12 A
11 650 V MOSFET
12 650 V MOSFET
13 peak max. 17 A
14 peak max. 17 A, average max. 12 A
15 lead inductance ca. 2 μH
16 filter capacitor 40 μF
17 1 200 V diode

Figure D.9 — Schematics of power electronics for the MF-WPT2/Z3 DD reference EV device

The value of the secondary coil inductance L2 varies depending on the secondary device ground clearance. Minimum and maximum values for z class Z3 are given in Table D.11.

Table D.11 — Value of the secondary coil inductance L2 depending on the secondary device ground clearance

Z class	**L_Min** (μH)	**L_Max** (μH)
Z2	16,8	17,1

The value of the parallel tuning capacitor varies depending on the z class. The value for z class Z3 is given in Table D.12.

Table D.12 — Value of the secondary tuning capacitor C

z class	**C** (nF)
Z3	205

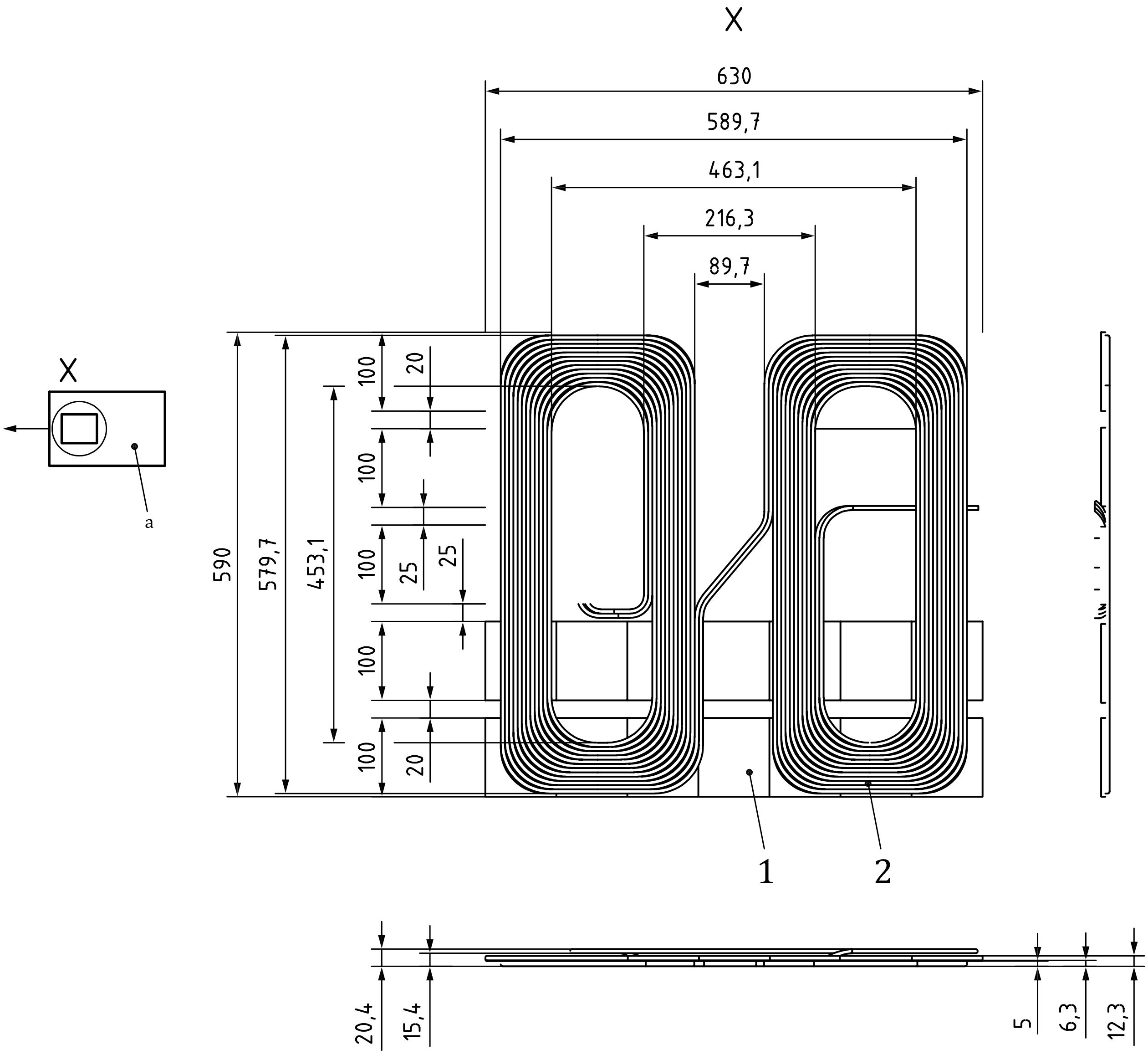
Annex E
(informative)

Corresponding reference supply devices proposals

E.1 DD reference supply device proposal for MF-WPT1 and MF-WPT2

E.1.1 Magnetic interface

Figure E.1 shows the mechanical dimensions of the ferrite and the coil for the MF-WPT1 and MF-WPT2 DD reference supply device. For clarity, the housing is not shown. The reference EV device orientation on the vehicle is indicated by the icon on the left.



Key

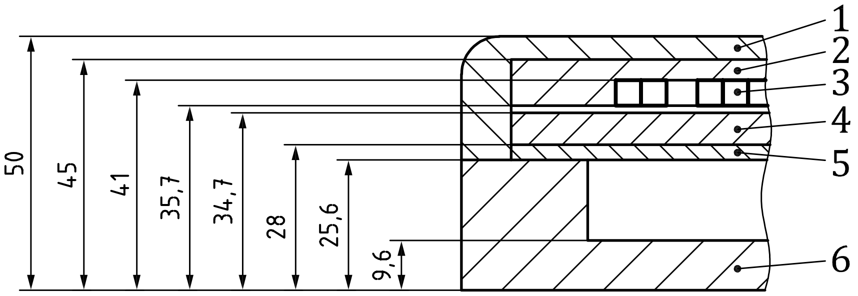
1 ferrite

2 coil

a Pad orientation on the vehicle (driving direction indicated by arrow).

Figure E.1 — Mechanical dimensions of DD reference supply device

Figure E.2 shows a detailed cross-section view of the reference supply device (including housing).



Key

1 plastic top cover

2 plastic coil holder

3 litz wire coil

4 ferrite

5 aluminium backplate

6 plastic bottom cover

Figure E.2 — Detailed cross-section view of the DD reference supply device

Table E.1 shows the mechanical dimensions of the reference supply device.

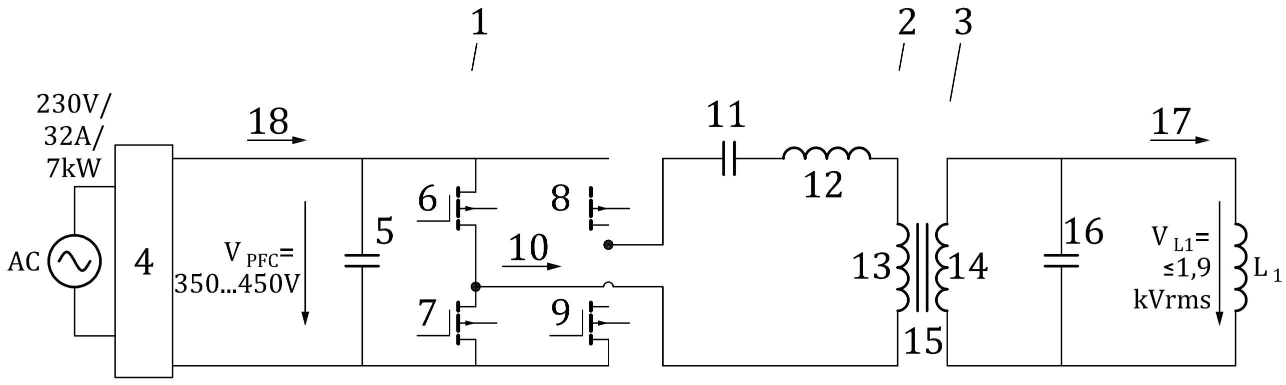
Table E.1 — Mechanical dimensions of the reference supply device

	Coil + ferrite only	Housing (w/o vehicle shield)
$L \times W \times H$ (mm)	630 × 590 × 20,4	650 × 650 × 50

The system is tuned for a fixed frequency operation at 85 kHz. Frequency tuning to compensate, for example, for height and alignment variation is not required.

E.1.2 Schematics of power electronics

Figure E.3 shows the tuning topology for the reference supply device as described in E.2.1. Typical currents and voltages for the MF-WPT class MF-WPT2 are indicated in the diagram.



Key

1 inverter
2 tuning and matching
3 matching transformer
4 7 kW single phase PFC
5 DC filter capacitor ca. 3 000 µF
6 650 V MOSFET
7 650 V MOSFET
8 650 V MOSFET
9 650 V MOSFET
10 max. 40 A rms
11 DC blocking capacitor 242 nF
12 transformer leakage 18 µH
13 0,9 mH
14 19,9 mH
15 HF transformer 1: 4,7
16 parallel tuning capacitor 46 nF
17 max. 45 A rms
18 I_PFC max. 20 A

Figure E.3 — Schematics of power electronics for the DD reference supply device

The value of the primary coil inductance L1 varies depending on the z class. Minimum and maximum values for L1 are given in Table E.2.

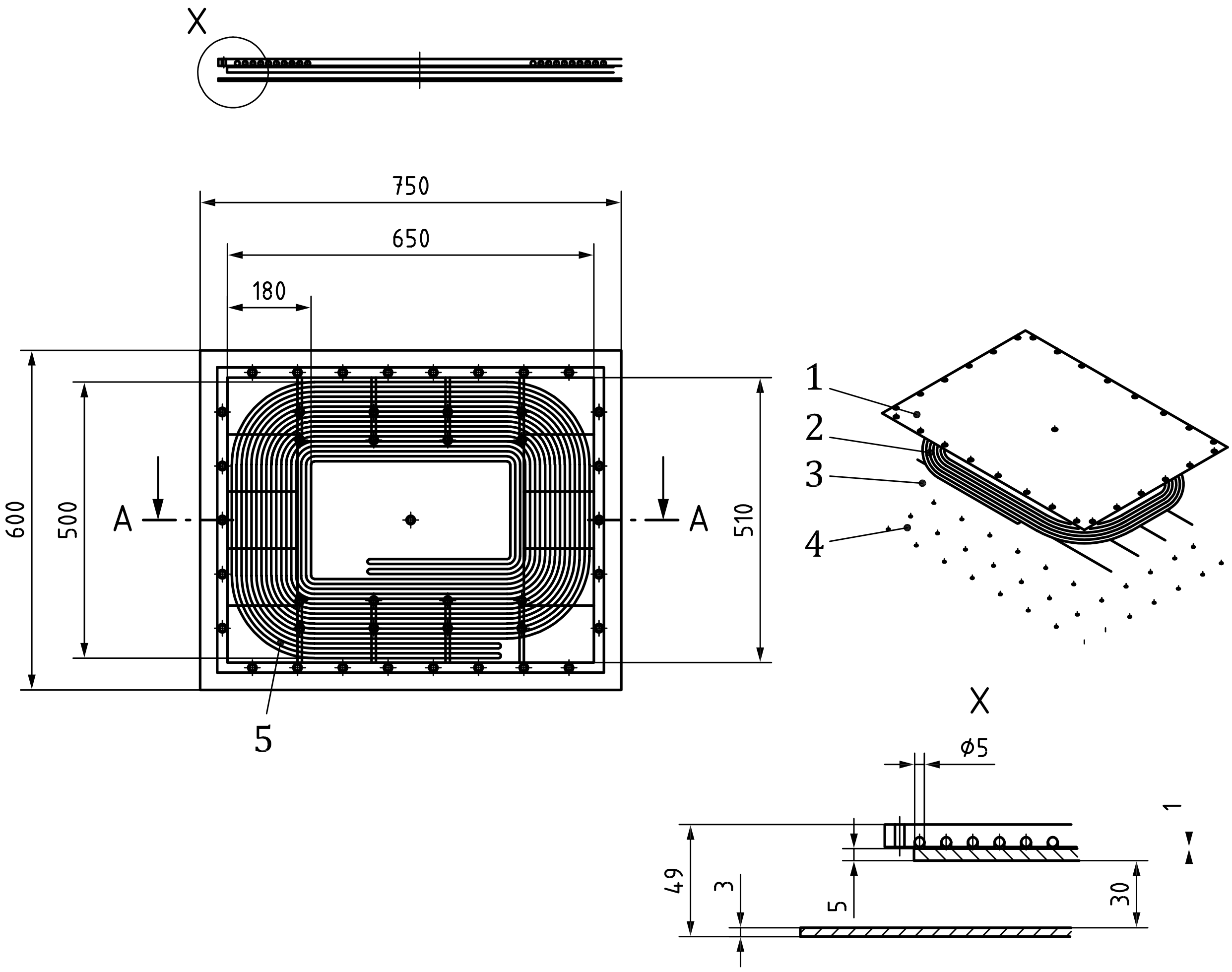
Table E.2 — Primary coil inductance L1 depending on the z class

z class	**L_Min** (µH)	**L_Max** (µH)
Z1	65,2	73,7
Z2	74,5	77,0
Z3	77,4	78,5

E.2 Circular reference supply device proposal for MF-WPT1 and MF-WPT2

E.2.1 Magnetic interface

Figure E.4 shows the mechanical dimensions of the MF-WPT1 and MF-WPT2 circular reference supply device.



Key

1 litz tray
2 litz wire
3 ferrite tiles
4 aluminium plate
5 8 turns with bifilar of 2 litz wires

Figure E.4 — Mechanical dimensions of the MF-WPT1 and MF-WPT2 circular reference supply device

Distance variation and misalignment between the supply device and EV device cause variation of inductance and coupling factor. In order to meet the minimum resonance condition and to achieve higher system efficiency, the supply device expects a frequency variation within the system frequency range according to Table 5.

Maximum coil current and maximum inverter voltage are according to Table E.3.

Table E.3 — Coil current and inverter voltage

Maximum coil current	80 A rms
Maximum inverter voltage	500 V (DC)

E.2.2 Schematics of power electronics

Figure E.5 shows the schematics of the power electronics for the reference supply device as described in E.2.1.

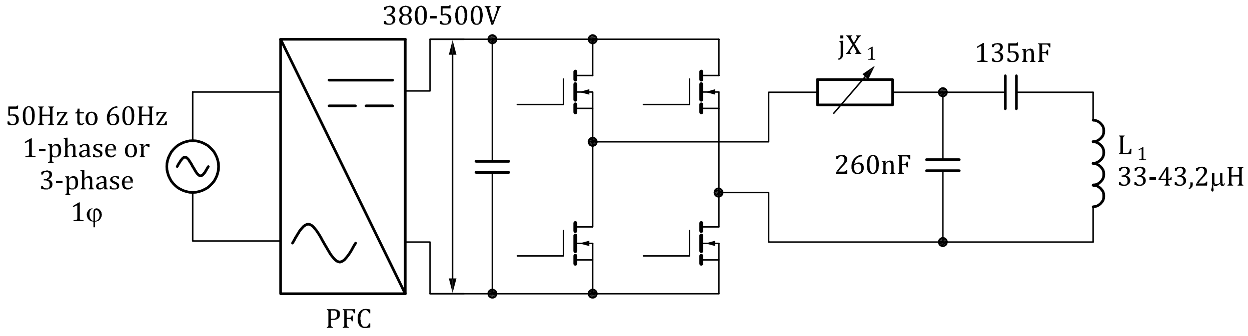


Figure E.5 — Schematics of power electronics for the MF-WPT1 and MF-WPT2 circular reference supply device

Table E.4 shows the reactance range of the variable element jX_1 as shown in Figure E.5.

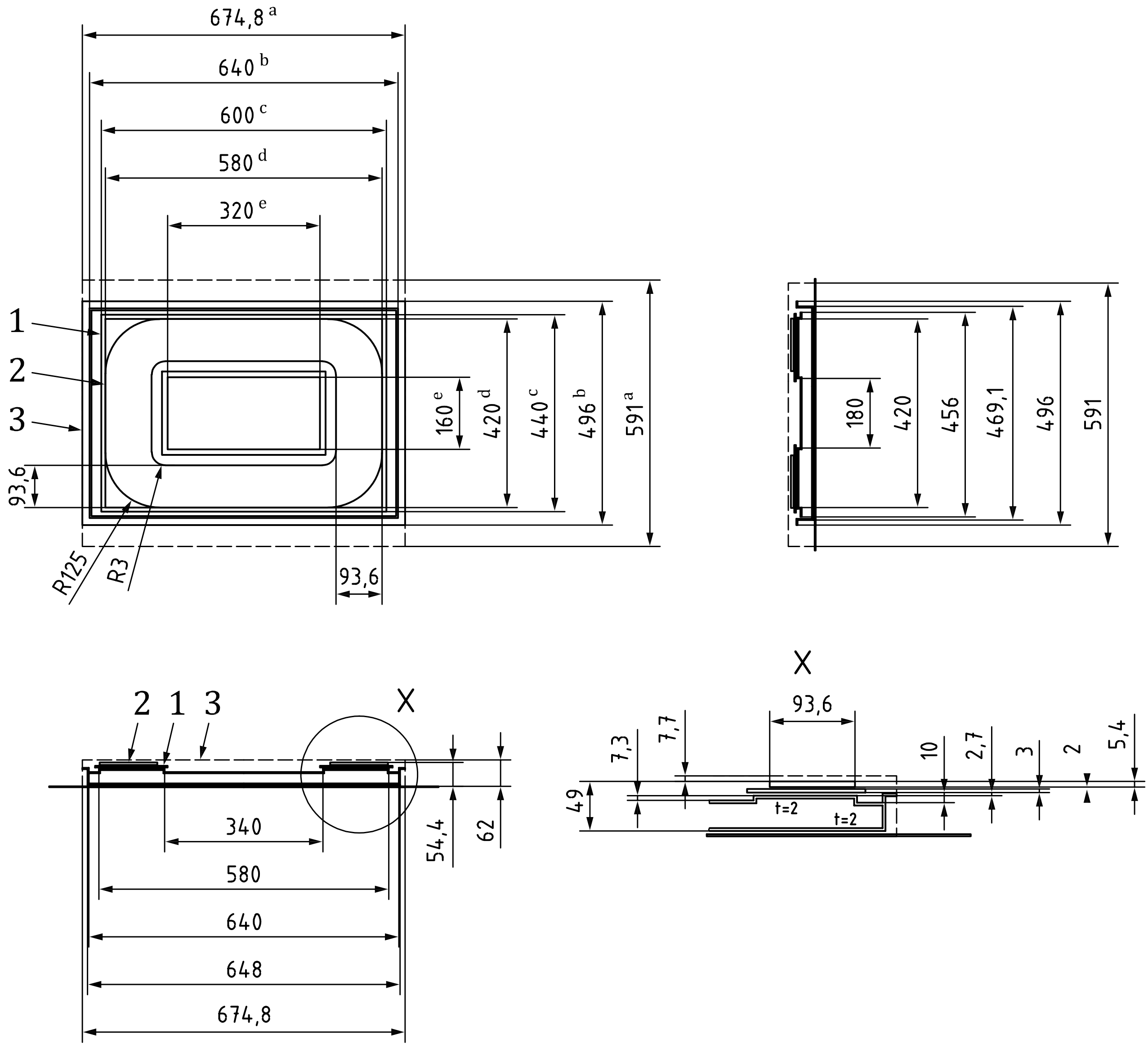
Table E.4 — Reactance range (jX_1) of MF-WPT2

Reactance range (Ω)	5 to 40

E.3 Circular reference supply device proposal for MF-WPT1

E.3.1 Magnetic interface

Figure E.6 shows the mechanical dimensions of the MF-WPT1 circular reference supply device.



Key

1 ferrite

2 coil (15 turns)

3 outer case (for reference)

a Outer case dimension.

b Shielding dimension.

c Outer core dimension.

d Coil dimension.

e Inner core dimension.

Figure E.6 — Mechanical dimensions of the MF-WPT1 circular reference supply device

Distance variation and misalignment between the supply device and EV device cause variation of inductance and coupling factor. In order to meet the minimum resonance condition and to enable to achieve higher system efficiency, the frequency of the circular reference supply device in this clause is within the range according to Table E.5.

Table E.5 — Frequency range

Frequency range	81,38 kHz to 90,00 kHz

Maximum coil current and maximum inverter voltage are according to Table E.6.

Table E.6 — Coil current and inverter voltage

Maximum coil current	30 A rms
Maximum inverter voltage	450 V (DC)

E.3.2 Schematics of power electronics

Figure E.7 shows the schematics of the power electronics for the reference supply device as described in E.3.1.

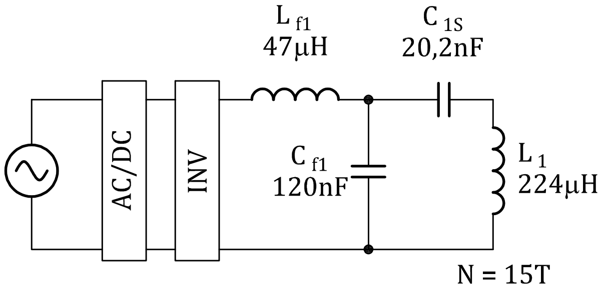


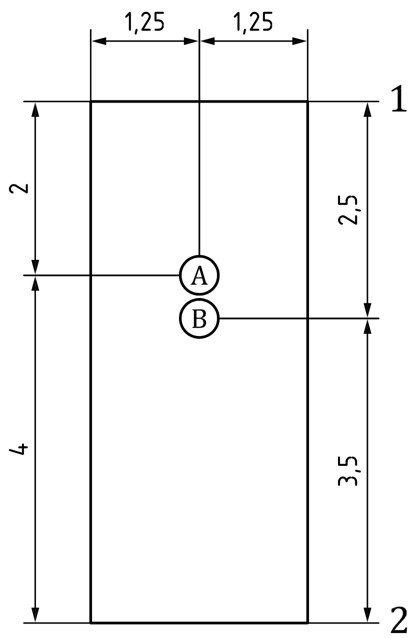
Figure E.7 — Schematics of power electronics for the MF-WPT1 circular reference supply device

Annex F
(informative)

Coil position in parking spot

According to the different package conditions in EVs, there is no single position that can be required for the EV device. Therefore, the position of the supply device in the parking spot is specified. To enable MF-WPT for all vehicles, the position of the supply device has to be combined to a minimum size of the parking spot.

For the position of the centre of the supply device, the positions between A and B in Figure F.1 are under discussion.



Key

1 front end of parking spot

2 back end of parking spot

Figure F.1 — Coil position in parking spot

All distances shown in Figure F.1 are minimal distances in metres. In case backward parking is required, the 2,0 m and 2,5 m are measured from the back end of the parking spot and the 4,0 m and 3,5 m from the front end.

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[2] ISO 6469-4, *Electrically propelled road vehicles — Safety specifications — Part 4: Post crash electrical safety*

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[5] ISO 15118-2, *Road vehicles — Vehicle to grid communication interface — Part 2: Network and application protocol requirements*

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[9] IEC 61980-2, *Electric vehicle wireless power transfer (WPT) Systems — Part 2: specific requirements for communication between electric road vehicle (EV) and infrastructure with respect to wireless power transfer (WPT) systems*

[10] IEC 61980-3, *Electric vehicle wireless power transfer (WPT) systems — Part 3: Specific requirements for the magnetic field power transfer systems*

[11] IEC 62311, *Assessment of electronic and electrical equipment related to human exposure restrictions for electromagnetic fields (0 Hz - 300 GHz)*

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