SURFACE VEHICLE STANDARD	**J1772™**	**JAN2024**
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INTERNATIONAL®

(R) SAE Electric Vehicle and Plug-in Hybrid Electric Vehicle Conductive Charge Coupler

RATIONALE

The SAE J1772 document has been updated to refine the language of the standard; better define the AC connector dimensions; correct typogriphical errors found in the previous version; address changes needed in Y-capacitor limitations due to supporting charging at up to 1000V; address harmonization with IEC 61851 and ISO 15118 series documents related to DC charging, safety improvements and interoperability; and to reflect liquid cooling of cable/plug to support high current DC fast charging.

FOREWORD

Energy stored in a battery provides power for an electric vehicle (EV) or plug in hybrid electric vehicles (PHEV). Conductive charging is a method for connecting the electric power supply network to the EV/PHEV for the purpose of transferring energy to charge the battery and operate other vehicle electrical systems, establishing a reliable equipment grounding path, and exchanging control information between the EV/PHEV and the supply equipment. This document describes the electrical and physical interfaces between the EV/PHEV and supply equipment to facilitate conductive charging. Functional and performance requirements for the EV/PHEV and supply equipment are also specified. This document contains 183 pages, including this page, and should not be used as a design tool if any of the pages are missing.

NOTE: This SAE Standard is intended as a guide toward standard practice and is subject to change in order to harmonize with international standards and to keep pace with experience and technical advances.

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1. SCOPE

This SAE Standard covers the general physical, electrical, functional, and performance requirements to facilitate conductive charging of EV/PHEV vehicles in North America. This document defines a common EV/PHEV and supply equipment vehicle conductive charging method, including operational requirements and the functional and dimensional requirements for the vehicle inlet and mating connector.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J1113-21 Electromagnetic Compatibility Measurement Procedure for Vehicle Components - Part 21: Immunity to Electromagnetic Fields, 30 MHz to 18 GHz, Absorber-Lined Chamber

SAE J1211 Handbook for Robustness Validation of Automotive Electrical/Electronic Modules

SAE J1812 Function Performance Status Classification for EMC Immunity Testing

SAE J2344 Guidelines for Electric Vehicle Safety

SAE J2847/1 Communication for Smart Charging of Plug-in Electric Vehicles Using Smart Energy Profile 2.0

SAE J2847/2 Communications Between Plug-In Vehicles and Off-Board DC Chargers

SAE J2931/1 Digital Communications for Plug-in Electric Vehicles

SAE J2931/4 Broadband PLC Communication for Plug-in Electric Vehicles

SAE J2953/1 Plug-In Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE)

SAE J2953/2 Test Procedures for the Plug-In Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE)

SAE USCAR 2 Performance Specification for Automotive Electrical Connector Systems

SAE USCAR 25 Ergonomics Specification for Electrical Connections

2.1.2 Canadian Standards Association (CSA Group) Publications

Available from Canadian Standards Association, 170 Rexdale Boulevard, Rexdale, Ontario, Canada M9W 1R3, Tel: 1-800-463-6727. www.csa.ca.

CSA C22.1 Canadian Electrical Code Part 1, Section 86

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2.1.3 Code of Federal Regulations (CFR) Publications

Available from the United States Government Printing Office, 732 North Capitol Street, NW, Washington, DC 20401, Tel: 202-512-1800, www.gpo.gov.

CFR 40 Title 40, Chapter 1, Subchapter Q, Part 600

CFR 47 Title 47, Parts 15A, 15B, and 18C

2.1.4 IEC Publications

Available from IEC Central Office, 3, rue de Verambe, P.O. Box 131, 1211 Geneva 20, Switzerland, Tel: +41-22-919-02-11, www.iec.ch.

IEC Publications are also available from the American National Standards Institute (ANSI), 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, https://webstore.ansi.org/.

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CISPR 16-1-2 Ancillary equipment - Conducted disturbances

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

IEC 60479-2 Effects of current on human beings and livestock - Part 2: Special aspects

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

IEC 60664-1 Insulation coordination for equipment within low-voltage systems - Part 1: Principles, requirements and tests

IEC 61000-4-3 Electromagnetic compatibility (EMC) - Part 4-3: Testing and measurement techniques - Radiated, radio-frequency, electromagnetic field immunity test

IEC 61000-4-6 Electromagnetic compatibility (EMC) - Part 4-6: Testing and measurement techniques - Immunity to conducted disturbances, induced by radiofrequency fields

IEC 61032 Protection of persons and equipment by enclosures - Probes for verification

IEC 61140 Protection against electric shock - Common aspects for installation and equipment

IEC 61300-2-6 Fibre optic interconnecting devices and passive components - Basic test and measurement procedures - Part 2-6: Tests - Tensile strength of coupling mechanism

IEC 61300-2-7 Fibre optic interconnecting devices and passive components - Basic test and measurement procedures - Part 2-7: Tests - Bending moment

IEC 61558-2-6 Safety of transformers, reactors, power supply units and combinations thereof - Part 2-6: Particular requirements and tests for safety isolating transformers and power supply units incorporating safety isolating transformers for general applications

IEC 61851-21-1 Electric vehicle conductive charging system - Part 21-1 Electric vehicle on-board charger EMC requirements for conductive connection to AC/DC supply

IEC 61851-21-2 Electric vehicle conductive charging system - Part 21-2: Electric vehicle requirements for conductive connection to an AC/DC supply - EMC requirements for off board electric vehicle charging systems

IEC 61851-23 Electric vehicle conductive charging system Part 23: DC electric vehicle supply equipment

IEC 62196-2 Plugs, socket-outlets, vehicles connectors and vehicle inlets - Part 2: Dimensional compatibility and interchangeability requirements for a.c. pin and contact-tube accessories

IEC 62196-3-1 Plugs, socket-outlets, vehicles connectors and vehicle inlets - Part 3: Dimensional compatibility and interchangeability requirements for d.c. and a.c./d.c. pin and contact-tube vehicle couplers

IEC 62196-3-1 Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles - Part 3-1: Vehicle connector, vehicle inlet and cable assembly for DC charging intended to be used with a thermal management system

IEC 62477-1 Safety requirements for power electronic converter systems and equipment - Part 1: General

2.1.5 ISO Publications

Copies of these documents are available online at http://webstore.ansi.org/

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

ISO 17409 Electrically propelled road vehicles - Conductive power transfer - Safety requirements

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

ISO 15118-1 Road vehicles - Vehicle-to-Grid Communication Interface - Part 1: General information and use-case definition

ISO 15118-2 Road vehicles - Vehicle-to-Grid Communication Interface - Part 2: Network and application protocol requirements

ISO 15118-3 Road vehicles - Vehicle-to-Grid Communication Interface - Part 3: Physical and data link layer requirements

2.1.6 National Fire Protection Agency Publications

Available from the NFPA, 1 Batterymarch Park, Quincy, MA 02169-7471, Tel: 617-770-3000, www.nfpa.org.

National Electric Code (NEC), NFPA 70 Article 625 (2023 edition) Electric Vehicle Power Transfer System

National Electric Code (NEC), NFPA 70 Article 750 (2023 edition) Energy Management Systems

2.1.7 UL Publications

Available from UL, 333 Pfingsten Road, Northbrook, IL 60062-2096, Tel: 847-272-8800, www.ul.com.

UL 50 Standard for Enclosures for Electrical Equipment

UL 1439 Determiniatino of Sharpness of Edges on Equipment

UL 2202 Standard for Electric Vehicle (EV) Charging System Equipment

UL 2231-1 Personnel Protection Systems for Electric Vehicle Supply Circuits: General Requirements

UL 2231-2 Personnel Protection Systems for Electric Vehicle Supply Circuits: Particular Requirements for Protection Devices for Use in Charging Systems

UL 2251 Plugs, Receptacles, and Couplers for Electric Vehicles

UL 2594 Electric Vehicle Supply Equipment

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2.1.8 United Nations Economic Commission for Europe (UNECE)

Available from the UN European Commission for Europe Information Service, Palais des Nations, CH-1211 Geneva 10, Switzerland, www.unece.org.

UNECE R100 Uniform provisions concerning the approval of vehicles with regard to specific requirements for the electric power train

2.1.9 DIN German Institute for Standardization (Deutsches Institut für Normung - DIN)

Available from Beuth Vertag GmbH, Am DIN-Platz, Bruggrafenstrafe 6, 10787 Berlin. Tel: +49 30 2601 1331, https://www.din.de/en/.

DIN 70121 Electromobility - Digital communication between a d.c. EV charging station and an electric vehicle for control of d.c. charging in the Combined Charging System

2.1.10 National Electrical Manufactures Association (NEMA)

Available from NEMA, 1300 17th St N #900, Arlington, VA 22209, Tel: 703-841-3200, https://www.nema.org/.

ANSI/NEMA WD 6-2021 Wiring Devices

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

2.2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J551-5 Performance Levels and Methods of Measurement of Magnetic and Electric Field Strength from Electric Vehicles, 150 kHz to 30 MHz

SAE J1715 Hybrid Electric Vehicle (HEV) and Electric Vehicle (EV) Terminology

SAE J1742 Connections for High Voltage On-Board Vehicle Electrical Wiring Harness - Test Methods and General Performance Requirements

SAE J1773 SAE Electric Vehicle Inductively Coupled Charging

SAE J1812 Function Performance Status Classification for EMC Immunity Testing

SAE J2178-1 Class B Data Communication Network Messages - Detailed Header Formats and Physical Address Assignments

SAE J2178-2 Class B Data Communication Network Messages - Part 2: Data Parameter Definitions

SAE J2178-3 Class B Data Communication Network Messages - Part 3 - Frame IDs for Single-Byte Forms of Headers

SAE J2178-4 Class B Data Communication Network Messages - Message Definitions for Three Byte Headers

SAE J2836/1 Use Cases for Communication Between Plug-in Vehicles and the Utility Grid

SAE J2836/2 Use Cases for Communication Between Plug-In Vehicles and Off-Board DC Charger

SAE J2836/3 Use Cases for Plug-in Vehicle Communication as a Distributed Energy Resource

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SAE J2836/4 Use Cases for Diagnostic Communication for Plug-in Electric Vehicles

SAE J2836/5 Use Cases for Customer Communication for Plug-in Electric Vehicles

SAE J2836/6 Use Cases for Wireless Charging Communication for Plug-in Electric Vehicles

SAE J2847/3 Communication for Plug-in Vehicles as a Distributed Energy Resource

SAE J2847/6 Communication for Wireless Power Transfer Between Light-Duty Plug-in Electric Vehicles and Wireless EV Charging Stations

SAE J2894/1 Power Quality Requirements for Plug-In Electric Vehicle Chargers

SAE J2894/2 Power Quality Test Procedures for Plug-In Electric Vehicle Chargers

SAE J2931/6 Signaling Communication for Wirelessly Charged Electric Vehicles

SAE J2931/7 Security for Plug-in Electric Vehicle Communications

SAE J3072 Interconnection Requirements for Onboard, Grid Support Inverter Systems

2.2.2 IEC Publications

Available from IEC Central Office, 3, rue de Verambe, P.O. Box 131, 1211 Geneva 20, Switzerland, Tel: +41-22-919-02-11, www.iec.ch.

IEC Publications are also available from the American National Standards Institute (ANSI), 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, https://webstore.ansi.org/.

IEC 61851-1 Electric vehicle conductive charging system Part 1: General requirements

IEC 61851-24 Electric vehicle conductive charging system Part 24: Digital communication between a d.c. EV charging station and an electric vehicle for control of d.c. charging

IEC 62196-1 Plugs, socket-outlets, vehicles connectors and vehicle inlets - conductive charging of electric vehicles

2.2.3 UL Publications

Available from UL, 333 Pfingsten Road, Northbrook, IL 60062-2096, Tel: 847-272-8800, www.ul.com.

UL 94 Tests for Flammability of Plastic Materials for Parts in Devices and Appliances

UL 231 Power Outlets

UL 746A Standard for Polymeric Materials - Short Term Property Evaluations

UL 840 Insulation Coordination Including Clearance and Creepage Distances for Electrical Equipment

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3. DEFINITIONS

3.1 AC LEVEL 1 CHARGING

A method that allows an EV/PHEV to be connected to the most common grounded electrical receptacles (NEMA 5-15R and NEMA 5-20R). The vehicle shall be fitted with an on-board charger capable of accepting energy from the existing single phase alternating current (AC) supply network. The maximum power supplied for AC Level 1 charging shall conform to the values in Table 10. A cord and plug EVSE with a NEMA 5-15P plug may be used with a NEMA 5-20R receptacle. A cord and plug EVSE with a NEMA 5-20P plug is not compatible with a NEMA 5-15R receptacle. Refer to ANSI/NEMA WD for descriptions of noted receptacles.

3.2 AC LEVEL 2 CHARGING

A method that uses dedicated AC EV/PHEV supply equipment in either private or public locations. The vehicle shall be fitted with an on-board charger capable of accepting energy from single phase AC electric vehicle supply equipment. The maximum power supplied for AC Level 2 charging shall conform to the values in Table 10.

3.3 CHARGER

An electrical device that converts alternating current energy to regulated direct current for replenishing the energy of a rechargeable energy storage device (i.e., battery) and may also provide energy for operating other vehicle electrical systems.

3.4 CHASSIS GROUND

The conductor used to connect the non-current-carrying metal parts of the vehicle high voltage system to the equipment ground.

3.5 COMBINED CHARGING SYSTEM

Conductive charge method defined by SAE J1772 and other international standards supporting both AC and DC power transfer using a common communication interface and a harmonized set of electrical/physical interfaces.

3.6 CONDUCTIVE

Having the ability to transmit electricity through a physical path (conductor).

3.7 CONNECTOR (CHARGE)

A conductive device that by insertion into a vehicle inlet establishes an electrical connection to the electric vehicle for the purpose of transferring energy and exchanging information. This is part of the coupler.

3.8 CONTACT (CHARGE)

A conductive element in a connector that mates with a corresponding element in the vehicle inlet to provide an electrical path.

3.9 CONTROL PILOT

An electrical signal that is sourced by the electric vehicle supply equipment (EVSE). Control pilot is the primary control conductor and is connected to the equipment ground through control circuitry on the vehicle and performs the following functions:

a. Verifies that the vehicle is present and connected

b. Permits energization/de-energization of the supply

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c. Transmits supply equipment current rating to the vehicle

d. Monitors the presence of the equipment ground

e. Establishes vehicle ventilation requirements

3.10 COUPLER (CHARGE)

A mating vehicle inlet and connector set.

3.11 DC LEVEL 1 CHARGING

A method that uses dedicated direct current (DC) EV/PHEV supply equipment to provide energy from an appropriate off-board charger to the EV/PHEV in either private or public locations using only the AC form factor portion of the SAE J1772 interface.

3.12 DC LEVEL 2 CHARGING

A method that uses dedicated DC EV/PHEV supply equipment to provide energy from an appropriate off-board charger to the EV/PHEV in either private or public locations using the combined coupler system (CCS).

3.13 ELECTRIC VEHICLE (EV)

An automotive type vehicle, intended for highway use, primarily powered by an electric motor that draws from a rechargeable energy storage device. For the purpose of this document, the definition in the United States Code of Federal Regulations – Title 40, Part 600, Subchapter Q is used. Specifically, an automobile means:

a. Any four-wheeled vehicle propelled by a combustion engine using on-board fuel or by an electric motor drawing current from a rechargeable storage battery or other portable energy devices (rechargeable using energy from a source off the vehicle such as residential electric service).

b. Which is manufactured primarily for use on public streets, roads, and highways.

c. Which is rated not more than 3855.6 kg (8500 pounds), which has a curb weight of not more than 2721.6 kg (6000 pounds), and which has a basic frontal area of not more than 4.18 m^2 (45 ft^2).

NOTE: While this standards was developed for use with EVs as defined above, this standard may be applied to other electrified vehicles, such as trucks, motorcycles, scooters, etc.

3.14 ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE)

The conductors, including the ungrounded, grounded, and equipment grounding conductors, and the electric vehicle connectors, attachment plugs, personnel protection system, and all other fittings, devices, power outlets, or apparatuses installed specifically for the purpose of transferring energy between the premises wiring to the electric vehicle. Charging cords with NEMA 5-15P and NEMA 5-20P attachment plugs are considered EVSEs.

3.15 EQUIPMENT GROUND (GROUNDING CONDUCTOR)

A conductor used to connect the non-current carrying metal parts of the EV/PHEV supply equipment to the system grounding conductor, the grounding electrode conductor, or both, at the service equipment.

3.16 EV/PHEV CHARGING SYSTEM

The equipment required to condition and transfer energy from the constant frequency, constant voltage supply network to the direct current, variable voltage EV/PHEV traction battery bus for the purpose of charging the battery and/or operating vehicle electrical systems while connected.

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3.17 INSULATOR

The portion of a charging system that provides for the separation, support, sealing, and protection from live parts.

3.18 INVALID CONTROL PILOT

A control pilot outside of the frequency definition of Table 4 or any control pilot duty cycle which is defined as an error state in Table 6.

3.19 OFF-BOARD CHARGER

A charger located off of the vehicle.

3.20 ON-BOARD CHARGER

A charger located on the vehicle.

3.21 PLUG IN HYBRID ELECTRIC VEHICLE (PHEV)

A hybrid vehicle with the ability to store and use off-board electrical energy in a rechargeable energy storage device.

3.22 PRE-CHARGE

Pre-charge circuits are designed to limit the electrical inrush current into the bulk capacitors prior to enabling the entire high voltage system. High inrush current can stress and damage the capacitors and other components on the high voltage DC bus, such as fuses, input filters, and power modules. Pre-charge circuits are typically comprised of a resistor and high voltage contactor.

3.23 VEHICLE INLET (CHARGE)

The device on the electric vehicle into which the connector is inserted for the purpose of transferring energy and exchanging information. This is part of the coupler.

4. GENERAL CONDUCTIVE CHARGING

In the most fundamental sense, there are three functions—two electrical and one mechanical—that must be performed to allow charging of the EV/PHEV battery from the electric supply network. The electric supply network transmits alternating current electrical energy at various nominal voltages (rms) and a frequency of 60 Hz. The EV/PHEV battery is a DC device that operates at a varying voltage, depending on the nominal battery voltage, state-of-charge, and charge/discharge rate. The first electrical function converts the AC to DC and is commonly referred to as rectification. The second electrical function is the control or regulation of the supply voltage to a level that permits a managed charge rate based on the battery charge acceptance characteristics (i.e., voltage, capacity, electrochemistry, and other parameters). The combination of these two functions are the embodiment of a charger. The mechanical function is the physical coupling or connecting of the EV/PHEV to the EVSE and is performed by the user. The conductive charging system consists of a charger and a coupler.

This document is organized into three major sections:

- Section 4: General Conductive Charging: Requirements that apply to all charging methods
- Section 5: AC Level 1 and Level 2 Charging: Requirements specific for AC Level 1 and Level 2 charging
- Section 6: DC Level 1 and Level 2 Charging: Requirements specific for DC Level 1 and Level 2 charging

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4.1 Electrical Ratings

Electrical ratings for each conductive charging method (AC and DC) are located in the corresponding Electrical Ratings section of each charging method.

It is recommended that residential EVSEs input current rating be limited to 32 A (40 A branch breaker) unless the EVSE is part of an energy management system, per NEC Article 750. Residential EVSEs with input current ratings of greater than 32 A without home energy management may require substantial infrastructure investment by the resident owner, utility, or both.

4.2 Charging Control and Information

4.2.1 Control Pilot

The control pilot circuit is the primary control means to ensure proper operation when connecting an EV/PHEV to the EVSE. This section describes the functions and sequencing of events for this circuit based on the recommended typical implementation or equivalent circuit parameters.

4.2.1.1 Control Pilot Circuit

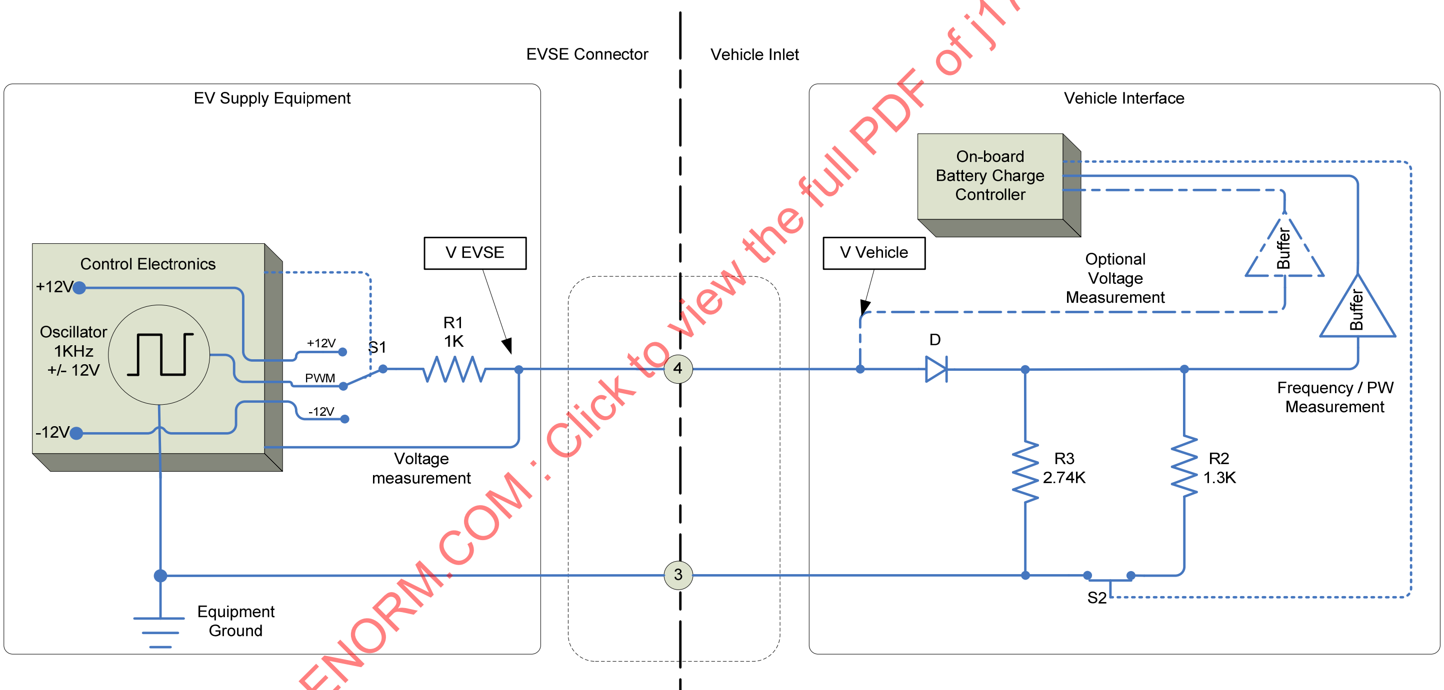

Figure 1 - Control pilot circuit

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4.2.1.2 Control Pilot Circuit Parameters and Vehicle States

The control pilot circuit parameters and vehicle states are shown in Figure 2 and defined in Tables 1, 2, 3, 4, and 5.

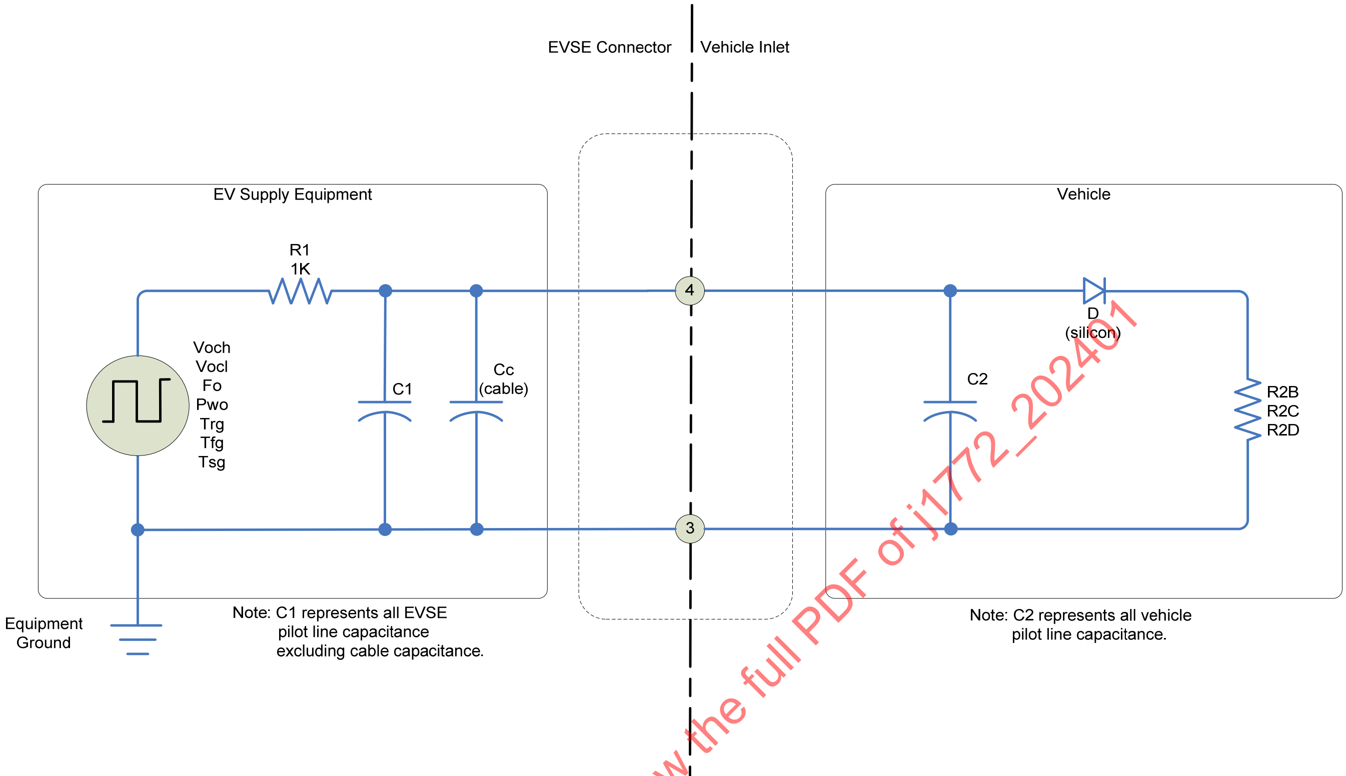

Figure 2 - Control pilot equivalent circuit

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Table 1 - Definition of vehicle/EVSE states

State Designation	V EVSE (vdc Nominal)[5]	V Vehicle (vdc Nominal)[5]	Description of Vehicle / EVSE State
State A	12.0[1]	0[1]	Vehicle not connected.
State B1	9.0[1]	9.0[1]	Vehicle connected / not ready to accept energy. EVSE not ready to supply energy.
State B2	9.0[2][3]	9.0[2][3]	Vehicle connected / not ready to accept energy. EVSE capable to supply energy.
State C	6.0[2]	6.0[2]	Vehicle connected / ready to accept energy / indoor charging area ventilation not required. EVSE capable to supply energy.
State D	3.0[2]	3.0[2]	Vehicle connected / ready to accept energy / indoor charging area ventilation required. EVSE capable to supply energy.
State E[4]	0	0	EVSE disconnected from vehicle / EVSE disconnected from utility, EVSE loss of utility power or control pilot short to control pilot reference.
State F	-12.0[1][6]	-12.0[1][6]	Other EVSE problem.

(1) Static voltage.
(2) Positive portion of 1 kHz square wave, measured after transition has fully settled.
(3) The transition from State B1 to State B2 begins as a static DC voltage which transitions to PWM upon the EVSE detection of vehicle connected / not ready to accept energy and EVSE capable to provide energy.
(4) EVSE is not required to actively generate State E.
(5) Voltage measured by EVSE / Vehicle as shown in Figure 1.
(6) Optional state. The EVSE may enter State F upon detecting a self-diagnosed fault that prevents the EVSE from delivering power. Once the EVSE is in STATE F, self-restoring (automatic restart) is not required. This option would require user intervention to reset the EVSE to restore normal operation. If the EVSE decides to self-restore while connected to an EV/PHEV, a maximum of 20 retries shall be allowed with a 15-minute minimum time interval between retries. If the EVSE does not recover within a maximum of 20 retries, user intervention is required to reset the EVSE to restore normal operation. EVSE equipment should make every effort to recover from state F when possible.

Table 2 - Control pilot state voltage range reference from mated charge coupler interface

State	Min Voltage	Nominal Voltage	Max Voltage
State B1	8.36	9.00	9.59
State B2	8.36	9.00	9.59
State C	5.47	6.00	6.53
State D	2.58	3.00	3.28

Notes:
Table Calculation Parameters
1. The maximum, nominal, and minimum positive regulator voltages from Table 4 (State A).
2. The maximum, nominal, and minimum resistance values allowed for each state from Table 5.
3. The maximum and minimum diode voltage extremes allowed in Table 5.
4. For nominal voltages, the midpoint of the diode voltage extremes in Table 5 (0.70V) was used.

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NOTE: The tolerances described in Table 2 represent calculated values assuming 3% resistors in the EVSE circuitry. These values do not take into account variances such as ground shift, chassis resistance, active accessory devices (air conditioning, rear defog, etc.), or other factors that could shift these values. These values do not include EVSE cable or vehicle inlet to vehicle charge controller cable resistance. Vehicle manufacturers should minimize these factors in their vehicle design. For example, in cases where different ground points are used for R2, R3, and vehicle control pilot voltage measurement, values of 0.3 V offset have been observed/measured, with worst case calculated offset of 0.7 V.

Table 3 - Control pilot state recommended boundary voltage range reference from mated charge coupler interface for the EVSE

State	Min Voltage	Nominal Voltage	Max Voltage
State B1	8.00	9.00	10.00
State B2	8.00	9.00	10.00
State C	5.00	6.00	7.00
State D	2.00	3.00	4.00

Table 4 - EVSE control pilot circuit parameters (see Figure 1)

Parameter[(1)]	Symbol	Units	Nominal Value	Max Value	Min Value
Generator					
Voltage high, open circuit	Voch	V	12.00	12.60	11.40
Voltage low, open circuit	Vocl	V	-12.00	-12.60	-11.40
Frequency	Fo	Hertz	1000	1020	980
Pulse width[(2)]	Pwo	μs	Per Figure 3	Nom, + 5 μs	Nom, - 5 μs
Rise time[(3)]	Trg	μs	n/a	2	n/a
Fall time[(3)]	Tfg	μs	n/a	2	n/a
Settling time[(4)]	Tsg	μs	n/a	3	n/a
Output Components					
Equivalent source resistance	R1	Ω	1000	1030[(5)]	970[(5)]
Total equivalent EVSE capacitance, w/o cable	C1	pF	n/a	n/a	300[(6)]
Total equivalent EVSE capacitance, including cable	C1 + Cc	pF	n/a	3100	n/a

(1) Tolerances to be maintained over the environmental conditions and useful life as specified by the manufacturer.
(2) Measured at 50% points of complete negative-to-positive or positive-to-negative transitions.
(3) 10 to 90% of complete negative-to-positive transition or 90 to 10% of complete positive-to-negative transition measured between the pulse generator output and R1. Note that the term Generator is referring to the EVSE circuitry prior to and driving the 1 KΩ source resistor with a ±12 V square wave. This circuitry shall have rise/fall times faster than 2 μs. Rise/fall times slower than this will begin to add noticeably to the output rise/fall times dictated by the 1 KΩ resistor and all capacitance on the Pilot line.
(4) To 95% of steady-state value, measured from start of transition.
(5) Maximum and minimum resistor values are ±3% about nominal.
(6) Guarantees rise time slow enough to remove transmission line effects from cable.

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Table 5 - EV/PHEV control pilot circuit parameters (see Figure 2)

Parameter[(1)]	Symbol	Units	Nominal value	Max value	Min value
Equivalent load resistance - State B1 and B2	R2B	Ω	2740	2822[(2)]	2658[(2)]
Equivalent load resistance - State C[(3)]	R2C	Ω	882	908[(2)]	856[(2)]
Equivalent load resistance - State D[(4)]	R2D	Ω	246	253[(2)]	239[(2)]
Total equivalent capacitance	C2	pF	n/a	2400	n/a
Equivalent diode voltage drop[(5)]	Vd	V	0.70	0.85	0.55

(1) Tolerances to be maintained over the environmental conditions and useful life as specified by the manufacturer.
(2) Maximum and minimum resistor values are ±3% about nominal.
(3) Vehicles not requiring ventilation for indoor charging areas.
(4) Vehicles requiring ventilation for indoor charging areas.
(5) Silicon small signal diode, -40 to 85 °C, forward current 3.00 to 10.0 ma.

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4.2.1.3 Control Pilot Functions

The control pilot performs the following functions. See Appendix F for specific requirements during DC charging.

4.2.1.3.1 Verification of Vehicle Connection

The EVSE is able to determine that the connector is inserted into the vehicle inlet and properly connected to the EV/PHEV by sensing resistance R3 as shown in Figure 1. The diode, D, is present to help an EVSE determine that an EV/PHEV is connected rather than other potential low impedance loads. If the EVSE does not detect diode D (missing or shorted), it may indicate a fault by entering State F. The EV/PHEV may optionally monitor the control pilot on the anode side of diode D as shown in Figure 1.

4.2.1.3.2 EVSE Not Ready to Supply Energy

The EVSE is able to indicate to the EV/PHEV that it is not ready to supply energy by not turning on the oscillator and maintaining State B1. State B1 may be used by the EVSE to maintain the current charge session during load management, fee transaction, or other events.

The EVSE may turn off the oscillator at any time while in State C or D during the current charge session. When the EVSE turns off the oscillator, the EVSE shall terminate energy transfer. The EV/PHEV then opens S2 resulting in State B1. See examples in Appendix E.2, transition 14 notes.

4.2.1.3.3 EVSE Ready to Supply Energy

The EVSE is able to indicate to the EV/PHEV that it is ready to supply energy by turning on the oscillator and providing the square wave signal according to the value derived from Figure 3. The EVSE shall not close contactors unless the oscillator is on and valid per Figure 3. In each of the states specified in Tables 1 and 2, the EVSE may supply the pilot as a DC signal or as an oscillating signal. However, normally the oscillator is only turned on in State B2, State C, or State D.

4.2.1.3.4 EV/PHEV Ready to Accept Energy

The EV/PHEV indicates that it is ready to accept energy from the EVSE by closing switch S2, as shown in Figure 1, when the current profile on the control pilot oscillator is sensed. The EV/PHEV may de-energize the EVSE at any time by opening switch S2.

4.2.1.3.5 Determination of Indoor Ventilation

The EVSE is able to determine if the EV/PHEV requires indoor charging ventilation by sensing the voltage as specified in Tables 1 and 2. If required, the EVSE shall provide a signal to turn on the indoor charging area ventilation system according to NEC Article 625.

4.2.1.3.6 EV/PHEV Current Control Tolerance

The EVSE communicates the available continuous current capacity to the EV/PHEV by modulating the pilot duty cycle as described in Table 6 and shown in Figure 3.

The EVSE shall not transmit a duty cycle that exceeds its maximum continuous rating. The EV/PHEV shall not draw more than the EVSE pilot indicates.

4.2.1.3.7 EVSE Current Capacity

The EVSE shall maintain ±0.5% tolerance on control pilot PWM duty cycle generation over the whole range, 5 to 96%. For EVSE nominal available current, see Table 6.

Table 6 - Control pilot duty cycle definition

Notes	EVSE NominalDuty Cycle	Vehicle Inlet	Max Current to be Drawn by Vehicle
1, 7	Duty Cycle = 0%	Duty Cycle <3%	State F or E; no charging allowed
2	Duty Cycle = 5%	4.5% ≤ Duty Cycle ≤5.5%	Indicates that digital communication is needed
3, 7		7% < Duty Cycle <8%	Error state; no charging allowed
4		9.5% ≤ Duty Cycle <10%	6A
	10% ≤ Duty Cycle ≤20%	10% ≤ Duty Cycle ≤20%	Maximum current = (duty cycle %) x 0.6
	20% < Duty Cycle ≤85%	20% < Duty Cycle ≤85%	Maximum current = (duty cycle %) x 0.6
	85% < Duty Cycle ≤96%	85% < Duty Cycle ≤96%	Maximum current = (duty cycle % - 64) x 2.5
5		96% < Duty Cycle ≤96.5%	80A
6, 7	Duty Cycle = 100%		State B1, C1, or D1; no charging allowed

Notes:

1. Some EVSEs implement state F (-12V) as PWM duty 0%. Depending on hardware implementation, short switching noise spikes are possible. Those spikes could be interpreted by the vehicle as PWM >0%.
2. Based on ±0.5% of the duty cycle tolerance. It will be up to OEM to decide whether to extend the digital communications zone up to the error states above and below.
3. Legacy carryover from previous editions. Need to remain to create the separation between digital communications and charging duty cycle values.
4. Based on ±0.5% EVSE duty cycle tolerance. Vehicle shall interpret 9.5% duty cycle as 10%.
5. Based on ±0.5% of the duty cycle tolerance. Vehicle shall interpret 96.5% as 96%.
6. Some EVSEs implement states B1, C1, D1 as PWM duty 100%. Depending on the hardware implementation, short switching noise spikes are possible. Those spikes could be interpreted by the vehicle as PWM <100%.
7. No charging allowed: no active charging is allowed; an unintentional leakage current of less than 1A is acceptable.

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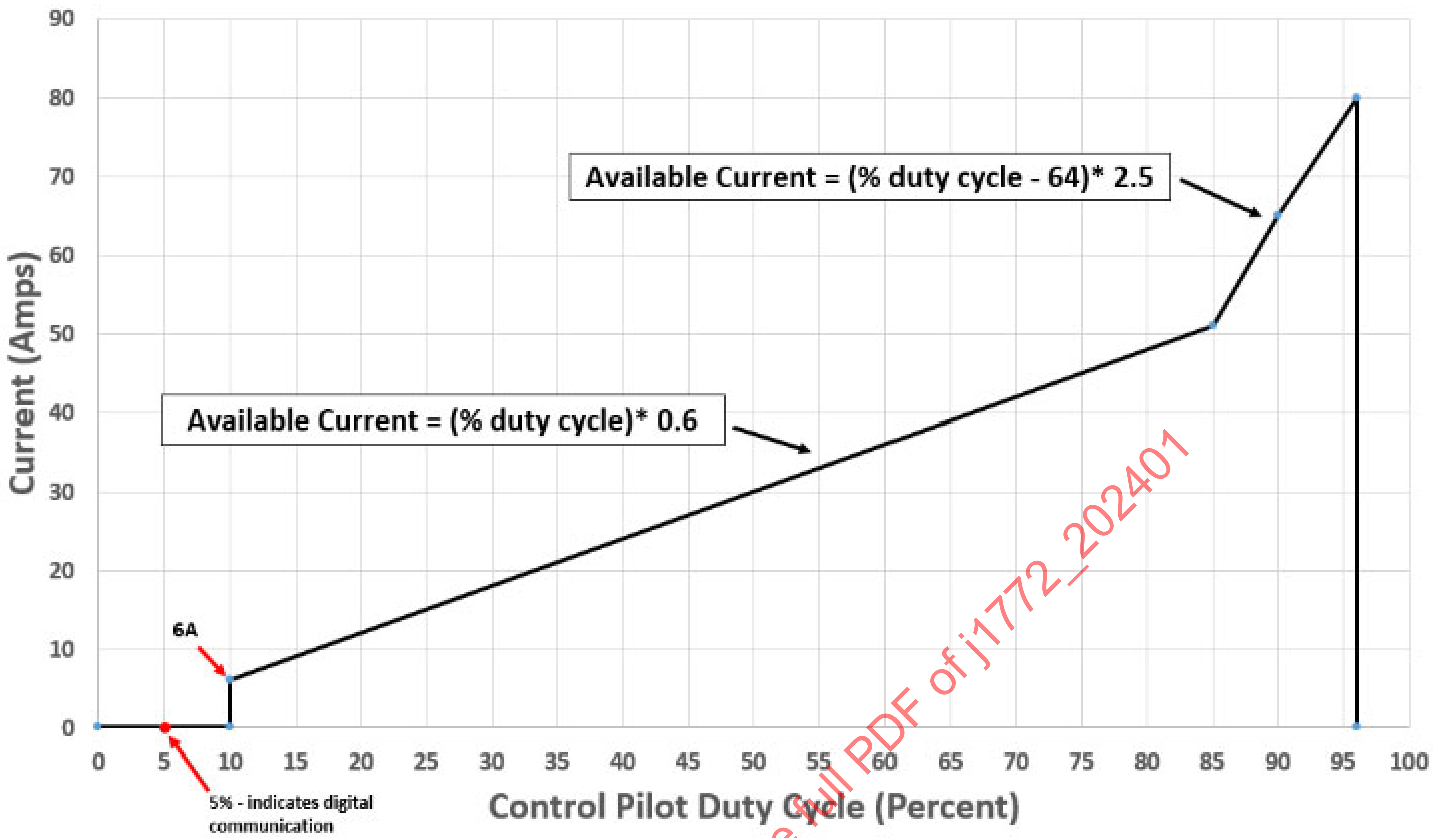

Figure 3 - Supply current rating versus pilot circuit duty cycle

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A duty cycle of 5% indicates that digital communication is needed. See 4.3.

The EVSE may accept an external signal to vary the duty cycle for supply or premises power limitations. The EV/PHEV vehicle shall use the duty cycle to control the on-board charger AC current drawn from the line.

4.2.1.3.8 Verification of Equipment Grounding Continuity

The equipment grounding conductor provides a return path for the control pilot current to ensure that the EVSE equipment ground is safely connected to the EV/PHEV vehicle chassis ground during charging. Loss of this signal shall result in the automatic de-energization at the EVSE.

4.2.1.4 Control Pilot Tolerance

The overall (EVSE and EV/PHEV) control pilot tolerance is not to exceed ±2%. This tolerance is distributed up to ±0.5% for the EVSE and up to 1.5% for the EV/PHEV. In the case of overlapping ranges, the valid state takes precedence over the error state.

Based on an overall tolerance of 2% duty cycle (see Table 6):

4.2.1.4.1 If the EV/PHEV reads a duty cycle of 3 to 7%, the EV/PHEV shall interpret this as a valid digital communications command. See 4.3.

4.2.1.4.2 If the EV/PHEV reads a duty cycle between 8% and less than 10%, the EV/PHEV shall interpret this as a valid 10% duty cycle.

4.2.1.4.3 If the EV/PHEV reads a duty cycle less than or equal to 85%, the EV/PHEV shall base the current on the Amps = (% duty cycle) * 0.6 formula.

4.2.1.4.4 If the EVPHEV reads a duty cycle greater than 85%, the EV/PHEV shall base the current on the Amps = (% duty cycle – 64) * 2.5 formula.

4.2.1.4.5 If the EV/PHEV reads a duty cycle of 97%, it is recommended the EV/PHEV consider this as a valid 96% duty cycle.

4.2.2 Proximity Detection

Upon insertion of the connector into the vehicle inlet, the coupler shall provide a means to detect the presence of the connector in the vehicle inlet as described in Table 7 and shown in Figure 4. Detection of the connector shall occur at a point where damage to coupler, EV/PHEV, or EVSE could occur if the EV/PHEV were to be intentionally moved.

Resistors R5-R7 allow for diagnostics of the circuit. S3 is mechanically linked to the connector latch release actuator. S3 is normally closed except when the connector latch release actuator is actuated.

Proximity detection may be used to meet the requirements in 5.5.2 and 4.6.2.

4.2.2.1 Proximity Detection Circuit

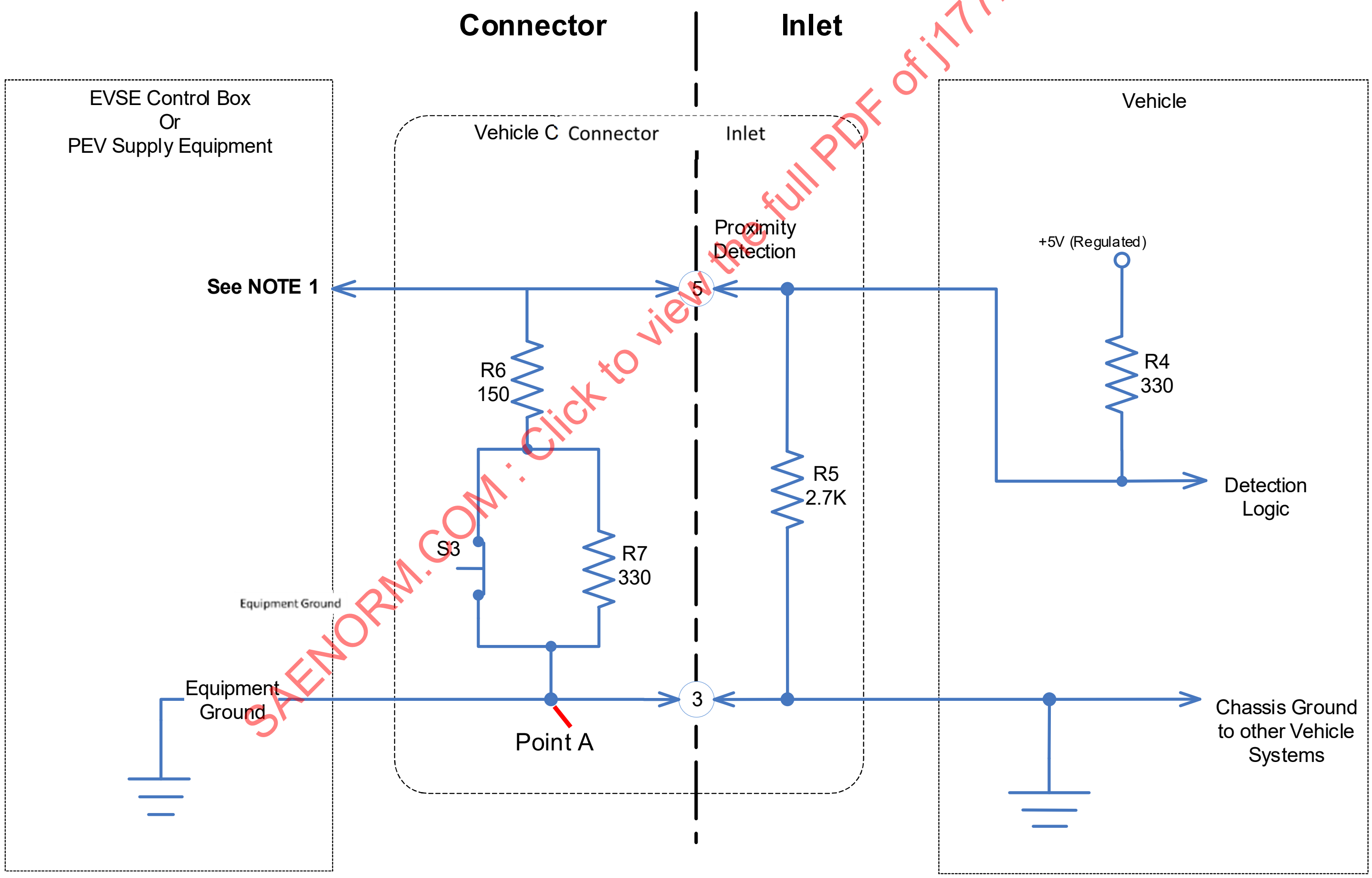

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Figure 4 - Proximity detection circuit

NOTE 1: R5 is required for both AC and DC charging. Monitoring of the Proximity Detection Circuit at the EVSE is optional for AC charging and mandatory for DC charging.

4.2.2.2 Proximity Detection Circuit Parameters

Table 7 - Proximity detection circuit component parameters (see Figure 4)

Parameter[1]	Symbol	Units	Nominal Value	Max Value	Min Value
Vehicle +5Vdc (regulated)	+5V Regulated	V	5.0	5.25[3]	4.75
Equivalent load resistance	R4	Ω	330	363[2]	297[2]
Equivalent load resistance	R5	Ω	2700	2970[2]	2430[2]
Equivalent load resistance	R6	Ω	150	165[2]	135[2]
Equivalent load resistance	R7	Ω	330	363[2]	297[2]

(1) Tolerances to be maintained over the environmental conditions and useful life as specified by the manufacturer.
(2) Maximum and minimum resistor values are ±10% about nominal.
(3) Based on 5% tolerance.

Table 8 - Proximity detection circuit voltage parameters[1][2][3] (see Figure 4) from mated charge coupler interface

Description	Min Voltage (V)	Nominal Voltage (V)	Max Voltage (V)
Potential measured between pin 5 (high) and pin 3 (low) at the vehicle inlet when EVSE connector not connected	4.13	4.46	4.78
Potential measured between pin 5 (high) and pin 3 (low) at the vehicle coupler when EVSE connector is plugged in and latch (S3) is released	1.23	1.53	1.82
Potential measured between pin 5 (high) and pin 3 (low) at the vehicle coupler when EVSE connector is plugged in and latch (S3) is depressed	2.38	2.77	3.16
Potential measured between pin 5 (high) and pin 3 (low) at the EVSE when the connector is not connected	-0.1	0	0.1

(1) Tolerances to be maintained over the environmental conditions and useful life as specified by the manufacturer.
(2) Maximum and minimum resistor values are ±10% about nominal.
(3) Tolerance of voltage regulator on vehicle ±5%.

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NOTE: The tolerances described in Table 8 represent calculated values assuming 10% resistors in the PHEV/EV circuitry. These values do not take into account variances such as ground shift, chassis resistance, active accessory devices (air conditioning, rear defog, etc.), or other factors that could shift these values. These values do not include EVSE cable or vehicle inlet to vehicle charge controller cable resistance. EVSE/Vehicle manufacturers must minimize these factors in their design. It is up to the EVSE manufacturer to widen the acceptable voltage range of their proximity detection interface. Since the proximity detection circuit is powered from the vehicle and for AC charging only monitored by the vehicle, tolerances may apply per Table 8. DC Charging requires the EVSE to also monitor this circuit and the additional impedance due to the EVSE circuit needs to be taken into account and allow an acceptable voltage range accordingly.

4.2.2.3 Charge Status Indicator

The PHEV shall provide charge status information visible to the operator while inserting the coupler into the vehicle inlet. The specific requirements (such as color, lamp type, styling, intensity, field of view, etc.) for the Charge Status Indicator can be defined by the vehicle manufacturer.

This indicator, as well as the AC Present Indicator on the EVSE (see 4.7.5), should be considered part of a diagnostic strategy that helps determine possible causes of no-charge events. This diagnostic strategy is optional for battery electric vehicles.

Vehicle diagnostic strategy may be regulated based on emission requirements. Emission requirements may be different for PHEV and EV vehicles.

4.3 Digital Data Transfer

A control pilot duty cycle of 5% indicates that digital communication is required and shall be established between the EVSE and vehicle before charging.

Refer to the corresponding Digital Data Transfer section of each charging method.

4.4 EVSE and EV/PHEV Charging Sequence, Timing, and Response

Refer to the corresponding EVSE and EV/PHEV Charging, Timing and Response section of each charging method.

4.5 EV/PHEV and EVSE Additional Requirements for Power Transfer

4.5.1 Alternative Measures

The EV/PHEV and EVSE shall implement alternative measures in addition to basic insulation. The following measures shall provide both basic protection and fault protection:

- double insulation;
- reinforced insulation;
- protective barriers in addition to the basic protection;
- protective enclosures in addition to the basic protection;
- conductive protective barrier with equipotential bonding in addition to basic insulation;
- conductive protective enclosure with equipotential bonding in addition to basic insulation;
- rigid protective barriers with sufficient mechanical robustness and durability over the vehicle service life;
- rigid protective enclosures with sufficient mechanical robustness and durability, over the vehicle service life.

The selected measure or combination of measures shall address the single failure for which it is intended.

Different measures may be used for different sections of a circuit

The requirements for protective provisions in 4.5.2 shall apply.

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4.5.2 General Requirements for Protective Provisions

4.5.2.1 Requirements for Insulation

The following requirements apply to basic insulation, double insulation, and reinforced insulation.

Insulation shall fulfil the specific requirements related to basic insulation, double insulation, or reinforced insulation in accordance with 4.5.2.2.4.

Insulation can be a solid, a liquid, or a gas (e.g., air), or any combination.

Where insulation is not provided by solid insulation only, access to live parts shall be prevented by protective barriers or protective enclosures. See 4.5.2.2.2 .

Live parts of cables not within protective enclosures or behind protective barriers shall be totally encapsulated by solid insulation that can be removed only by destruction.

4.5.2.2 Requirements for Protective Barriers/Protective Enclosures

4.5.2.2.1 General

Protective barriers/protective enclosures shall have sufficient mechanical strength, stability, and durability to maintain the specified provisions of protection, taking into account all relevant environmental conditions.

It shall not be possible to open or remove protective barriers/protective enclosures without the use of tools, or they shall have means to de-energize voltage class B live parts. Voltage class B is defined in ISO 6469-3.

The protective barriers/protective enclosures may be electrically conductive or provided by solid insulation.

4.5.2.2.2 Degree of Protection for Protective Barriers/Protective Enclosures

Protective barriers/protective enclosures shall comply with the degree of protection IPXXB at a minimum.

Protective barriers/protective enclosures in passenger and load compartments shall comply with the degree of protection IPXXD at a minimum.

4.5.2.2.3 Requirements for Connectors

Connectors for voltage class B electric circuits shall comply with 4.5.2.2.2. in the mated condition. Voltage class B is defined in ISO 6469-3.

Vehicle inlet shall comply with 4.5.3 in unmated condition.

Connectors for voltage class B (voltage class B is defined in ISO 6469-3) electric circuits, excluding vehicle inlet, shall comply with at least one of the following requirements:

a. A connector shall comply with 4.5.2.2.2 in the unmated condition.

b. It shall not be possible to unmate a connector without the use of tools.

c. Voltage class B live parts of a connector shall be de-energized when it is unmated. One of the following conditions shall be met for the de-energized live parts:

   1. The voltage shall be reduced to a value below the lower limits of voltage class B.

   2. The total stored energy of the circuit shall be ≤0.,2 J and the touch current flowing between simultaneously accessible conductive parts shall not exceed 2 mA a.c. or 10 mA d.c. Compliance shall be tested according to 10.5 or demonstrated by calculation.

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4.5.2.2.4 Insulation Coordination

Clearance, creepage distance, and solid insulation of voltage class B components and wiring shall be designed according to the applicable sections of IEC 60664. Voltage class B is defined in ISO 6469-3.

4.5.3 Requirements for Unmated Vehicle Connectors

4.5.3.1 General

This subclause specifies the safety requirements for the contacts of the EV/PHEV plug (case A), the vehicle inlet (case B and case C), the ACD counterpart (case D), or the ACD (case E) when they are not mated.

The requirements given in this clause shall be achieved by implementing basic and fault protection according to ISO 6469-3.

The requirements in 4.5.3.3 shall be fulfilled:

- within 10 seconds after un-mating if the contacts cannot be touched by a test probe 18 according to IEC 61032, or
- within 5 seconds after un-mating if the contacts are protected, according to IPXXB according to ISO 20653, or
- within 1 second after un-mating if the contacts are not protected according to IPXXB according to ISO 20653.

If there is a latching or locking device, the vehicle shall allow only unlatching or unlocking after the relevant thresholds, as specified in 4.5.3.2 and in 4.5.3.3, are maintained.

If there is no latching and no locking device, then 4.5.3.2 shall be fulfilled:

- within 10 seconds after un-mating if the contacts cannot be touched by a test probe 18 according to IEC 61032, or
- within 5 seconds after un-mating if the contacts are protected according to IPXXB according to ISO 20653, or
- within 1 second after un-mating if the contacts are not protected according to IPXXB according to ISO 20653.

NOTE 1: If contacts are protected according to IPXXD, IPXXB is also fulfilled.

NOTE 2: The latching or locking device might be part of the electric vehicle or part of the external electric equipment.

4.5.3.2 Normal Operation

At least one of the following requirements applies for each contact of the EV/PHEV plug (case A), the vehicle inlet (case B and case C), the ACD counterpart (case D), or the ACD (case E) when it is not mated:

a. the contact shall be protected by the degree of protection IPXXD according to ISO 20653;

b. the voltage between the contact and any other contact not protected by IPXXD according to ISO 20653, as well as the voltage between the contact and the electric chassis, shall be below 60 V DC and 30 V AC;

c. the steady state touch current between the contact and any other contact not protected by IPXXD according to ISO 20653, as well as the steady state touch current between the contact and the electric chassis, shall be below 0.5 mA AC and 2 mA DC and the stored energy between the contact and any other contact not protected by IPXXD according to ISO 20653, as well as the stored energy between the contact and the electric chassis, shall not cause a startle reaction. The limit shall be specified by the OEM under the consideration of the IEC 60479 series.

NOTE 1: The thresholds for steady state touch current are derived from IEC 61140 and IEC 60479-1.

NOTE 2: The energy stored in electrical power sources (e.g., rechargeble energy storage system [RESS]) that is only available through a sufficiently high protective impedance which limits the touch current is not relevant.

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NOTE 3: A threshold of perception and a threshold of pain are defined in IEC 60479-2.

NOTE 4: According to IEC 60479-2, the threshold of pain is the specific charge or specific energy. The specific energy given in IEC 60479-2 might not correlate with the fault case for the inlet.

The steady state touch current requirement is deemed to be fulfilled if it can be proven by design review that there is no conductive path from electrical power sources (e.g., RESS) to accessible conductive parts.

4.5.3.3 Operation Under a Single Fault Condition

In case of a single fault condition, at least one of the following requirements applies for each contact of the EV/PHEV plug (case A), the vehicle inlet (case B and case C), the ACD counterpart (case D), or the ACD (case E) when it is not mated:

a. the contact shall be protected by the degree of protection IPXXD according to ISO 20653;

b. the voltage between the contact and any other contact not protected by IPXXD according to ISO 20653 as well as the voltage between the contact and the electric chassis shall be below 60 V DC and 30 V AC;

NOTE 1: De-energization will result in the same voltage level as for normal operation. A different threshold is not relevant for single fault conditions.

c. the steady state touch current between the contact and any other contact not protected by IPXXD according to ISO 20653, as well as the steady state touch current between the contact and the electric chassis shall be below 3.5 mA AC and 10 mA DC and the stored energy between the contact and any other contact not protected by IPXXD according to ISO 20653, as well as the stored energy between the contact and the electric chassis shall not cause strong involuntary muscular reactions. The limit shall be specified by the OEM under the consideration of the IEC 60479 series.

NOTE 2: The thresholds for steady state touch current are derived from IEC 61140 and IEC 60479-1.

NOTE 3: The energy stored in electrical power sources (e.g., RESS) that is only available through a sufficiently high protective impedance which limits the touch current is not relevant.

The steady state touch current requirement is deemed to be fulfilled if it can be proven by design review that there is no conductive path from electrical power sources (e.g., RESS) to accessible conductive parts.

The vehicle should detect and issue a warning if an applied threshold for normal operation, i.e., voltage or touch current and energy, is exceeded.

4.6 EV/PHEV Requirements

4.6.1 Environmental

The on-board EV/PHEV charging system electronic components shall meet the requirements specified in SAE J1211.

4.6.2 Vehicle Movement with Mated Coupler

The EV/PHEV shall prevent operator intended vehicle movement when the connector is mated to the vehicle inlet.

4.6.3 Control Pilot Continuity

The EV/PHEV shall not intentionally open the control pilot circuit while the vehicle connector is mated to the vehicle inlet.

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4.7 EVSE Requirements

4.7.1 EVSE EMC Requirements

4.7.1.1 Electromagnetic Emissions

The following electromagnetic compatibility (EMC) paragraphs (see 4.7.1.1 through 4.7.1.9) apply to the off-vehicle EVSE. SAE test methods for on-vehicle EV/PHEV charging equipment are under consideration.

The CFR Title 47, Part 15 includes requirements for unintentional radiators and power line communication systems. The cordset and other EVSE external to the vehicle, if employing an internal frequency source exceeding 9 kHz, shall comply with FCC CFR 47, Title 47, Parts 15A, 15B as a separate device.

NOTE 1: Charging or support equipment used exclusively in vehicles may be formally exempted from FCC specific technical standards per paragraph 15.103, but FCC strongly recommends compliance to the FCC limits. The applicability of the FCC paragraph 15.103 exemption to specific devices is outside the scope of this document. The FCC Office of Engineering and Technology Laboratory Division Knowledge Database website provides up-to-date published interpretations of FCC rules.

NOTE 2: An on-board Power Line Communication system may require separate FCC Part 15 compliance testing in a representative configuration, if the vehicle is so equipped. Refer to FCC rules for composite systems incorporating carrier current communication systems.

NOTE 3: Additionally, some markets may regulate EMC via the relevant sections of IEC 61851-21-1 and IEC 61851-21-2. Specific market requirements are outside the scope of this document.

4.7.1.1.1 EVSE Conducted Emissions

The EVSE shall meet FCC Part 15 conducted limits for unintentional radiators.

4.7.1.1.2 EVSE Radiated Emissions

The EVSE shall meet FCC Part 15 radiated limits for unintentional radiators. See 4.7.1.1, Note 1.

4.7.1.2 EVSE Electromagnetic Immunity

The EVSE shall be tested in accordance with and shall meet requirements for electromagnetic field immunity as specified in UL 2231-2. In addition to the performance requirements specified in UL 2231-2, the functions defined in 4.2 shall perform as designed during and after testing at the specified levels. Additional requirements may optionally be specified. Refer to SAE J1812 for methods of specification of test levels and function performance status.

NOTE 1: The UL 2231-2 standard specifies radiated immunity testing from 150 kHz to 1000 MHz. IEC 61000-4-6 is referenced for the 150 kHz to 80 MHz range. IEC 61000-4-3 is referenced with a 20 V/m carrier test severity level for the 80 to 1000 MHz range.

NOTE 2: For developmental testing, use of the frequency step sizes specified in ISO 11452-1 will facilitate an efficient evaluation of product immunity.

4.7.1.3 EVSE Electrostatic Discharge

The EVSE shall be tested in accordance with and shall meet the requirements for electrostatic discharge specified in UL 2231-2.

4.7.1.4 EVSE Harmonic Distortion Immunity

The EVSE shall be tested in accordance with and shall meet the requirements for harmonic distortion immunity specified in UL 2231-2.

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4.7.1.5 EVSE Electrical Fast Transient Immunity

The EVSE shall be tested in accordance with and shall meet the requirements for electrical fast transient immunity specified in UL 2231-2.

4.7.1.6 EVSE Voltage Sags, Short Interruptions, and Voltage Variations Immunity

The EVSE shall be tested in accordance with and shall meet the requirements for voltage sags, short interruptions, and voltage variations immunity specified in UL 2231-2.

4.7.1.7 EVSE Magnetic Field Immunity

The EVSE shall be tested in accordance with and shall meet the requirements for magnetic field immunity specified in UL 2231-2.

4.7.1.8 EVSE Capacitor Switching Transient Test

The EVSE shall be tested in accordance with and shall meet the capacitor switching transient test requirements specified in UL 2231-2.

4.7.1.9 EVSE Voltage Surge Test

The EVSE shall be tested in accordance with and shall meet the requirements for voltage surge specified in UL 2231-2.

The EVSE shall be tested in accordance with and shall meet the capacitor switching transient test requirements specified in UL 2231-2.

4.7.2 Installation Requirements

The EVSE shall meet the requirements specified in the NEC Article 625 and CSA C22.1.

4.7.3 General Product Standards

The EVSE shall meet and be listed to the general product requirements specified in UL 2594.

4.7.4 Personnel Protection System

The EVSE shall incorporate a listed system of personnel protection as specified in UL 2231-1 and UL 2231-2.

4.7.5 AC Present Indicator

The EVSE shall incorporate a feature that indicates that the EVSE is receiving AC input power. The specific requirements for this indicator (such as color, lamp type, intensity, field of view, etc.) can be defined by the EVSE manufacturer. The indicator shall be labeled as to its function and, when illuminated, the indicator would signal presence of AC electrical energy from the premises wiring. See 4.2.2.3 for additional information.

4.7.6 Conductor Cord Requirements

The conductor cord shall meet the requirements specified in the NEC Article 625 and UL 2594.

4.8 Charge Coupler Requirements

The conductive coupler consists of a connector/vehicle inlet set with electromechanical contacts imbedded in an insulator and contained within a housing for each of the mating parts. The contacts provide a physical connection at the vehicle interface for the power conductors, equipment grounding conductor, and control pilot conductor between the EV/PHEV and EVSE. In addition, a proximity sense conductor is provided between the EV/PHEV and charge connector.

The EV/PHEV coupler shall meet the requirements specified in the NEC Article 625, UL 2251, and 4.8 and 4.10 of this document.

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4.8.1 Ergonomic Requirements

The coupler shall comply with the following ergonomic requirements.

4.8.1.1 Ease of Use

During connection and disconnection, the human efforts required shall be ≤75 N at beginning of life. This amount of force is typically within the physical capabilities of the general adult population and persons with limited or restricted capabilities.

EVSE and/or DC coupler manufacturers should provide a handle or other manipulation features on the top/rear side of the vehicle coupler to support ease of mating to the vehicle when the coupler is either heavy in weight or near the maximum allowable space-claim defined in this standard, since no hand clearance may be available between the maximum coupler volume and the vehicle body.

4.8.1.2 Indexing

During connection and disconnection, the insertion/removal of the connector and inlet shall be intuitively obvious and free of multiple orientations.

4.8.1.3 Tactile Feel

The coupler shall incorporate a means to provide tactile and/or audible feedback to the user when fully engaged.

4.8.1.4 Latching

The coupler shall have a latching mechanism to prevent inadvertent or accidental decoupling. The latching mechanism should provide a means in the connector to open the proximity detection conductor (see 4.2.2) when disengaging from the vehicle inlet.

4.8.1.5 Locking Function

The coupler locking function is intended to reduce the likelihood of tampering with, or an unauthorized removal, of the vehicle connector from the vehicle inlet. If the vehicle inlet and vehicle connector support a locking function, the proximity switch S3 (see 4.2.2) shall not open when the vehicle connector is locked to the vehicle inlet.

4.8.2 Safety Requirements

The coupler shall comply with the following safety requirements.

4.8.2.1 Surface Temperature

The maximum external surface temperature of the coupler shall be as specified in UL 2251. Surface Temperature test shall be conducted as per the requirements of Surface Temperature test in UL 2251.

4.8.2.2 Hazardous Conditions

The coupler should be designed to avoid or mitigate potentially hazardous conditions; fire, electric shock, or personnel injury.

4.8.2.3 Unauthorized Access

For unattended public access charging, the coupler may provide a means to engage an optional coupler locking mechanism to reduce the likelihood of tampering or unauthorized removal.

Dimensional requirements to implement an optional coupler locking mechanism are be found in Appendix B, sheets 1 to 3.

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4.8.3 Performance Requirements

The coupler shall comply with the following performance requirements:

4.8.3.1 Design Life

The coupler shall be designed to a minimum of 10000 cycles of mechanical operation. The coupler performance shall not be reduced by the environment conditions specified in 4.8.4 of this document.

4.8.4 Environmental Requirements

The coupler shall comply with the following environmental requirements:

4.8.4.1 Temperature Range

The coupler shall be designed to withstand continuous ambient temperatures in the range of -30 to +40 °C during operation when supplied with the EVSE or installed in the EV/PHEV and continuous ambient temperatures in the range of -40 to +80 °C during shipping or storage when the components parts are assembled, supplied with the EVSE, or installed in the EV/PHEV. Temperature Rise Test shall be conducted as per the requirements of Temperature Rise test of UL 2251.

4.8.4.2 Temperature Rise

The temperature rise of the coupler shall be as specified in UL 2251.

4.8.4.3 Insulation Resistance

The insulation resistance of the coupler shall be as specified in UL 2251.

4.8.4.4 Fluid Resistance

The coupler shall be unaffected by automotive lubricants, solvents, and fuels as specified in SAE USCAR 2.

4.8.5 General Coupler Physical Description

The vehicle inlet designs shall be of a common physical configuration that is capable of accepting common connector physical configurations as defined for each charging method. Additionally, the physical requirements shall ensure compatibility of connectors and vehicle inlets manufactured by the same manufacturer at different points in time, as well as different manufacturers of the mating connectors and vehicle inlets.

4.8.6 Contact Sequencing

During connection, the connector and vehicle inlet shall comply with the following contact sequencing; equipment/chassis ground contact is first make/last break, and the control pilot contact is last make/first break.

4.8.7 Charge Coupler Optional Markings

A connector and/or vehicle inlet manufactured to this Standard are permitted to optionally visibly display the following identification on its outer surface in Arial font: “SAE J1772.” Any party providing such identification warrants that the connector and/ or vehicle inlet complies with all mandatory requirements of this standard and agrees to indemnify and hold SAE harmless from any and all liability arising out of any failure to comply and any resulting injury or damage arising from such failure.

4.9 Vehicle Inlet

4.9.1 Physical Dimensions

The vehicle inlet shall comply with the key physical dimensions as defined for each charging method.

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4.9.2 Inlet Access Zone

The vehicle inlet shall be installed in the vehicle to allow connector access when the cover door is opened as defined for each charging method.

4.9.3 Alignment

The vehicle inlet shall provide a lead-in feature for automatic alignment during insertion and removal of the connector.

4.9.4 Isolation

The vehicle inlet power contacts shall be electrically isolated from battery voltages when the connector is removed from the vehicle inlet.

4.9.5 Exposure of Contacts

The vehicle inlet shall be designed to prevent direct contact with live parts according to UL 2251.

Vehicle inlets used for reverse power flow shall prevent direct contact with live parts when not mated to the vehicle connector. Direct contact is evaluated by using the probe defined in section 13 of UL 2251 .

4.9.6 Sharp Edges

The vehicle inlet shall be free of sharp edges and potentially injurious protrusions per UL1439.

4.9.7 Environmental Considerations

The vehicle inlet shall meet the performance requirements specified in 4.8.5 under weather and environmental conditions specified by the individual automobile manufacturers.

4.9.8 Mechanical Requirements

The vehicle inlet shall be able to withstand the minimum automotive vibration conditions when tested to the following procedures and pass/fail criteria:

a. Vibration Test Procedure - A vehicle inlet as mounted on a test fixture shall be securely bolted to the table of the vibration test machine and subjected to vibration according to the following test parameters:

    1. Frequency: Varied from 10 to 55 Hz and return to 10 Hz at a linear sweep period of 2 minutes/complete sweep cycle.

    2. Excursion: 1.0 + 0.1/-0.0 mm peak to peak over the specified frequency range.

    3. Direction of Vibration: Vertical axis of the vehicle inlet as it is mounted on the vehicle.

    4. Test Duration: 60 + 1/-0 minutes.

    5. Pass/Fail Criteria: After completion of the test, there shall be no observed rotation, displacement, cracking, or rupture of parts of the device that could result in failure to operate as intended or cause it to fail any of the other test requirements specified in this document. Cracking or rupture of the parts of the device that affect mounting shall constitute a failure.

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4.9.9 Sealing Requirements

The vehicle inlet shall be sealed in a manner that the following requirements are met:

a. When decoupled, the vehicle inlet shall have an effective sealing system for outdoor use to provide a degree of protection against corrosion, windblown dust and rain, splashing water, hose-directed water, and external ice formation, per UL 50, type 3S as specified in UL 2251.

b. When coupled, the vehicle inlet shall have an effective sealing system for outdoor use to provide a degree of protection against corrosion, windblown dust and rain, splashing water, hose-directed water, and external ice formation, per UL 50, type 3S as specified in UL 2251.

c. The vehicle inlet shall provide for the egress of fluids.

4.10 Vehicle Connector

4.10.1 Physical Dimensions

The vehicle connector shall comply with the key physical dimensions as defined for each charging method.

4.10.2 Exposure of Contacts

The connector shall be designed to prevent direct contact with live parts according to UL 2251.

Vehicle connectors shall prevent direct contact with live parts when not mated to the vehicle inlet. Direct contact is evaluated by using the probe defined in Section 13 of UL 2251

4.10.3 Sharp Edges

The vehicle connector shall be free of sharp edges and potentially injurious protrusions per UL 1439.

4.10.4 Impact Resistance

The connector shall continue to function as intended after being dropped from a height of 1 m onto a concrete surface per UL 2251.

4.10.5 Vehicle Drive-Over

The connector shall continue to function as intended or fail in a safe manner after being driven over by a vehicle as specified in UL 2251.

5. AC CHARGING

Two levels of AC charging are defined. AC Level 1 and AC Level 2. AC charging architecture is shown in Figure 5.

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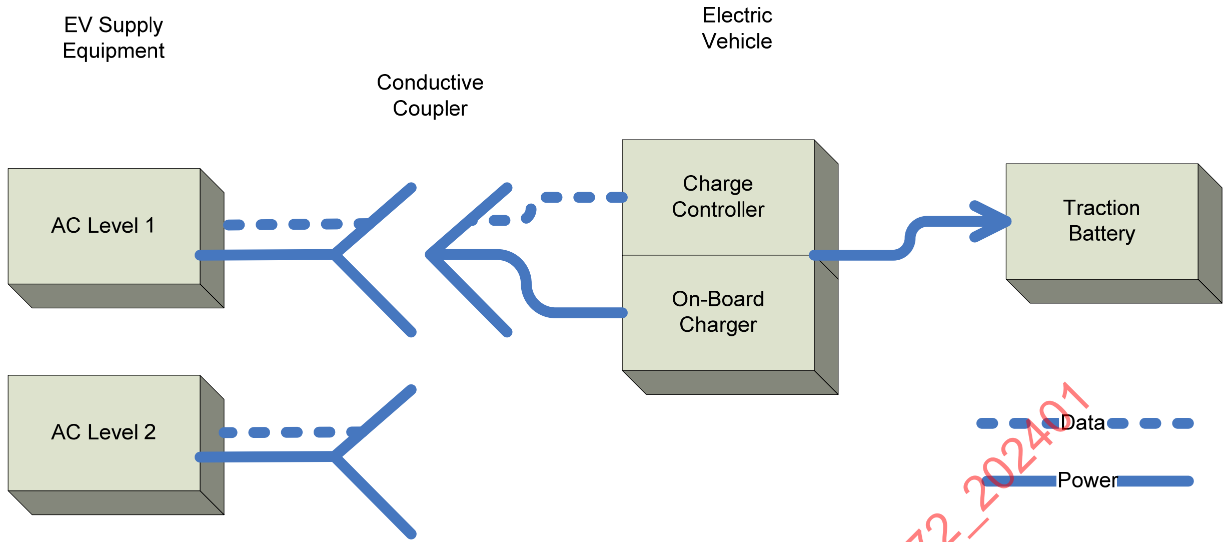

Figure 5 - AC conductive EV/PHEV charging system architecture

The interface consists of five contacts that perform the interface functions as shown in Figure 6 and specified in Table 9.

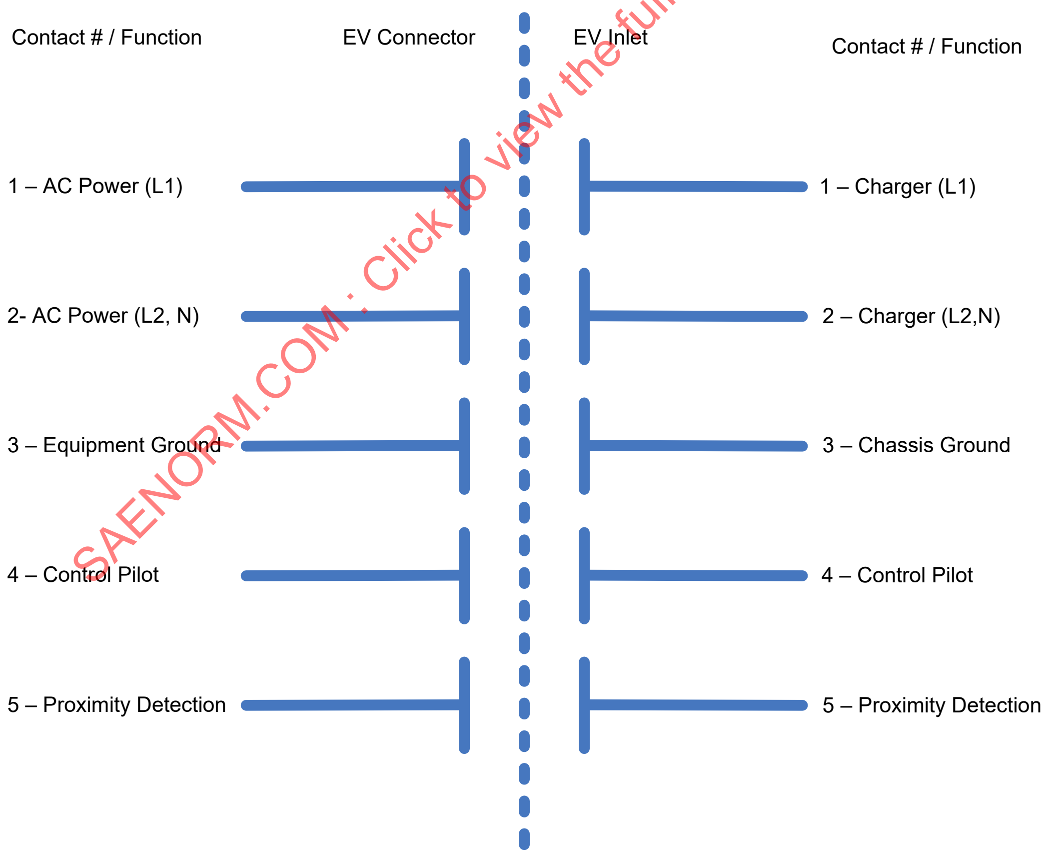

Figure 6 - AC level 1 and AC level 2 conductive coupler contact interface functions

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Table 9 - AC level 1 and AC level 2 conductive coupler contact functions

Contact #	Connector Function	Vehicle Inlet Function	Description
1	L1 AC	Power	Power for AC Level 1 and 2
2	N - AC Level 1, L2 – AC Level 2	Power	Power for AC Level 1 and 2
3	Equipment ground	Chassis ground	Connect EVSE equipment grounding conductor to EV/PHEV chassis ground during charging
4	Control pilot	Control pilot	Primary control conductor (operation described in 5.2.1)
5	Proximity Detection	Proximity Detection	Allows vehicle to detect presence of charge connector

A method of EV/PHEV charging that extends AC power from the most common grounded electrical receptacle to an on-board charger using an appropriate cord set, as shown in Figure 7 at the electrical ratings specified in Table 10. AC level 1 allows connection to existing electrical receptacles in compliance with the NEC Article 625.

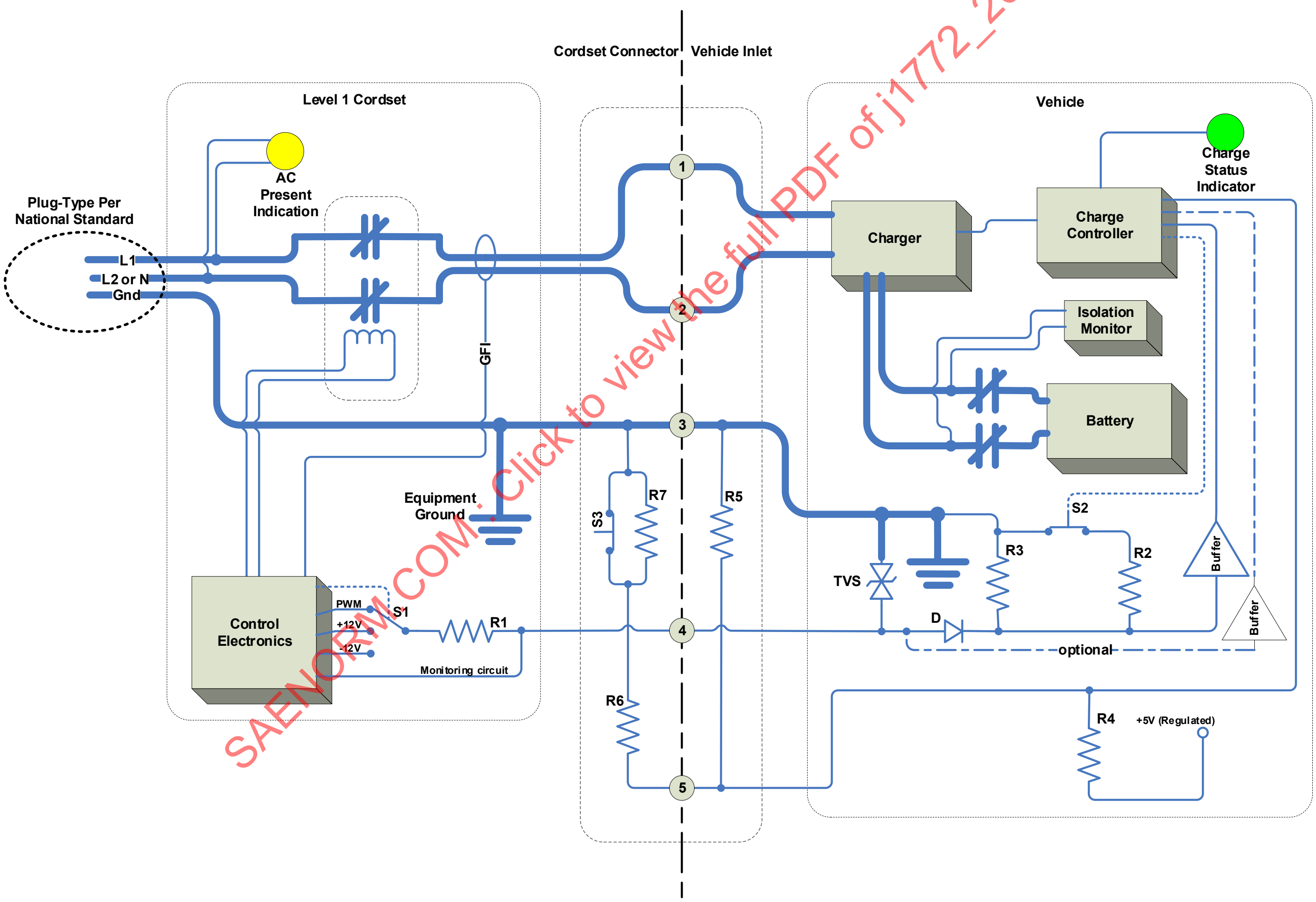

Figure 7 - AC level 1 system configuration
(figure illustrates vehicle charging)

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The primary method of EV/PHEV charging that extends AC power from the electric supply to an on-board charger from a dedicated EVSE, as shown in Figure 8. The electrical ratings are similar to large household appliances and specified in Table 10. AC Level 2 may be utilized at home, workplace, and public charging facilities.

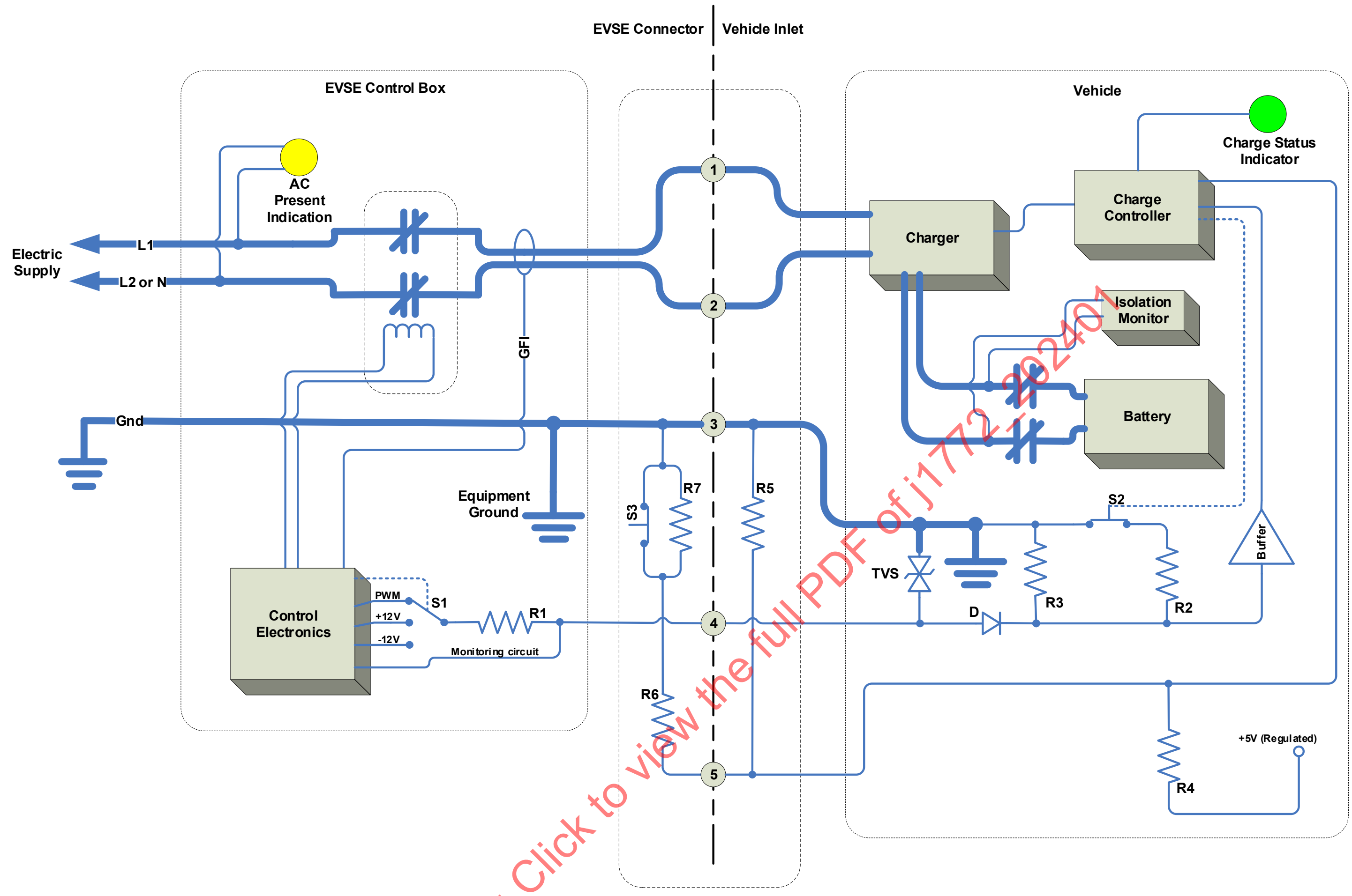

Figure 8 - AC level 2 system configuration
(figure illustrates vehicle charging)

Figure for illustration only. Not intended to constrain EVSE or EV/PHEV design.

5.1 Electrical Ratings

Table 10 - AC charging electrical ratings*

Charge Method	Nominal Supply Voltage (V)	Max Current (Amps-continuous)
AC Level 1	120 VAC, 1-phase	≤ 50 A
AC Level 2	208 to 240 VAC, 1-phase	≤ 80 A

Note:
*Branch circuit rating governed by local regulation.

5.2 Charging Control and Information

5.2.1 Control Pilot

As defined in 4.2.1.

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5.2.2 Proximity Detection

As defined in 4.2.2.

5.2.3 Digital Data Transfer

As defined in 4.3.

Digital communication is optional at any valid control pilot duty cycle for AC Level 1 and 2 charging. When optionally used with AC Level 1 and 2 charging, more functions may be accommodated than by control pilot duty cycle functionality alone.

When optionally used with AC Level 1 and 2 charging, the EV/PHEV may receive charge current limits via the control pilot and digital communications. If these charge current limits do not correlate, the EV/PHEV shall charge at the lower of the two indicated current limits.

Digital data transfer is specified in the following SAE documents:

- SAE J2847/1 - Communication for Smart Charging of Plug-in Electric Vehicles Using Smart Energy Profile 2.0
- SAE J2931/1 - Digital Communications for Plug-in Electric Vehicles
- SAE J2931/4 - Broadband PLC Communication for Plug-in Electric Vehicles
- SAE J2953/1 - Plug-In Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE)
- SAE J2953/2 - Test Procedures for the Plug-In Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE)

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5.3 EVSE and EV/PHEV Charging Sequence, Timing, and Response

As defined in Appendix E.

5.4 EV/PHEV Requirements

As defined in 4.6.

5.4.1 EV/PHEV Cable Ampacity Coordination

Vehicle cabling used for the AC mains and equipment ground should be coordinated with the supply input from the EVSE (known from the control pilot duty cycle). The following are examples of possible methods of coordination that could possibly be achieved:

1. Sizing the cables for maximum EVSE supply input.
2. Provide circuit protection, such as fuses, for the cables.

NOTE: A plug-in vehicle should be able to connect and charge from any EVSE. The maximum rating for 240 VAC energy transfer is Level 2 which is 80 A using a 100 A premises circuit breaker. The design of the vehicle wiring from the charge connector to the charger needs to comprehend the full range of EVSE output.

5.4.2 Coupler Disconnect Current Limit

Under consideration.

5.5 EVSE Requirements

As defined in 0 with addition below.

5.5.1 Radiated Immunity

The test setup for radiated immunity is shown in Figure 9. Additional details are as follows:

a. The test bench shall be covered with a ground plane, located 800 mm above the test site ground plane, or absorber lined shield enclosure (ALSE) floor.

b. The back edge of the test bench ground plane shall be connected to the test site ground plane or ALSE floor or wall, using a series of straps. Refer to SAE J1113-21 for bench grounding requirements.

c. The AC receptacle or Level 2 EVSE (if applicable) shall be mounted on a dielectric support, 200 mm above the front edge of the bench ground plane.

d. Level 1 EVSE (if applicable) shall be positioned at a minimum height of 700 mm above the test site, or ALSE ground plane, and connected to the AC receptacle with a cord having a maximum length of 305 mm.

e. The AC receptacle (or Level 1 EVSE) mains conductors shall be connected to a pair of 50 uH line impedance stabilization networks (LISNs), using conductors having a maximum length of 200 mm. The 50 Ω LISN ports shall be terminated with 50 Ω loads. The ground conductors from the AC receptacle and the incoming mains line shall connect to the test bench at a point near the LISN terminals on the EVSE side of the LISNs. Refer to CISPR 16-1-2 for LISN specifications.

f. The cordset length shall be in accordance with NEC Article 625. Excluding the vertical section exposed to the test field, the remainder of the cordset shall lay on the floor in a non-inductive pattern (i.e., "zig-zag," not coiled).

g. A grounded plate shall be provided on the floor for mounting of the vehicle charge coupler and vehicle electrical/electronic equipment necessary for operation of the EVSE. Representative RF loading of conductive coupler circuits shall be included.

h. The standard tolerance for radiated immunity test setup dimensions shall be 5%, unless otherwise specified.

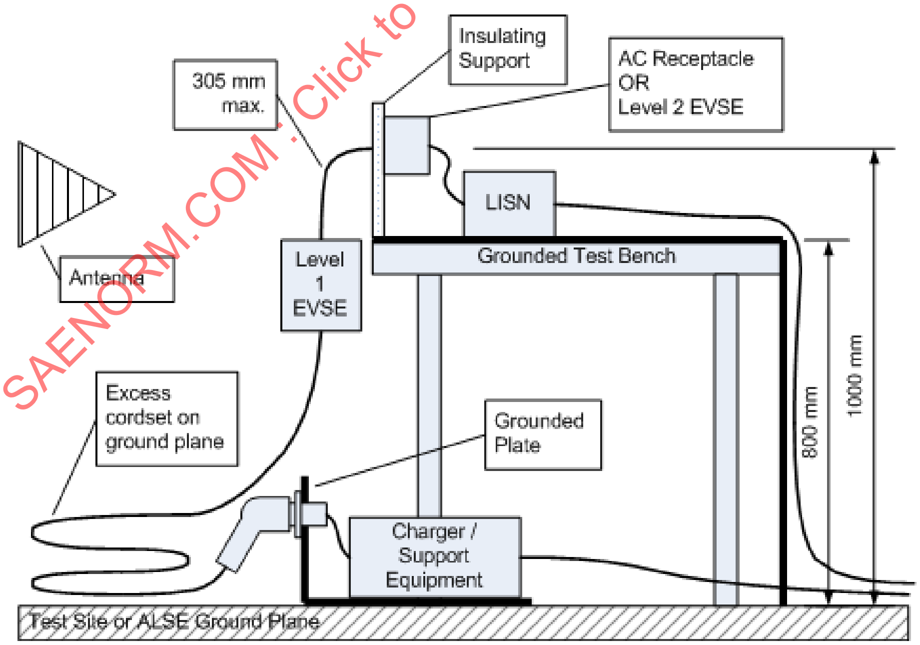

Figure 9 - Radiated immunity test setup

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5.6 Charge Coupler Requirements

As defined in 4.8.

The general contact sizes at the coupler interface shall comply with the dimensions as specified in Table 11.

Table 11 - Contact size electrical ratings

Contact #	Function	Size (mm)	Current Rating (Amps)	Voltage Rating
1	Power	3.6 diameter	Up to 80 A	300 min, up to 600 VAC/VDC
2	Power	3.6 diameter	Up to 80 A	300 min, up to 600 VAC/VDC
3	Equipment/chassis ground	2.8 diameter	Per coupler rating as defined in Ground Path Current Test of UL2251	
4	Control pilot	1.5 diameter	2 A	30 VDC
5	Proximity	1.5 diameter	2 A	30 VDC

5.7 Vehicle Inlet

For the vehicle inlet, according to Section 16 of UL 2251, an isolated DC supply system may use the functional ground wire size necessary for the AC portion of the system identified in UL 2251 Section 15, Table 15.1, providing the EV/PHEV safety strategy is designed using the first fault protection. If the EV/PHEV safety strategy allows for the occurrence of a second fault, then it is required to include the functional ground sized according to the full DC current rating.

A standard configuration shall be capable of AC Level 1 and Level 2 charging. The contact requirements shall be as specified in Table 11.

Vehicle inlet dimensional requirements are defined in APPENDIX A, sheet A1.

Dimensional requirements to implement an optional coupler locking mechanism are found in APPENDIX D, sheet D-1.

5.8 Vehicle Connector

The connector shall be fitted with a cord corresponding to its intended usage and shall meet the requirements specified in the UL 2251, Section 15, Table 15.1 for ground conductors, or Section 16 for isolated systems.

Table 11 defines contact requirements.

Vehicle connector dimensional requirements for non-lockable vehicle connectors are defined in APPENDIX A, sheets A2-A5.

Vehicle connector dimensional requirements for lockable vehicle connectors are defined in APPENDIX B, sheets B1 to B3.

6. DC CHARGING

Two levels of DC charging are defined. DC Level 1 and Level 2. DC charging architecture is shown in Figure 10.

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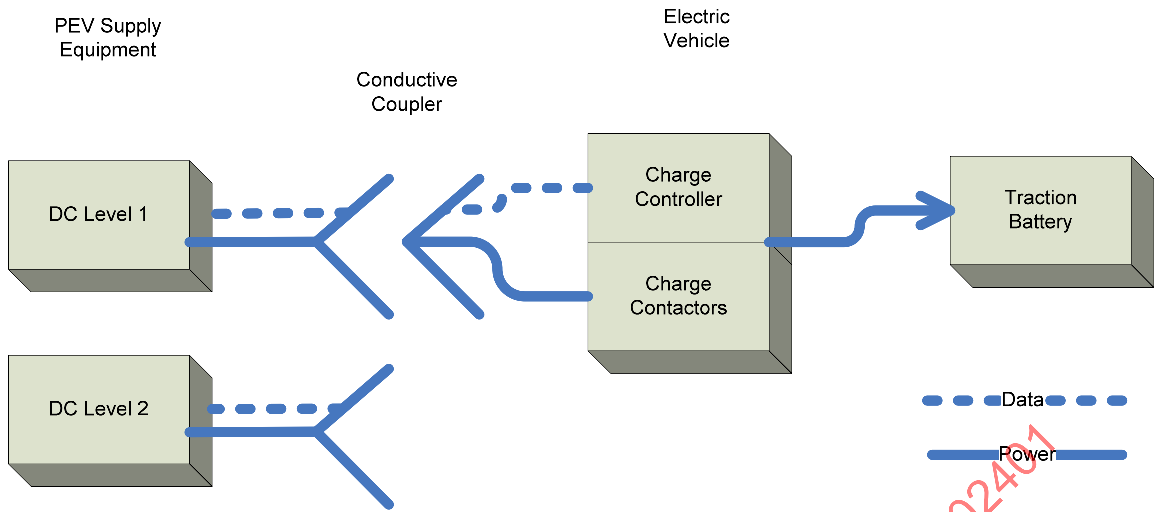

Figure 10 - DC conductive EV/PHEV charging system architecture

The interface consists of seven contacts that perform the interface functions as shown in Figure 11 and specified in Table 12.

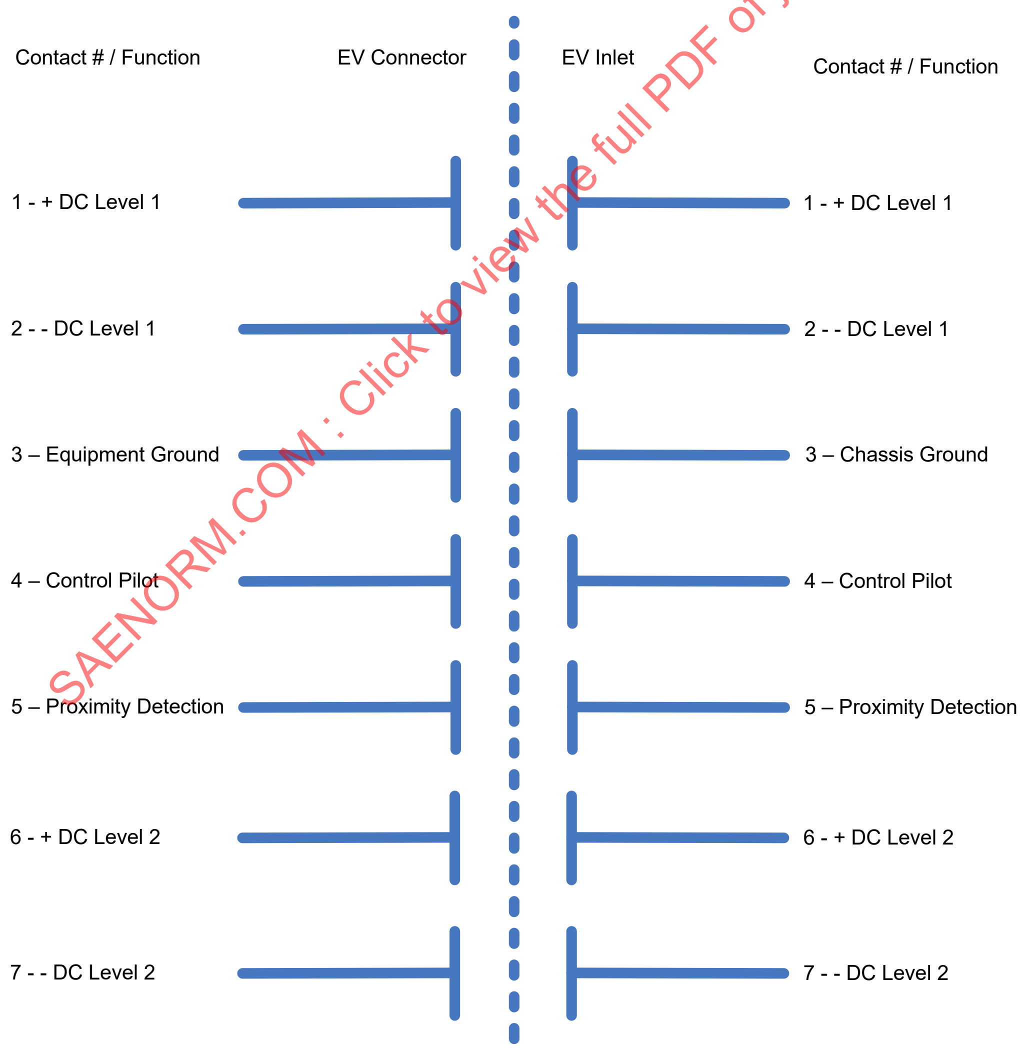

Figure 11 - DC level 1 and DC level 2 conductive coupler contact interface functions

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Table 12 - DC level 1 and DC level 2 conductive coupler contact functions

Contact #	Connector Function	Vehicle Inlet Function	Description
1	+ DC Level 1 Power	Power	+ Power for DC Level 1
2	- DC Level 1 Power	Power	- Power for DC Level 1
3	Equipment ground	Chassis ground	Connect EVSE equipment grounding conductor to EV/PHEV chassis ground during charging
4	Control pilot	Control pilot	Primary control conductor (operation described in Section 5)
5	Proximity Detection	Proximity Detection	Allows vehicle to detect presence of charge connector
6	+ DC Level 2 Power	Power	+ Power for DC Level 2
7	- DC Level 2 Power	Power	- Power for DC Level 2

A method of DC EV/PHEV charging is shown in Figure 12 at the electrical ratings specified in Table 13. This is the configuration for DC Level 1 charging. This configuration allows DC charging with the vehicle inlet and charge coupler defined in Appendix A. For combinations of DC L1 and L2 between the PEV and EVSE, see APPENDIX I, Figures 22 and 23.

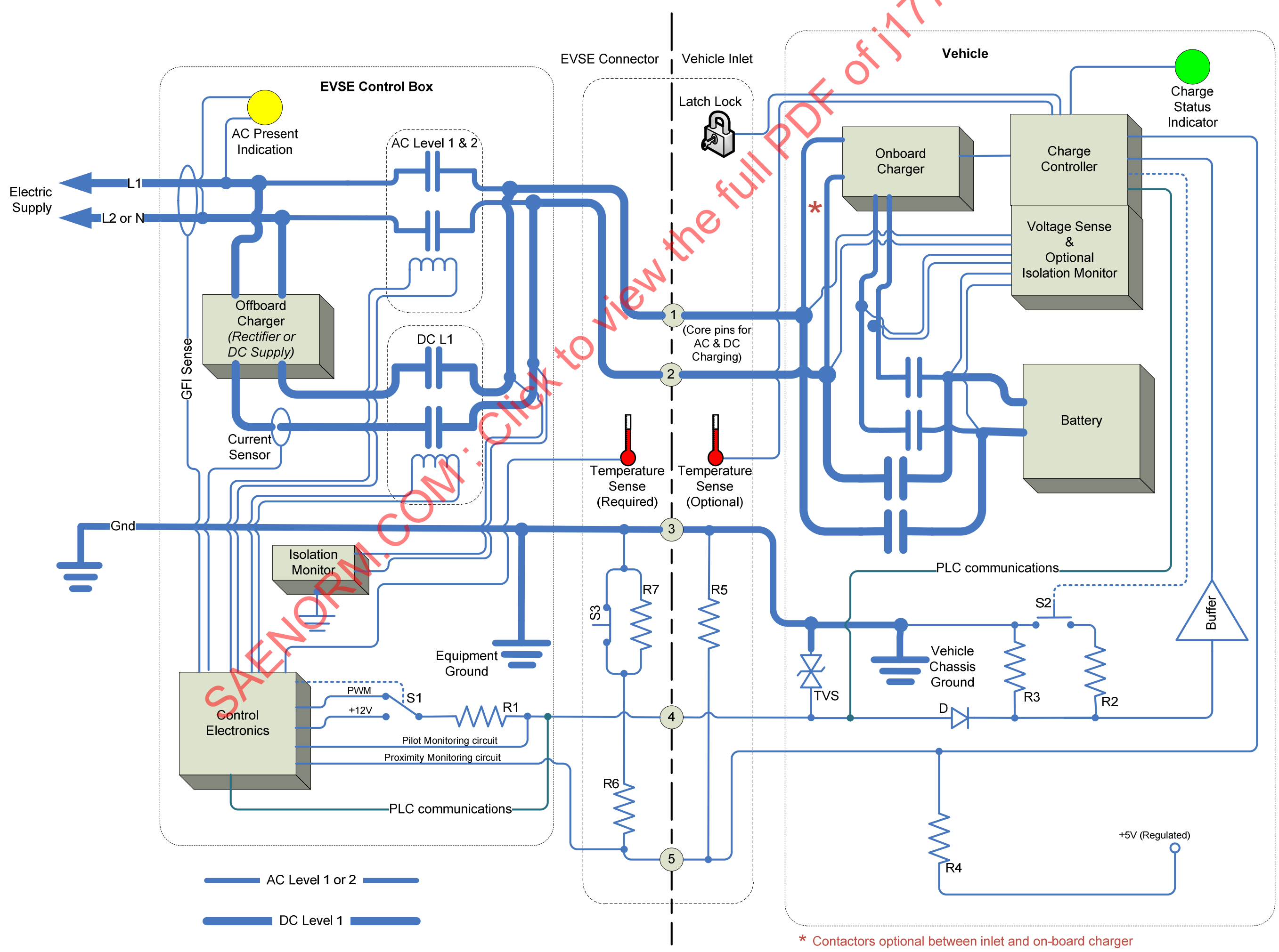

Figure 12 - DC level 1 system configuration
figure illustrates vehicle not charging

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A method of DC EV/PHEV charging is shown in Figure 13 at the electrical ratings specified in Table 13. This is the configuration for DC Level 2 charging. This configuration allows DC charging with the vehicle inlet and charge coupler defined in APPENDIX C. For combinations of DC L1 and L2 between the EV/PHEV and EVSE, see APPENDIX I, Figures 22 and 23.

NOTE: Power contacts for AC Level 1, AC Level 2, and DC Level 1 may not be populated in DC Level 2 charge connector.

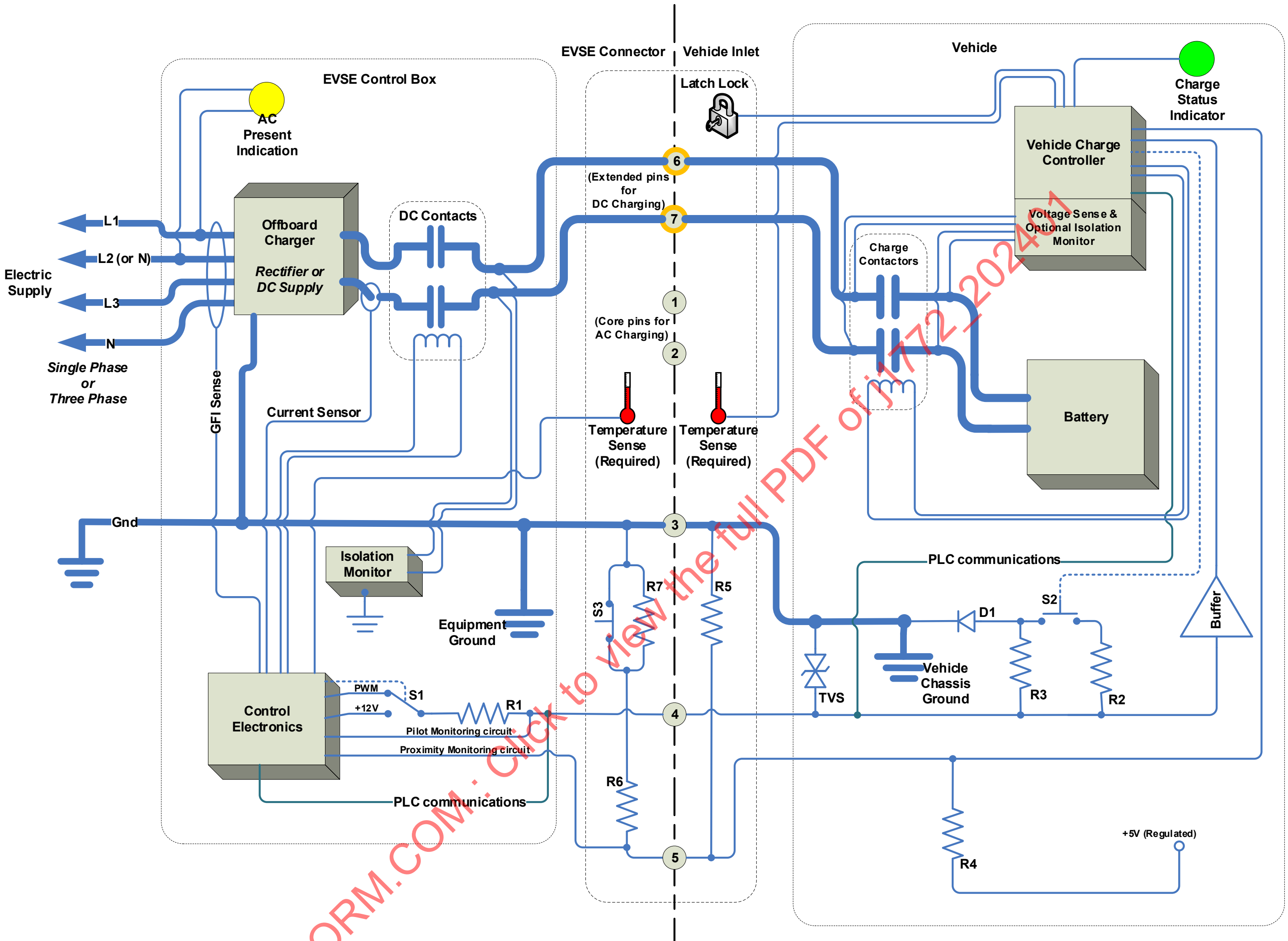

Figure 13 - DC level 2 system configuration
figure illustrates vehicle not charging

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6.1 Electrical Ratings

Table 13 - DC charging electrical ratings

Charge Method	EVSE DC Output Voltage (VDC)	Max Current (Amps-continuous)
DC Level 1	50-1000*	80
DC Level 2	50-1000*	500**

Notes:
*Operational range; not a requirement.
**This is a nominal current limit, and value is subject to change depending on specified design requirements of SAE J1772 and IEC 62196-3-1.

6.2 Charging Control and Information

6.2.1 Control Pilot

As defined in 4.2.1 with addition below.

6.2.1.1 EVSE Shutdown - Control Pilot

When an unintended transition from CP state C/D to state B/A, any other, or an unknown state occurs, the EVSE shall trigger an emergency shutdown in 10 ms or less.

6.2.1.2 EV/PHEV Shutdown - Control Pilot

When an unintended transition from CP state C/D to state B/A, any other, or an unknown state occurs, the EV shall trigger an emergency shutdown in 50 ms or less.

6.2.2 Proximity Detection

As defined in 4.2.2 with addition below.

6.2.2.1 EVSE Shutdown - Proximity Detection

The EVSE shall monitor the proximity circuit as shown in Figure 13.

6.2.2.2 Valid proximity circuit voltages are defined in Table 8. EVSE input impedance shall have high input impedance (>=10 MΩ) to prevent loading of vehicle proximity voltage monitoring circuit.

6.2.2.3 DC charging shall only be allowed when the EVSE detects a proximity circuit voltage that indicates that the latch is released according to Table 8.

6.2.2.4 The EVSE shall not initiate a charge cycle unless a proximity circuit voltage (S3 closed), according to Table 8, is detected.

6.2.2.5 If the voltage measured at the proximity detection contact is <0.8 V DC or >3.6 V DC, the EVSE shall trigger an emergency shutdown in 10 ms or less. Invalid proximity circuit voltage means any other voltage level than a proximity circuit voltage with S3 closed according to Table 8. See APPENDIX F.

6.2.3 Digital Data Transfer

A control pilot duty cycle of 5% indicates that digital communication is required and must be established between the EVSE and vehicle before charging. This is required for DC charging.

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Digital data transfer is specified in the following documents:

- SAE J2847/2 - Communications Between Plug-in Vehicles and Off-Board DC Chargers
- SAE J2931/1 - Digital Communications for Plug-in Electric Vehicles
- SAE J2931/4 - Broadband PLC Communication for Plug-in Electric Vehicles
- SAE J2953/1 - Plug-In Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE)
- SAE J2953/2 - Test Procedures for the Plug-In Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE)
- ISO 15118-1 Road vehicles - Vehicle-to-Grid Communication Interface - Part 1: General information and use-case definition
- ISO 15118-2 Road vehicles - Vehicle-to-Grid Communication Interface - Part 2: Network and application protocol requirements
- ISO 15118-3 Road vehicles - Vehicle-to-Grid Communication Interface - Part 3: Physical and data link layer requirements

6.3 EVSE and EV/PHEV Charging Sequence, Timing, and Response

As defined in APPENDIX F.

6.3.1 EVSE and EV/PHEV Message Table

As defined in APPENDIX G.

6.4 EV/PHEV Requirements

As defined in 4.6 with the addition below.

6.4.1 Lock Function Diagnostics

The EV/PHEV shall provide lock function diagnostics to monitor lock function operation. Diagnostics are to be defined by the EV/PHEV manufacturer. The lock function diagnostic shall be complete prior to the EV/PHEV closing S2. See Table F1 for more information on how to communicate locking problems to the EVSE.

6.4.2 Manual Lock Release

The EV/PHEV may provide means to manually release the locking mechanism. The manual release shall prevent exposure to HV or arcing.

6.4.3 EV/PHEV Isolation Monitoring

If the EV/PHEV is equipped with its own isolation monitoring system, the vehicle isolation monitoring system should not interfere with the EVSE isolation monitoring system. The vehicle should consider various EVSE isolation monitoring technologies (AC signal injection, bus shifting, etc.) to satisfy this requirement. The sequences defined in APPENDIX F specify when the EV/PHEV shall disable its isolation monitoring system.

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6.4.4 EV/PHEV Maximum Y Capacitance

The EV/PHEV total permissible parallel system Y capacitance is a function of the maximum voltage (Vmax) applied to the Y capacitors. For purposes of this standard, that voltage shall be defined as the maximum battery voltage. The total permissible parallel system Y capacitance (Ct,max) (in microFarads) can then be calculated by the rules and the equation:

For a vehicle of maximum battery working voltage 500 V or below, shall have a maximum Y-capacitance of 4 uF.

For a vehicle of maximum battery working voltage above 500 V, shall follow the formula for maximum Y-capacitance.

$$C_y = \frac{1{,}6mV}{U}\ F \qquad \text{(Eq. 1)}$$

This implies equal Y capacitance of 1/2 Cv,max between each DC rail and ground for an EV/PHEV. The maximum EV/PHEV vehicle Y cap value (Cv,max) includes any Y caps on AC devices operating during DC charging.

6.4.5 Loss of Communications

When DC charging control communications with the EVSE is lost, the EV/PHEV shall trigger an error shutdown. See APPENDIX F. This will allow the EVSE to discharge the HV bus.

6.4.6 Inlet Contact Area Temperature Monitor

The EV/PHEV shall monitor the contact temperature at each DC inlet. The contact temperature of either contact shall not exceed 90 °C according to the requirements specified as follows:

- If the temperature exceeds 90 °C for 8 consecutive seconds, the EV/PHEV shall transfer to error shutdown sequence within 1 second.

- If the temperature exceeds 95 °C for 1 second, the EV/PHEV shall transfer to error shutdown sequence within 1 second.

Manufacturer should consider the location of the temperature measurement relative to the point of contact (POC), the sensor tolerance, the thermal time constant of the system, and overall system response in making their calculations. Information note: For an ambient temperature above 40 °C, the vehicle manufacturer should determine system response.

6.4.7 Charge Contactors During Charging

The EV/PHEV shall not close the charge contactors during charging.

If the charge contactors of the EV/PHEV open during charging, the EV/PHEV shall not close the charge contactors without either:

a. performing a normal shutdown and reinitiating a new charging session by the restart sequence, as specified in 6.4.8, and then continue to t1 in the normal start up sequence F.1.8; or

b. performing a renegotiation as defined in F.1.13.

6.4.8 Sleep Mode and Charging Session Restart Method for the EV/PHEV

Sleep mode is an operating mode of the EVSE or EV/PHEV designed for reduced energy consumption when a charging session is not occurring. In this case, the EV/PHEV or EVSE are permitted to not communicate via digital communication.

The EV/PHEV can request a pause of the charging session, after which both EV/PHEV and EVSE can enter sleep mode.

To restart digital communication, the EV/PHEV can perform a restart method as specified in 6.4.8.1.

The restart methods can also be used to restart digital communication after an error condition, for example, loss of digital communication.

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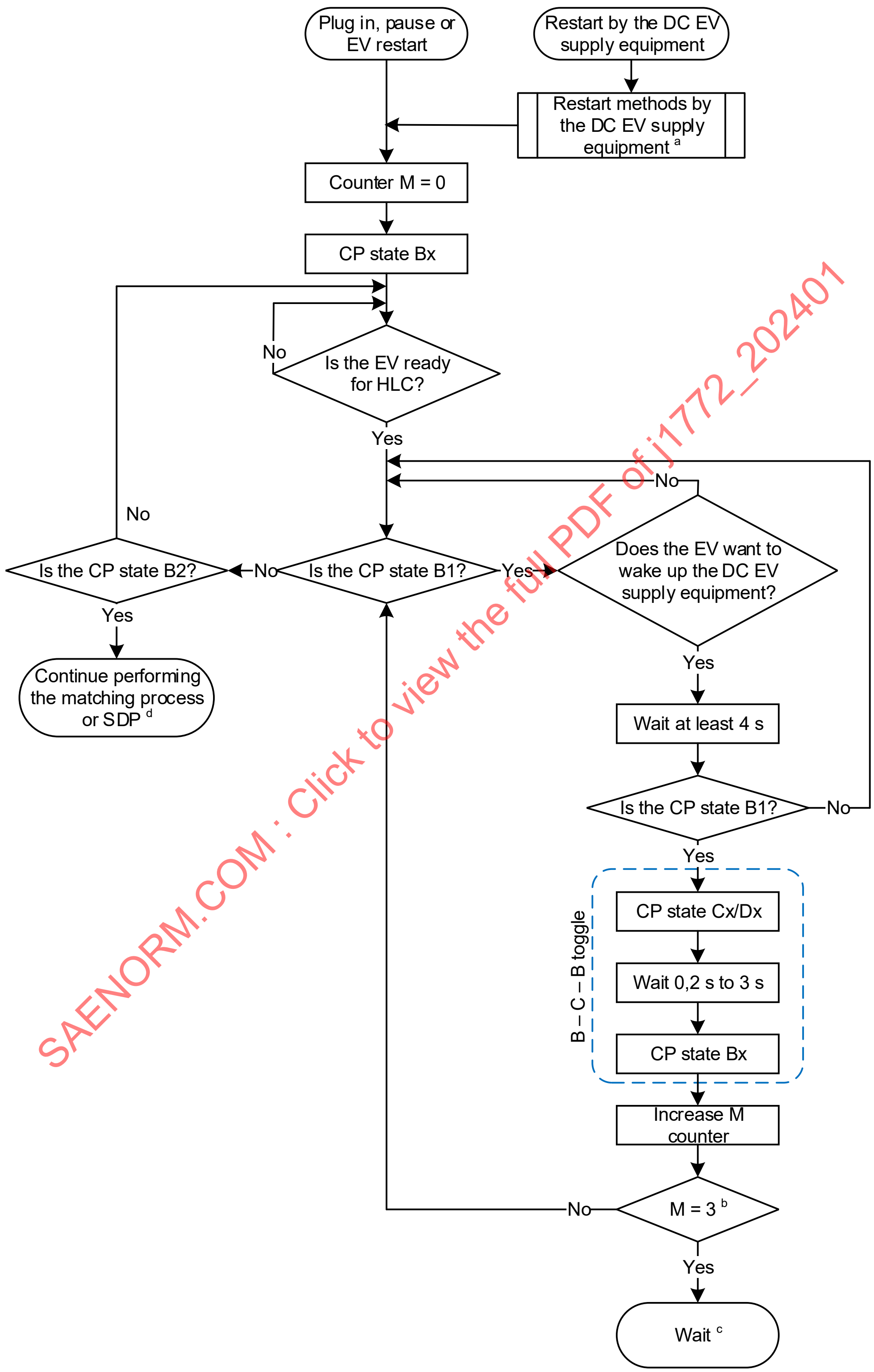
6.4.8.1 Restart by the EV/PHEV

The EV/PHEV shall follow the restart sequence as shown in Figure 14.



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Notes:

[a] The EVSE may perform different restart methods to wake up the EV/PHEV, according to Figure 15.

[b] The EV/PHEV manufacturer can specify a different number of restart cycles.

[c] The EV/PHEV manufacturer can perform additional restarts, enter sleep mode or the EVSE can decide to perform a restart.

[d] Supply Equipment Charge Controller (SECC) Discovery Protocol.

Figure 14 - Restart methods sequence for the EV/PHEV

The EV/PHEV may restart the digital communication with the EVSE by using a B1 – C1 – B1 or B1 – D1 – B1 toggle according to Table A.6 Sequence 11 in IEC 61851-1:2017. See the example in Figure 15.

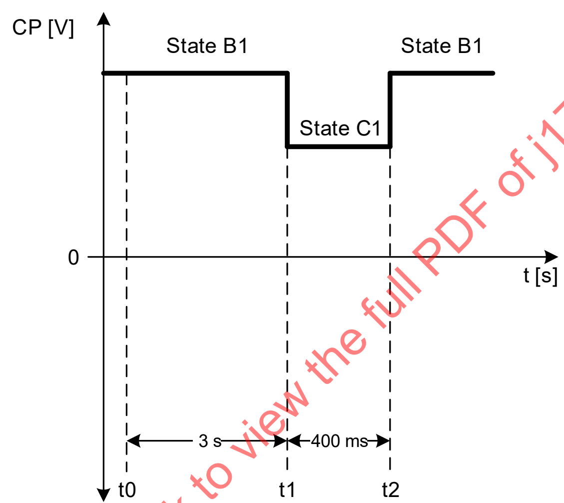

Figure 15 - Example of a B – C – B toggle

After a successful restart, the EVSE shall enable the CP oscillator with a duty cycle of 5%.

If the EVSE generated a pause of the charging session (see 6.5.32), the EV/PHEV shall wait until the EVSE performs a restart method to continue the charging session. The EV/PHEV is allowed to terminate the digital communication session while the EVSE is in sleep mode.

NOTE: If the EV/PHEV detects a CP state change from state E to state Bx, where CP state E had a duration more than the 4 seconds defined for restart method 2, the EVSE might be restarting, for example, due to power loss on the energy supply network.

Refer to 7.6 of ISO 15118-3:2015 for additional requirements related to sleep mode.

6.4.9 EV/PHEV Pre-Charge

During pre-charge, the EV/PHEV shall limit its current draw between DC+ and DC- to 10 mA.

According to ISO 17409, the voltage difference between both sides of the charge contactors must be <20 V DC before the EV/PHEV closes the charge contactors.

The EV/PHEV shall not close the charge contactors if the polarity of the DC output is reversed.

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The EV/PHEV shall measure the DC output voltage at the vehicle inlet and may use the measured voltage for adjusting the subsequent target voltage of the EV/PHEV during pre-charge. It is recommended for the EV/PHEV not to modify the target voltage of the EV/PHEV in 3 seconds or less after the first pre-charge request message.

The EV/PHEV shall not solely use the measured voltage at the DC output communicated by the EVSE to check if the absolute difference between the DC output voltage and the voltage of the vehicle/traction battery is ≤20 V.

6.4.10 Loss of Electrical Continuity of the Protective Conductor

The EV/PHEV shall monitor the electrical continuity of the protective conductor from point A (see Figure 4) to the EV/PHEV by doing the following:

a. the EV/PHEV shall check the PP circuit before each initiating a charging session for correct values specified by the EV/PHEV manufacturer. This includes the continuity of the protective conductor from point A up to the EV/PHEV; and

b. the EV/PHEV shall check the PP circuit during energy transfer and, in case of loss of electrical continuity of the protective conductor, the EV/PHEV shall trigger an emergency shutdown in 150 ms or less.

6.5 EVSE Requirements

6.5.1 EVSE Electromagnetic Emissions

As defined in 4.7.1.

6.5.2 Installation Requirements

As defined in 4.7.2.

6.5.3 General Product Standards

The following replaces the requirements in 4.7.3.

The EVSE shall meet and be listed to the general product requirements for isolated circuits specified in UL 2202.

6.5.4 Personnel Protection System

The EVSE shall incorporate a listed system of personnel protection for isolated circuits, as specified in UL 2231, with the exception that “nominal system voltage” is replaced with “rated system voltage.”

Rail isolation is the resistance between each DC rail and ground, including any measuring device. Total isolation is the parallel combination of both rail isolation values.

NOTE 1: Vehicle isolation requirements of 100 Ω/V (DC) or 500 Ω/V (AC or AC/DC) are stated in multiple documents, including UNECE R100, ISO 6469-3, and SAE J2344. EVSE DC output isolation requirements are stated in IEC 61851-23 and UL2231. These documents state that the EVSE shall terminate charge when the isolation of the output falls below 100 Ω/V. The EVSE shall implement one of the following time management strategies of isolation self-test: directly prior to supply cycle with vehicle connector plugged into the vehicle inlet or at regular intervals with a maximum period of 1 hour. Independently, the vehicle and EVSE each meet their individual requirements for isolation. When connected as a system, the resulting isolation cannot be greater than the lowest isolation of either the vehicle or EVSE. Because of EVSE tolerance and component aging, some vehicles with isolation as low as the allowable 100 Ω/V may not be able to charge.

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6.5.4.1 General

Protection against electric shock including potential hazards at the output of the EVSE under conditions of intended use and reasonably foreseeable misuse shall be provided by at least one of the following measures:

- Basic protection and fault protection (see 6.5.4.2 and 6.5.4.3).

- Enhanced protective provisions (see 6.5.4.4).

Protection for normal operating conditions is provided by basic protection. Protection for single fault conditions is provided by fault protection.

Specific protective measures for the secondary circuit supplying the DC output are provided in 6.5.4.5.

6.5.4.1.1 Intended Use and Reasonably Foreseeable Misuse

Considering intended use and reasonably foreseeable misuse:

a. hazardous-live-parts shall not be accessible and accessible-conductive-parts shall not be hazardous live, and

b. hazardous voltage shall not be disconnected with the vehicle connector.

6.5.4.1.2 Limitation of Touch Current or Touch Voltage

Under normal operating conditions and single fault conditions, an ordinary person shall be protected against a harmful electric shock by either:

a. limiting the touch current and the touch energy, or

b. limiting the touch voltage.

A body impedance corresponding to water wet conditions in IEC 60479-1 shall be considered under the normal operation conditions and single fault conditions.

6.5.4.1.3 Threshold of Perception and Startle Reaction

Protective measures shall be provided to prevent startle reactions during intended use and reasonably foreseeable misuse, before, during, and after an energy transfer session, under normal conditions and during single fault conditions. During the normal operating conditions, perception may be possible.

NOTE 1: Curve a (boundary between AC-1/AC-2, DC-1/DC-2) of Table 11 and Table 13 of IEC 60479-1 corresponds to the threshold of startle reaction in this document.

NOTE 2: The intended use includes, but is not limited to, handling of energy transfer accessories, such as charging cable assembly, vehicle connector and vehicle inlets, initiating a charging session, ending a charging session, an ordinary person or animal entering or exiting the vehicle, opening and retrieving an item from a vehicle storage area, touching the vehicle chassis, and touching exposed metal parts of the DC EVSE.

For the current path, finger at the vehicle connector to feet and hand at the vehicle chassis to feet, shall be used.

Protection by means of limitation of touch current shall be provided, such that a steady-state touch current flowing between simultaneously accessible conductive parts shall be less than:

- 0.5 mA AC/2 mA DC under normal operation.

- 3.5 mA AC/10 mA DC under single fault condition.

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Additional protection shall be provided, such that in case of a failure of the provision for basic protection and a simultaneous failure of the provision for fault protection of the DC EVSE output, the steady-state touch current is less than or equal to Curve b, the upper boundary of the DC-2 zone, as specified in Figure 22 and Table 13 of IEC 60479-1.

The DC EVSE shall limit the discharge energy, such that discharge energy shall be less than:

- 5 µJ under normal operation.
- 0.5 mJ under single fault condition.

Note that these values are based on IEC 61140, paragraph 5.2.7 b).

Additional protection shall be provided, such that in case of a failure of the provision for basic protection and a simultaneous failure of the provision for fault protection of the EVSE output, the touch current is less than or equal to the c1 curve as specified in Figure 23 of IEC 60479-2 and in Figure 22 of IEC 60479-1, respectively.

The following parameters shall be used:

- A human body impedance of 575 Ω.
- The maximum Y-capacitances of the EV/PHEV according to ISO 17409.
- A worst-case asymmetric leakage resistance of the EV/PHEV where charging energy transfer is still possible.

6.5.4.2 Basic Protection

6.5.4.2.1 General

Basic protection in the EVSE is employed to prevent persons from touching hazardous live parts. Basic protection shall be provided by one or more of the measures given in 6.5.4.2.2, 6.5.4.2.3, 6.5.4.2.4, and 6.5.4.2.5.

6.5.4.2.2 Protection by Basic Insulation

Protection by means of basic insulation of live parts in DC the EVSE shall be according to 4.4.3.2 of IEC 62477-1.

Basic insulation shall be provided by solid insulation or clearance and/or creepage distance.

Any accessible conductive part is considered to be a hazardous live part if not separated from the live parts by required insulation.

Basic insulation shall be designed and tested to withstand the impulse voltages and temporary over voltage conditions for the circuits to which they are connected.

6.5.4.2.3 Protection by Enclosures or Barriers

Protection by means of enclosures or barriers in DC EVSE shall be according to 6.5.4.5.4 and 4.5.2.2.2.

Enclosures shall meet the packaging requirements of UL 2202.

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6.5.4.2.4 Protection by Limitation of Voltage

Basic protection by the provision of limitation of voltage is fulfilled where the following conditions are met:

a. steady-state touch voltage under normal operation is less than the values in Table 14;

b. steady-state touch voltage under single fault condition is less than the values in Table 15;

c. a nonrecurring DC touch voltage under normal operation is less than the limit of in Table 14;

d. a nonrecurring DC touch voltage for fingertip to feet under single fault condition is less than the limit of in Figure 16;

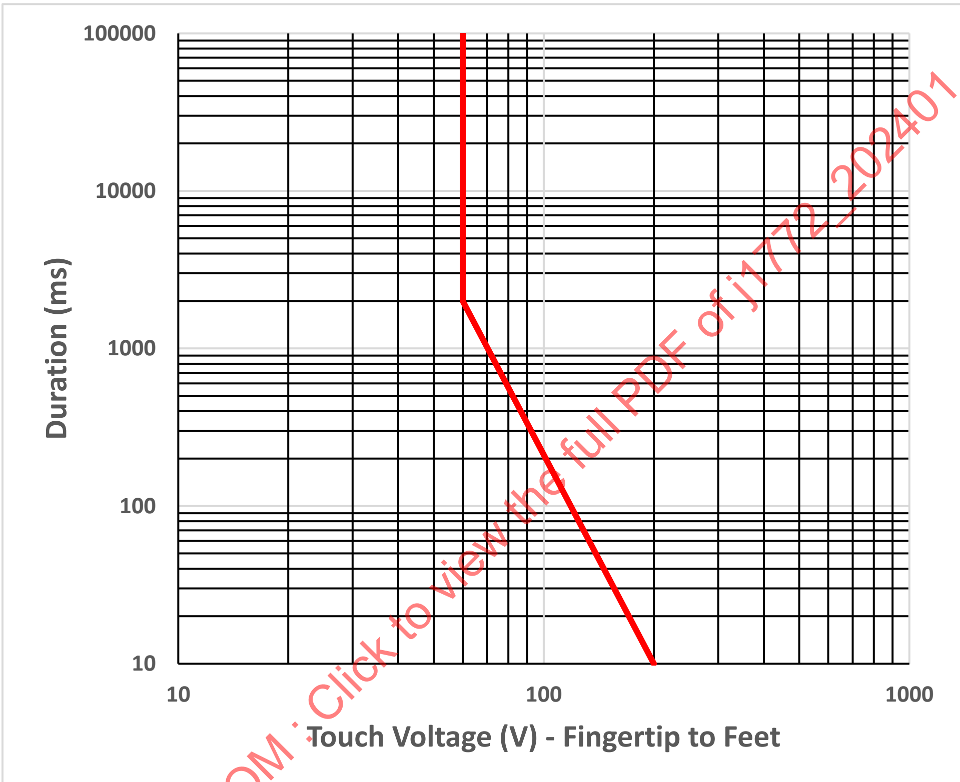

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Figure 16 - Touch time for DC voltage - single fault condition, water wet, fingertip to feet

e. the voltage is supplied by one of the following sources:

1. a safety isolating transformer for the auxiliary circuit including control pilot;

NOTE: Safety isolating transformers are those that comply with IEC 61558-2-6.

2. a source of voltage providing a degree of safety equivalent to that of a safety isolating transformer;

3. electrochemical (for example, a battery system).

Table 14 - Touch voltage, normal operation

Body Contact Location	AC	DC
Any part of body	Basic Protection	
Hand		
Fingertip	12 Vrms	30 V

Note:
Values based on current path from body contact area to feet for a standing position.

Table 15 - Touch voltage, single fault

Body Contact Location	AC	DC
Any part of body	Fault Protection	
Hand		
Fingertip	30 Vrms	60 V

Note 1: Values based on current path from body contact area to feet for a standing position.
Note 2: If these values cannot be met under single fault conditions, protective separation is needed.

6.5.4.2.5 Protection by Limitation of Steady-State Touch Current

Limitation of steady-state touch current is a provision whereby touch current is limited to nonhazardous values. The limits are provided in 6.5.4.1.3.

The protective impedance limiting the touch current shall comply with 4.4.5.4 of IEC 62477-1.

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6.5.4.3 Fault Protection

6.5.4.3.1 General

Fault protection provides protection against bodily harm due to contact with hazardous electrical energy during and after failure of the basic protection.

Fault protection shall be provided by one or more of the following measures:

a. protective equipotential bonding in 6.5.4.3.2 in combination with the protective conductor,

b. automatic disconnection of supply in 6.5.4.3.4,

c. supplementary insulation in 6.5.4.3.5,

d. electrically protective screening in 6.5.4.3.6.

Fault protection shall be independent and additional to those for basic protection.

6.5.4.3.2 Protective Equipotential Bonding

Protective-equipotential-bonding is a provision whereby items are bonded together to avoid hazardous touch voltages.

Protective-equipotential-bonding in DC EVSE shall be according to 4.4.4.2 of IEC 62477-1.

6.5.4.3.3 Continuity Between Enclosure and External Protective Circuit

Exposed conductive parts of the DC EVSE shall be effectively connected to the terminal for the external protective conductor, and the resistance from the conductive part to the terminal of the external protective conductor shall be ≤ 0.1 Ω.

6.5.4.3.4 Automatic Supply Disconnection

Automatic disconnection of supply in DC EVSE shall be according to 4.4.4.4 of IEC 62477-1, except as follows:

The protective device may be provided in any suitable upstream part of the installation or DC EVSE. The EVSE manufacturer shall give appropriate information for the installation of external protection. The information may be provided in a circuit diagram.

6.5.4.3.5 Supplementary Insulation

Supplementary insulation in DC EVSE shall be according to 4.4.4.5 of IEC 62477-1.

6.5.4.3.6 Electrically Protective Screening

Electrically protective screening in DC EVSE shall be according to 4.4.4.7 of IEC 62477-1. Electrically protective screening shall consist of a conductive screen interposed between hazardous-live-parts of the DC EVSE and the part being protected, whereby the screen is separated from live parts by at least basic insulation.

The protective screen shall:

a. be connected to the protective-equipotential-bonding system of the DC EVSE and that interconnection shall comply with the requirements of 4.4.4.2 of IEC 62477-1, and,

b. comply with the requirements for elements of the protective-equipotential-bonding system according to 5.3.3.3, 5.3.3.4, and 5.3.3.5 of IEC 61140.

6.5.4.4 Enhanced Protection Provisions

6.5.4.4.1 General

An enhanced protective provision provides both basic protection and fault protection in according to one or more of the provisions specified in 6.5.4.4.2 and 6.5.4.4.3.

6.5.4.4.2 Reinforced Insulation

Reinforced insulation in DC EVSE shall be according to 4.4.5.2 of IEC 62477-1.

UL 2202 requirements for use of double and or reinforced insulation shall be followed.

6.5.4.4.3 Protective Separation of Circuits

Protective separation between circuits in DC the EVSE shall be according to 4.4.5.3 of IEC 62477-1.

For the DC EVSE output, the steady-state touch current shall be less than or equal to curve b, the upper boundary of the DC-2 zone, as specified in Figure 22 and Table 13 of IEC 60479-1. Additionally, the touch current shall be less than or equal to the c1 curve as specified in Figure 23 of IEC 60479-2 and in Figure 22 of IEC 60479-1, respectively. See 6.5.4.1.3.

6.5.4.5 Requirements of the Isolated DC EVSE

6.5.4.5.1 General

The DC EVSE output shall be designed according to the provisions against electric shock, for basic protection, fault protection and additional protection as specified in Table 16.

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Table 16 - Provision for protection against electric shock at EVSE output

Basic Protection in Absence of a Fault	Provision for Protection in Case of a Fault	Provisions for Additional Protection
• Basic insulation (solid dielectric) (see Note 1) • Basic insulation (air dielectric) • Barriers or enclosures.	For Class I (see Note 2) portions of system: • Protective separation between AC input and DC output (see Notes 3 and 4) (see 6.5.4.5.5). • Protective equipotential bonding to accessible conductive parts (refer to IEC 61140; see 5.3.3.2), for example, for metal housing (see Note 3) (see 6.5.4.5.1), in combination with: Mechanical robustness of the equipotential bonding by both: Minimum cross section of the protective conductor, and using a vehicle coupler according to SAE J1772. • Electrically protective screening (shielding) between hazardous-live-parts and accessible surfaces of parts of insulating material (see 6.5.4.5.5). For Class II (see Note 2) portions of system: • Double or reinforced insulation (see 6.5.4.5.5). Accessible SELV/PELV circuits: • Protective separation between DC output and the SELV/PELV circuit, or basic insulation and all of the conditions given in (see Note 6) (see 6.5.4.5.5).	• Protective separation between AC input and DC output (see Notes 3 and 4) (see 6.5.4.5.5). • Continuous continuity checking of the protective conductor and de energization upon loss of continuity (see Notes 3 and 5) (see F.1.4.1). • Perform an error shutdown when an asymmetric or symmetric insulation fault to protective conductor occurs, measured by the isolation monitoring (see Note 3) (see 6.5.4.5.1). • Multiple DC outputs shall be separated from each other by basic insulation (see Notes 3 and 7) (see 6.5.4.5.1). • Limitation of steady-state touch current (B) and impulse current (C1) (see Note 3) (see 6.5.4.1.3). • Limitation of Y-capacitance to <500 nF per rail (see Notes 3 and 8) (see 6.5.4.5.1).

Note 1: For each portion of the EVSE, one of these provisions for basic protection shall be implemented. Refer also to 5.2 of IEC 61140.
Note 2: Considering 7.3 and 7.4 of IEC 61140.
*Note 3: The EVSE shall provide this provision in order to support the protective provisions of an EV/*PHEV *that is designed entirely as Class I equipment or that contains portions that are designed as Class I equipment. This applies even if the EVSE itself is designed entirely as Class II equipment.*
Note 4: This single provision serves simultaneously as:
– Fault protection for class I equipment, or class I portions of the system, in case of a failure of the basic protection between live parts and accessible conductive parts,
– Additional protection for class II equipment, or class II portions of the system, in case of a failure of the provision for basic protection and a simultaneous failure of the provision for fault protection.
Note 5: This provision serves simultaneously:
– To prevent hazards caused by "blinding" of the isolation monitoring*/leakage current monitoring device for faults occurring "behind" a broken PE.*
– To prevent hazards caused by a loss of equipotential bonding for class I portions of the system.
Note 6: Conditions:
– Tthe PELV circuit is connected to the protective conductor;
– No hazardous voltage or touch current occurs (see 6.5.4.1.2) in the PELV circuit due to an insulation fault between the PELV circuit and the DC circuit;
– The isolation monitoring *or earth leakage current monitoring device detects this insulation fault between the PELV circuit and the DC circuit and triggers an error or emergency shutdown.*
*Note 7: In order to consider only one EV/*PHEV *for calculation of the Y-capacitance (Cy) and in order to prevent interference caused by multiple* isolation monitors*.*
*Note 8: The EVSE shall provide this provision in order to support the protective provisions of an EV/*PHEV *that uses limitation of touch energy as provision for fault protection in accordance with ISO 6469-3 and ISO 17409.*

In case the DC EVSE can supply more than one vehicle simultaneously, independent protection means (protection against electrical shock, overload, and short-circuit protection) for each vehicle connector shall be implemented.

If the DC ESVE has multiple vehicle connectors, all the requirements in this document on the DC EVSE output shall apply at each vehicle connector individually.

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If the DC EVSE has multiple vehicle connectors, each output shall be isolated from each other by at least basic insulation.

NOTE 1: This means each DC output cannot share a DC+ and/or DC- with any other DC output.

NOTE 2: The protective conductor of each vehicle connector is shared by bonding to the protective conductor of the EVSE supply. See 6.5.4.5.2.

6.5.4.5.2 Equipotential Bonding of DC EVSE Output

The DC EVSE shall provide a protective conductor for the DC output. This protective conductor shall provide protective equipotential bonding of exposed conductive parts of the DC EVSE and the EV. This protective conductor shall also be used for earth leakage monitoring, insulation resistance check, or isolation monitoring (see 6.5.4), respectively.

The DC EVSE shall provide this protective conductor to the EV/PHEV through the appropriate pin contact of the vehicle connector according to SAE J1772.

The DC EVSE AC input protective conductor terminal, if any, shall be bonded to the DC output protective conductor. If the supply network provides a protective conductor to the DC EVSE, this protective conductor shall be bonded to the protective conductor of the DC output.

If the supply circuit network does not provide a protective conductor to the DC EVSE or the protective conductor provided by the supply circuit is not earthed, the user manual shall state that the DC EVSE is only allowed to be operated by skilled personnel or instructed personnel.

6.5.4.5.3 DC Output Isolation

When the DC output is live, the actual total physical insulation resistance of the DC EVSE between DC output live parts (DC+/DC-) to the protective conductor, which will not result in a shutdown, shall limit the touch current within the DC-2 area of Figure 22 of IEC 60479-1.

NOTE 1: The actual total physical insulation resistance is a combination of the impedance of all the components within the DC EVSE and the electric vehicle in parallel.

NOTE 2: The measured insulation resistance does not include the internal resistance of the insulation measurement device or earth leakage current monitoring device.

An insulation monitoring device (IMD) shall detect the first fault and disconnect the supply or perform an error shutdown. The earth leakage current monitoring device and the IMD do not provide fault protection, but can prevent a hazardous electric shock as an additional protection.

The reaction time of IMD or earth leakage current monitoring device shall be according to 6.5.4.6. The value of the Y-capacitances shall ensure that the reaction time of IMD or earth leakage current monitoring device is less than the limit. In any case, Y-capacitance per output (DC+/DC-) of the EVSE shall <500 nF.

The limitation of stored energy in the Y-capacitors shall not be used as fault protection under single fault condition for the DC EVSE.

Additional protection may be provided by limited impedance between the DC output live parts (DC+/DC-) and the protective conductor, including the connected EV. See 6.5.4.1.3 for the requirements for additional protection.

6.5.4.5.4 Hazardous Live Parts

The degree of protection for enclosures of DC EVSE shall be IPXXC at a minimum.

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6.5.4.5.5 Insulation Barriers

Between the DC output (DC+/DC-) and the ordinary person, double insulation, reinforced insulation, or basic insulation and electrically protective screening (shielding) shall be used as basic and fault protection.

The DC EVSE shall have insulation barriers as shown in Figure 17. The DC EVSE shall provide the minimum protective measures as defined in Table 17.

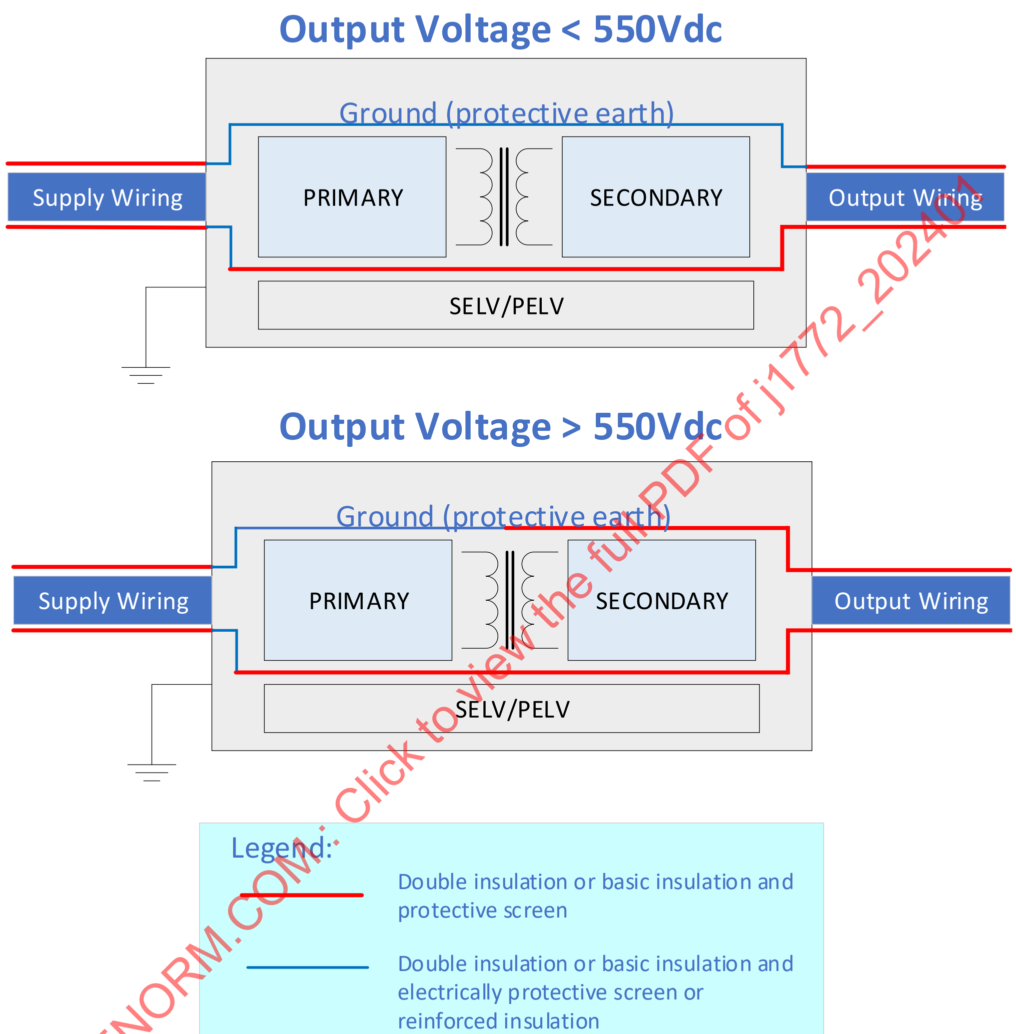

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Figure 17 - Insulation barriers

Table 17 gives the required property (with respect to protection) of barriers between the type of circuits given in the first column of this table and the type of circuits, or persons, given in the first row of the table.

Table 17 - Minimum protective measures

	EVSE DC Output	SEVL/PELV	Protective Conductor	Ordinary Person
EVSE AC Input	Protective separation	Protective separation	Basic Insulation (1)	- Double/reinforced insulation, or - Basic insulation and electrically protective screening (shielding), or - A combination of both
EVSE DC Output	NA	Protective separation(2)	For a working voltage ≤550 V DC: Basic insulation For a working voltage >550 V DC: Basic insulation, or Double/reinforced insulation(3)	- Double/reinforced insulation, or - Basic insulation and electrically protective screening (shielding), or - A combination of both
SELV	NA	NA	Functional Insulation(4)	None
Protective Conductor	NA	NA	NA	None

(1) Local regulation may require double insulation.
(2) In accordance with Table 6 and Clause 4.4.5.4 of IEC 62477:2012, if all of the following conditions are met:
– The PELV circuit is connected to the protective conductor;
– No hazardous voltage or touch current occurs (see 6.5.4.1.2) in the PELV circuit due to an insulation fault between the PELV circuit and the DC circuit;
– The IMD or earth leakage current monitoring device detects this insulation fault between the PELV circuit and EVSE output, and triggers an error or emergency shutdown;
then basic insulation between EVSE output and PELV is allowed.
(3) For EVSE output, if there is a part of the circuit with a working voltage of >550 V DC and a fault to the protective conductor will cause an offset between DC output live parts (DC+/DC-) to protective conductor of >110 % of the present voltage at output, double/reinforced insulation to the protective conductor is required. See IEC 61851-23 6.3.1.112.2.
NOTE: Threshold of 550 V DC is due to backward compatibility with IEC 61851-23:2014.
(4) If SELV is not connected to the protective conductor, a 500 V AC RMS test voltage may be applied to test the insulation.

Outside of a fire enclosure, DC output live parts (DC+ and DC-) shall be separated by double or reinforced insulation from each other and other circuits.

6.5.4.5.6 Stored Energy - AC Input of DC EVSE

The voltage between EVSE AC input live parts and the protective conductor, when measured at the AC input terminals of the DC EVSE, shall be ≤60 VDC and ≤12 VAC (RMS) or the stored energy shall be ≤0.5 mJ within in 5 seconds or less after disconnecting the power supply voltage to the DC EVSE.

6.5.4.5.7 Disconnection from Vehicle

If the present voltage between any contacts at the vehicle connector is >60 VDC or >12 VAC (RMS) during energy transfer, the DC EVSE shall comply with at least one of the following requirements:

a. the energy between any contacts shall be <0.5 mJ in 1 second or less after un-mating the vehicle connector from the vehicle inlet (case 1);

b. the voltage between any contacts shall be ≤60 VDC and ≤12 VAC (RMS) within in 1 second or less after un-mating the vehicle connector from the vehicle inlet (case 2).

The voltage or energy shall be measured at the unmated vehicle connector.

6.5.4.5.8 Supply Network Grounding

The size and rating of the protective earthing conductor is determined by the NEC.

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The DC EVSE shall provide either:

a. a protective (earthing) conductor from the AC input earthing terminal of the AC supply network to the EV/PHEV; or

b. a protective conductor from the DC EVSE to the EV/PHEV, if fault protection is based on protective separation. See requirements in 6.5.4.5.9.

Protective (earthing) conductors shall not be switched.

Protection Class II DC EVSE shall have a lead-through protective conductor with double insulation or reinforced insulation for the protective conductor bonded to the vehicle chassis.

6.5.4.5.9 DC EVSE to EV/PHEV Signaling Circuits

Any circuit for signaling, which extends beyond the DC EVSE enclosure for connection with the EV/PHEV (for example, control pilot circuit) shall be extra low voltage (SELV or PELV), according to IEC 62477-1.

6.5.4.6 Insulation Monitoring During Charging

During charging, the insulation resistance of the system shall be continuously monitored. The insulation states can be as follows:

a. Valid: The measured insulation resistance between the DC+/DC- and protective earth is above or equal to a value of 100 kΩ (without negative tolerance);

b. Fault: The measured insulation resistance between DC+/DC- and protective earth is below a value of 100 kΩ (without negative tolerance). The DC EVSE shall trigger an error shutdown within 10 seconds and send a fault message to EV/PHEV if necessary, according to SAE J2847/2.

NOTE 1: The DC EVSE can issue a visual or audible signal to the user.

NOTE 2: Section 9.4 of ISO 17409:2020 contains the requirement for the EV/PHEV isolation resistance monitoring system to avoid interference with the IMD of the DC EVSE, from time t4 in F.1.8 Normal Startup timing diagram.

6.5.4.7 DC Output Isolation Monitoring States

The EVSE shall report the following isolation states per APPENDIX F. The isolation is defined as the EVSE total isolation.

6.5.4.7.1 Invalid State

An isolation self-test has not been completed per 6.5.4, or the EVSE has detected a Fault State as described below. Charging is not allowed.

6.5.4.7.2 Valid State

After an isolation monitor self-test has successfully been performed per 6.5.4, the station enters the Valid State and charging is allowed. The EVSE remains in this state unless a Fault State is detected as defined below. Upon detection of a Fault State, the EVSE shall enter the Invalid State.

6.5.4.7.3 Warning State

It is recommended that the EVSE send a Warning message to the vehicle and also log the warning internally when the isolation of either rail to ground <500 kΩ (500 Ω /V @ 1000 V) with a recommended accuracy of +50 kΩ, - 0 Ω.

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If Warning state occurs during energy transfer the EVSE should perform a self-test after disconnection of the vehicle connector from the vehicle. If the self-test results in Warning or Fault state, the EVSE should enter the Invalid state and remain in the Invalid state until serviced. The EVSE should communicate that service is required and charging cannot occur.

NOTE: For EVSEs that measure total isolation resistance, the EVSE shall accommodate the unbalanced case where one rail to ground isolation is at the 250 kΩ minimum value but the other rail to ground isolation is extremely high isolation resistance.

6.5.4.7.4 Fault State

The EVSE shall terminate charge per 6.5.4, send a Fault message to the vehicle, and log the fault internally when the isolation of either rail to ground <100 kΩ, per Table 18. The EVSE shall detect the Fault state and indicate the Invalid State (6.5.4.7.1) <= 10 seconds of the isolation resistance <= 100 kΩ.

Table 18 - Insulation resistance fault states and response

DC+ to PE or DC- to PE (asymetric fault)	DC+ to PE and DC- to PE (symetric fault)	State	EVSE Reaction
>150 kohm	>300 kohm	Normal	Allow Charging
<100 kohm	<100 kohm	Fault	Implement error shutdown

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If Fault state occurs during energy transfer, the EVSE should perform a self-test after disconnection of the vehicle connector from the vehicle. If the self-test results in Warning or Fault state, the EVSE should enter the Invalid state and remain in the Invalid state until serviced. The EVSE should communicate that service is required and charging cannot occur.

NOTE: For EVSEs that measure total isolation resistance, the EVSE shall accommodate the unbalanced case where one rail to ground isolation is at the 100 kΩ minimum value but the other rail to ground isolation is extremely high isolation resistance.

6.5.4.8 EVSE Measured Isolation Value

The EVSE may optionally communicate the last valid measured isolation value to the EV/PHEV. See SAE J2847/2.

6.5.5 Maximum EVSE Output Y Capacitance

The maximum total parallel Y capacitance shall not exceed 1 µF. This implies <= 500 nF Y capacitance across each DC rail and ground for an EVSE with Y capacitance equally distributed between each DC rail and ground.

6.5.6 AC Present Indicator

As defined in 4.7.5.

6.5.7 Conductor Cord Requirements

As defined in 4.7.6.

6.5.8 Diagnostics Using High Voltage or High Energy

Whenever a diagnostic applies >= 60 VDC or >= 0.2 J to the vehicle connector, the vehicle connector shall be locked in either its EVSE storage location or the vehicle inlet.

6.5.9 Vehicle Connector Interlock and Latch Diagnostics

Prior to initially charging a vehicle, presence of the latch device and operation of switch (S3) in the vehicle connector shall be verified. During mating of the coupler, the EVSE shall detect the state change of the switch (S3) which is actuated by the movement of the latch device over the corresponding feature on the vehicle inlet housing. The EVSE shall detect the resistance value of the proximity circuit at the moment of terminal mating and the corresponding resistance value change when the switch (S3) is cycled during the coupler mating process. Charging shall only be allowed after the EVSE verifies the proximity circuit and the operation of switch (S3).

6.5.10 DC Output Current Measurement Accuracy

The measured current reported shall be within ±1.5% of reading with a minimum resolution of ±0.5 A.

6.5.11 DC Output Voltage Measurement Accuracy

The measured voltage reported shall be within ±1% (of full scale) or less.

6.5.12 DC Output Current Regulation

When in current regulation mode, the EVSE shall provide direct current to the vehicle. The maximum allowable error between the actual average DC output current value and the target current of the EV/PHEV is:

a. ±150 mA when the target current of the EV/PHEV is less than 5 A.

b. ±1.5 A when the target current of the EV/PHEV is greater than or equal to 5 A but less than or equal to 50 A.

c. ±3% of the maximum current output of the EVSE when the target current of the EV/PHEV is greater than 50 A.

6.5.13 DC Output Descending Current Output Slew Rate

- Normal Shutdown or Zero Current Request: -100 A/s or greater.

- Malfunction or Emergency Shutdown: -200 A/s or greater.

See the requirements for error shutdown in F.1.10 and emergency shutdown in F.1.11.

6.5.14 DC Output Current Ripple

During regulation the EVSE shall maintain a peak-to-peak current ripple as shown in Table 19.

Table 19 - Peak-to-peak current ripple

<table>
<tr><td rowspan="2">Frequency[1]</td><td colspan="3">Present Current at DC Output (I)</td></tr>
<tr><td>I ≤200 A DC</td><td>200 A DC < I ≤400 A DC</td><td>I >400 A DC</td></tr>
<tr><td>10 Hz</td><td>1.5[3]</td><td>I x 0.75%[3]</td><td>3.0[2]
I x 0.75%[3]</td></tr>
<tr><td>5 kHz</td><td>(I x 1.5% + 3)[2]
6.0[3]</td><td>6.0[3]</td><td>I x 1.5%[3]</td></tr>
<tr><td>150 kHz</td><td>9.0[3]</td><td>I x 4.5%[3]</td><td>18.0[2]
I x 4.5%[3]</td></tr>
</table>

(1) Cut-off frequency of the first order low pass filter.
(2) Recommended limit in $A_{peak\text{-}to\text{-}peak}$.
(3) Absolute maximum limit in $A_{peak\text{-}to\text{-}peak}$.

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6.5.15 DC Output Voltage Ripple - No Load Voltage Regulation

Under no load conditions, for example during pre-charge, the actual output of the charger shall be ±5 V of the EV/PHEV request within 2 seconds. In steady state the tolerance between requested and provided voltages shall be ≤2% for the maximum rated voltage of the DC EVSE.

For a target voltage of the EV/PHEV ≤ 500 V DC, the maximum voltage ripple at the DC output in normal operation and pre-charge phase, if applicable, shall be between ±5 V.

For a target voltage of the EV/PHEV > 500 V DC, the maximum voltage ripple at the DC output in normal operation and pre-charge phase, if applicable, shall be between ±1 % of the target voltage of the EV/PHEV.

6.5.16 DC Output Voltage Transient

DC output voltage transient shall be measured at rated power and rated voltage. Voltage transient shall be limited as shown in Table 20.

Table 20 - Voltage transient limits

Measuring Point	Between Positive (+) and Negative (-)	Between Positive (+) and Ground	Between Negative (-) and Ground
Limit	+/- 50 V	+/- 50 V	+/- 50 V

6.5.17 DC Output Current Overshoot Time

If Vehicle Maximum Current Limit (message defined in SAE J2847/2) is exceeded by more than the amount specified in 6.5.12 for more than 400 ms, the EVSE shall perform an error shutdown. This is the case where the current output is no longer under the control of the vehicle, and the EVSE will use its conversion circuitry to reduce current flow.

See also 6.5.29.8.

6.5.18 DC Output Short Circuit Test

Prior to enabling its high voltage DC output, the EVSE shall check for a short circuit between the high voltage DC+ and DC-in the charge cable, connector, vehicle inlet, and vehicle cabling up to the vehicle DC charge contactors. Short circuit is defined as minimum current of 1 A up to 4% of max output current rating with a maximum of 20 A. See Appendix F.1.10.

6.5.19 Loss of Communications

When DC charging control communications with the EV/PHEV is lost, the EVSE shall trigger an error shutdown. See Appendix F.

6.5.20 Connector Contact Area Temperature Monitor

The EVSE shall monitor the contact temperature at each DC connector. The contact temperature of either contact shall not exceed 90 °C according to the requirements specified as follows:

- If the temperature exceeds 90 °C for 8 consecutive seconds, the EVSE shall transfer to error shutdown sequence within 1 second.

- If the temperature exceeds 95 °C for 1 second, the EVSE shall transfer to error shutdown sequence within 1 second.

The EVSE manufacturer should consider the location of the temperature measurement relative to the point of contact (POC), the sensor tolerance, the thermal time constant of the system, and overall system response in making their calculations. Information note: For an ambient temperature above 40 °C the EVSE manufacturer should determine system response.

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6.5.21 Protection Against Unintended Reverse Power Flow

The EVSE shall protect itself from unintended reverse power flow from the EV/PHEV.

6.5.22 User Initiated Charge Termination

The EVSE shall provide a means to allow the user to terminate a charge cycle.

6.5.23 Available Current Slew Rate Changes

The rate of change of the Available Current shall be limited to ±20 A/s under non-fault conditions.

6.5.24 DC Output Overvoltage Between DC+ and DC-

6.5.24.1 General

The EVSE shall detect an overvoltage between DC+ and DC- at the vehicle connector and perform an emergency shutdown or error shutdown if an overvoltage is detected, according to 6.5.24.2 and 6.5.24.3.

When the vehicle connector is being mated to the vehicle inlet, the EVSE and the EV/PHEV shall not trigger a shutdown due to a present voltage at the DC output (positive or negative voltage), between DC+ and DC-, between DC+ and PE or between DC- and PE, unless otherwise specified in 6.5.33.

NOTE 1: According to 6.5.2 of ISO 17409:2020, when unmated, the EV/PHEV may have a voltage >60 V DC and >30 V AC between DC+ and PE, and between DC- and PE. It is recommended that the EV/PHEV does not have a common mode voltage >60 V, as unbalanced insulation faults can generate differential voltages at the DC output >60 V. The EV/PHEV may try to use RS6 and RS7 in Figure 18 of the disabled DC output circuit to limit this common mode voltage.

Overvoltage protection during the initialization stage, cable-check phase, and pre-charge phase is under consideration.

6.5.24.2 Protection Against Overvoltage at the DC Output Between DC+ And DC- by Emergency Shutdown

The EVSE shall trigger an emergency shutdown in 1 ms or less if, during the energy transfer stage, the present voltage at the DC output between DC+ and DC- is more than the voltage thresholds specified in Table 21 for more than 9 consecutive ms.

Table 21 - Voltage threshold for emergency shutdown reaction

Negotiated Maximum Voltage at the DC Output During ChargeParameterDiscovery (U)	Voltage Threshold V
U ≤500 V	550
500 V < U ≤750 V	825
750 V < U ≤850 V	935
850 V < U ≤1000 V	1100

6.5.24.3 Protection Against Overvoltage at the DC Output Between DC+ And DC- by Error Shutdown

The EVSE shall also react depending on condition of the present voltage at the DC output between DC+ and DC- according to Table 22.

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Table 22 - EVSE reaction depending on the present voltage at the DC output condition

Present Voltage at the DC Output Condition[1]	EVSE Reaction
The present voltage at the DC output between DC+ and DC- is more than the negotiated maximum voltage at the DC output for 400 consecutive ms.	Trigger an error shutdown in 50 ms or less .
The present voltage at the DC output between DC+ and DC- is more than the negotiated maximum voltage at the DC output for more than 200 consecutive ms and less than 400 consecutive ms.	Allow energy transfer or trigger an error shutdown.
The present voltage at the DC output between DC+ and DC- is more than the negotiated maximum voltage at the DC output for 200 or less consecutive ms.	Allow energy transfer.

(1) The negotiated values are defined at the end of the compatibility check (ChargeParameterDiscoveryReq/Res messages).

NOTE: The emergency and error shutdown are necessary to prevent overcharging the battery system and cannot be assumed as a withstand capability of the EVSE.

6.5.25 Voltage Deviation During Pre-Charge

The maximum voltage deviation during pre-charge state and during charging of the vehicle/traction battery shall not exceed ±5% of the requested voltage.

6.5.26 Maximum Voltage Slew Rate in Normal Operation

The maximum voltage slew rate in normal operation shall not exceed ±20 V/ms.

6.5.27 Disabled DC Output Circuit

The DC output of the EVSE, when disabled, shall have the equivalent electrical behavior as the circuit in Figure 18, with the component limits defined in Table 23.

During normal shutdown, the common mode and differential mode voltages of the disabled DC output shall be discharged to <60 V DC in 2 s or less after the EV/PHEV opens the charge contactors. See Appendix F.1.9.

During error shutdown and emergency shutdown, the DC output voltage discharge requirements are defined in Appendix F.1.10 and F.1.11, respectively.

The equivalent C_S4 capacitance shall be limited to 1 uF.

NOTE: The limitation of C_S4 in the disabled DC output reduces the energy stored if the EV/PHEV closes the charge contactors during welding detection.

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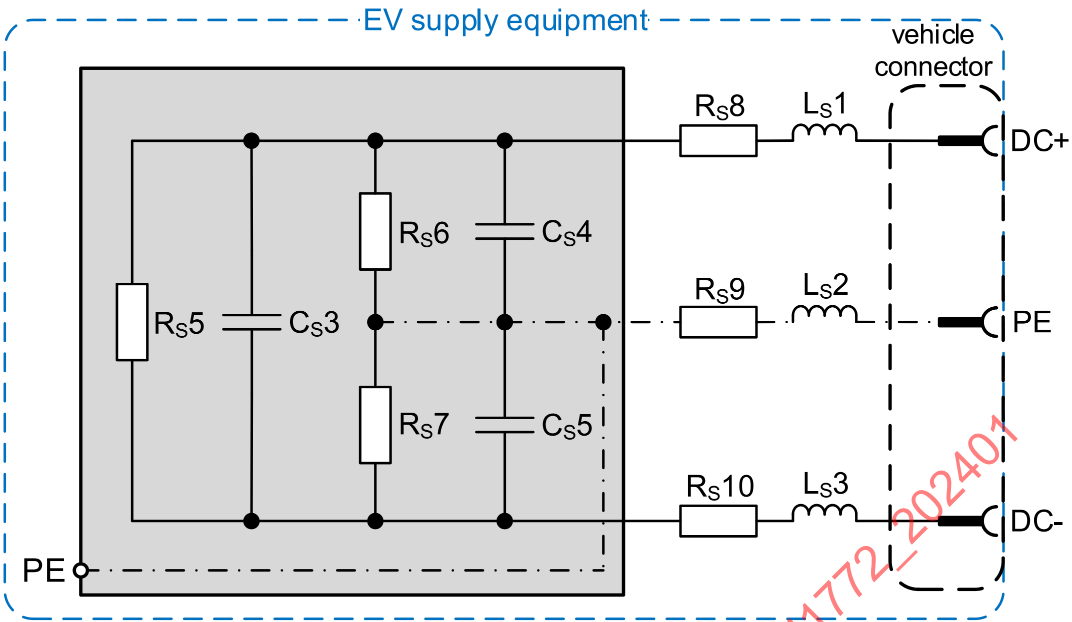

Figure 18 - Equivalent disabled DC output circuit of the EVSE

Table 23 - Component limits for the disabled DC output circuit of the EVSE

Component[1]	Minimum Value[1]	Maximum Value[1]
$C_{S}4$	-	500 nF
$C_{S}5$	-	500 nF
$R_{S}6$ [2],[3]	70 kΩ	300 kΩ
$R_{S}7$ [2],[3]	70 kΩ	300 kΩ
$C_{S}3$	-	1 µF
$R_{S}5$ [3]	7 kΩ	-
$L_{S}1$	-	(Under consideration)
$L_{S}2$[3]	-	
$L_{S}3$	-	220 µH
$R_{S}8$	0 mΩ	-
$R_{S}9$	0 mΩ	-
$R_{S}10$	0 mΩ	-

(1) Unspecified components or values are to be defined by the EVSE manufacturer.
(2) This value is excluding a possible insulation fault.
(3) This component may have to withstand the complete rated maximum voltage of the EVSE at the DC output for an extended time.

6.5.28 DC Output Pre-Charge and Inrush Current

During the pre-charge phase, the EVSE shall operate in CV to follow the target voltage of the EV/PHEV according to 6.5.15 and 6.5.25. The EVSE shall:

a. be able to pre-charge the circuit defined in Figure 19 with the values according to Table 24 for its entire operating range in 3 seconds or less; and

b. subsequently follow a change in the target voltage of the EV/PHEV of a maximum of ±50 V DC in 1 second or less.

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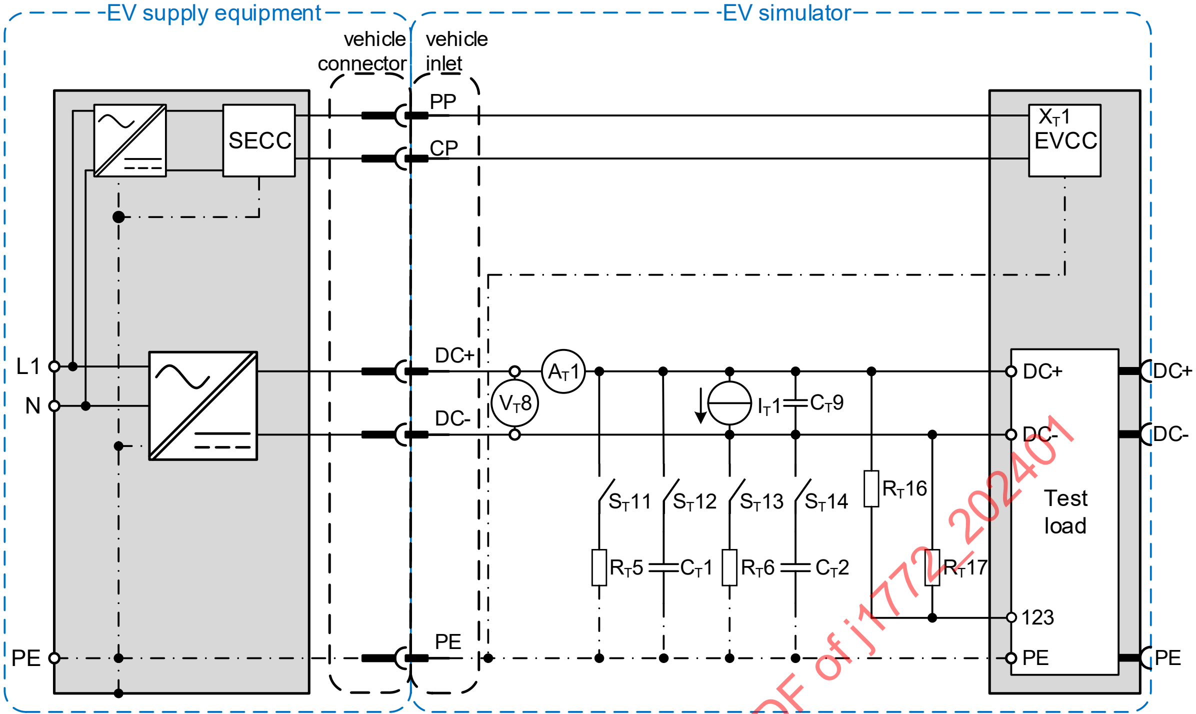

Key

I_T1	EV/PHEV current load
C_T1, C_T2	Maximum Y-capacitance on the vehicle inlet
C_T9	Maximum X-capacitance on the vehicle inlet
R_T5, R_T6	Minimum insulation resistance (due to an error) on the vehicle inlet
R_T16, R_T17	Minimum resistance of the EV/PHEV simulator measurement circuit on vehicle inlet
A_T1	Ammeter in the EV/PHEV simulator
V_T8	Voltmeter in the EV/PHEV simulator
SECC	Supply Equipment Charge Controller
EVCC	Electric Vehicle Charge Controller

Figure 19 - Worst case equivalent circuit during pre-charge

Table 24 - Component values for the worst case scenario during pre-charge

Symbol	Value
I_T1	12 mA ± 2 mA
C_T1, C_T2	2 µF
C_T9	10 nF
R_T5, R_T6	100 kΩ
R_T16, R_T17	500 kΩ
S_T17	Closed
S_T18	Open

The EVSE may trigger an error shutdown if the PowerDeliveryReq <6a> message is not received by the EVSE in 20 seconds or less after receiving the first PreChargeReq <5a> message.

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NOTE 1: This is to limit the heating of the pre-charge circuit in the EVSE.

During the entire pre-charge stage (from t7 to t10), the EVSE shall operate in CVC to follow the target voltage of the EV, and shall limit the DC output current to a maximum of ±2 A DC. The target current of the EV/PHEV shall be ignored.

From the beginning of the pre-charge stage (t7) until the EVSE receives message PowerDeliveryReq <6a>, the EVSE shall limit the DC output current to <±20 A peak, including the inrush current and a continuous current, if any.

From the reception of message PowerDeliveryReq <6a> until the end of the pre-charge stage (t10), the EVSE shall:

a. *limit the DC output current to <±125 A peak, including the transient current and a continuous current, if any; and*

b. *limit the integral of the DC output current > 2 A over time (I>2 A×t) to ≤3 As.*

NOTE 2: The inrush current is the transient current due to the energization of cables and capacitors when the EV/PHEV closes the charge contactors. It is not a continuous current.

NOTE 3: The EV/PHEV might close several charge contactors in individual steps between t7 and sending message PowerDeliveryReq <6a>.

6.5.29 Handling of Operating Ranges

6.5.29.1 General

The target current, target voltage, and target power of the EVSE are the intended current, voltage, and power at the DC output. Depending on the mode (CCC or CVC) and the operating point between the operating range , the current and/or voltage at the DC output of the EVSE will be at one or more of these targets.

The relationship between the target voltage of the EV/PHEV and the DC putput voltage is shown in Equation 1, under normal conditions.

$$V_{EVSE_{Out}} \leq V_{EVSE_{Target}} + |V_{Deviation}| + |V_{Ripple}| \quad \text{(Eq. 1)}$$

where:

V_{EVSE_Target} = the target voltage of the EVSE at the DC output, expressed in volts

V_{EVSE_Out} = the present voltage at the DC output, expressed in volts

$V_{deviation}$ = the deviation on the present voltage at the DC output as defined in 6.5.15, expressed in volts

V_{ripple} = the voltage ripple on the present voltage at the DC output as defined in 6.5.15, expressed in volts

The relationship between the target DC output current and the DC output current is shown in Equation 2, under normal conditions.

$$I_{EVSE_{Out}} \leq I_{EVSE_{Target}} + |I_{Deviation}| + |I_{Ripple}| \quad if\ I_{EVSE_{Target}} > 0\ A \quad \text{(Eq. 2)}$$

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where:

I_{EVSE_Target} = the target current of the EVSE at the DC output, expressed in amperes.

I_{EVSE_Out} = the present current at the DC output, expressed in amperes

$I_{deviation}$ = the deviation on the present current at the DC output as defined in 6.5.12, expressed in amperes

I_{ripple} = the current ripple on the present current at the DC output as defined in 6.5.14, expressed in amperes

The relationship between the target power of the EVSE and the present power at the DC output is under consideration.

6.5.29.2 Zero Amp (0 A) Mode During Charging

If the EVSE cannot deliver any current at the DC output, the EVSE shall send 0 A as its applicable maximum current of the EVSE at the DC output to the EV/PHEV within the next communicated message. The 0 A mode initiated by the EVSE shall not trigger an immediate shutdown by the EV/PHEV. The EV/PHEV should continue the charging session for 5 min or more.

If the target current of the EV/PHEV is 0 A DC or the applicable maximum current of the EVSE at the DC output is 0 A, then the EVSE shall reduce and maintain the present current at the DC output <0,15 A DC with a minimum of -0,15 A DC, to prevent reverse power transfer from the EV/PHEV to the EVSE. See Formula IEC3. See 6.5.29.7 regarding the 0 A target current of the EV/PHEV.

NOTE: The 0 A mode is used to temporarily continue with the energy transfer phase without a present current at the DC output. For example, when there are power fluctuations in the supply network, or there is no power available.

The relationship between the target current of the EVSE at the DC output and the present current at the DC output is shown in Equation 3, during the 0 A mode.

$$-0{,}15\ A \leq I_{EVSE\_Out} \leq 0{,}15\ A \quad if\ I_{EVSE\_Target} = 0\ A \qquad \text{(Eq. 3)}$$

where:

I_{EVSE_Target} = the target current of the EVSE at the DC output, expressed in amperes

I_{EVSE_Out} = the present current at the DC output, expressed in amperes

6.5.29.3 Changing the Applicable Maximum Voltage of the EVSE at the DC Output

The EVSE shall limit the applicable maximum voltage of the EVSE at the DC output to the negotiated maximum voltage at the DC output, as communicated in the last ChargeParameterDiscoveryReq/Res messages. See Equation 4.

$$V_{EVSE\_MAX} \leq V_{EVSE\_MAX\_CPD} \qquad \text{(Eq. 4)}$$

where:

V_{EVSE_MAX} = the applicable maximum voltage of the EVSE at the DC output, expressed in volts.

VEVSE_MAX_CPD = the negotiated maximum voltage at the DC output, communicated in the last ChargeParameterDiscoveryRes, expressed in volts

6.5.29.4 Changing the Applicable Maximum Current of the EVSE at the DC Output

The present current at the DC output can be less than the target current of the EV/PHEV if the applicable maximum current of the EVSE at the DC output is less than the target current of the EV/PHEV.

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The EVSE shall communicate the change of applicable maximum current of the EVSE at the DC output in the next communicated message.

The EVSE shall limit the applicable maximum current of the EVSE at the DC output to the negotiated maximum current at the DC output which is communicated within the ChargeParameterDiscoveryReq/Res messages. See Equation 5.

$$I_{EVSE\_MAX} \leq I_{EVSE\_MAX\_CPD} \quad \text{(Eq. 5)}$$

where:

I_{EVSE_MAX} = the applicable maximum current of the EVSE at the DC output, expressed in amperes.

IEVSE_MAX_CPD = the negotiated maximum current at the DC output, communicated in the last ChargeParameterDiscoveryRes message, expressed in amperes.

6.5.29.5 Changing the Applicable Maximum Power of the EVSE at the DC Output

The EVSE shall limit the applicable maximum power of the EVSE at the DC output to the negotiated maximum power at the DC output, as communicated in the last ChargeParameterDiscoveryReq/Res messages. See Equation 6.

$$P_{EVSE\_MAX} \leq P_{EVSE\_MAX\_CPD} \quad \text{(Eq. 6)}$$

where:

P_{EVSE_MAX} = the applicable maximum power of the EVSE at the DC output, expressed in watts

PEVSE_MAX_CPD = the negotiated maximum power at the DC output, communicated in the last ChargeParameterDiscoveryRes message, expressed in watts

The EVSE is allowed to reduce the present current at the DC output to less than the target current of the EV/PHEV if the applicable maximum power of the EVSE at the DC output drops to a value less than the present power at the DC output. See 6.5.29.6.

The EVSE shall communicate the change of applicable maximum power of the EVSE at the DC output in the next communicated message.

6.5.29.6 The Present Current at the DC Output Is Less Than the Target Current of the EV/PHEV

The EV/PHEV shall not trigger a shutdown if the present current at the DC output is less than the target current of the EV/PHEV.

NOTE: This decrease in present current at the DC output can be caused by supply network dips, CVC mode or a change in applicable maximum current of the EVSE at the DC output. See 6.5.29.4.

6.5.29.7 The Target Current of the EV/PHEV Is Less Than the Applicable Minimum Current of the EVSE at the DC Output

The EVSE shall enable 0 A mode (see 6.5.29.2) as if the target current of the EV/PHEV were 0 A, when the target current of the EV/PHEV is less than the applicable minimum current of the EVSE at the DC output. See Equation 7.

$$I_{EVSE\_Target} = 0\,A \quad if\ I_{EV\_Req} < I_{EVSE\_MIN} \quad \text{(Eq. 7)}$$

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where:

I_{EVSE_Target} = the target current of the EVSE at the DC output, expressed in amperes

I_{EVSE_MIN} = the applicable minimum current of the EVSE at the DC output, expressed in amperes

I_{EV_Req} = the target current of the EV/PHEV, expressed in amperes

6.5.29.8 The Target Current of the EV/PHEV Is More Than the Applicable Maximum Current of the EVSE at the DC Output

The EVSE shall continue the charging session with the applicable maximum current of the EVSE at the DC output or the rated maximum current of the EV/PHEV, whichever is less, if the target current of the EV/PHEV is more than the applicable maximum current of the EVSE at the DC output or the rated maximum current of the EV/PHEV. See Equation 8.

$$I_{EVSE\_Target} = MIN(I_{EV\_MAX}, I_{EVSE\_MAX}) \;\; if\; I_{EV\_Req} > MIN(I_{EV\_MAX}, I_{EVSE\_MAX}) \quad \text{(Eq. 8)}$$

where:

I_{EVSE_Target} = the target current of the EVSE at the DC output, expressed in amperes

I_{EVSE_MAX} = the applicable maximum current of the EVSE at the DC output, expressed in amperes

I_{EV_MAX} = the rated maximum current of the EV/PHEV, expressed in amperes

I_{EV_Req} = the target current of the E/PHEV V, expressed in amperes

6.5.29.9 The Target voltage of the EV/PHEV Is Less Than the Present Voltage at the DC Output

The EVSE shall enable 0 A mode (see 6.5.29.2), as if the target current of the EV/PHEV were 0 A, when the target voltage of the EV/PHEV is less present voltage at the DC output, to prevent reverse power transfer. See Equation 9.

$$I_{EVSE\_Target} = MIN(I_{EV\_MAX}, I_{EVSE\_MAX}) \;\; if\; I_{EV\_Req} > MIN(I_{EV\_MAX}, I_{EVSE\_MAX}) \quad \text{(Eq. 9)}$$

where:

I_{EVSE_Target} = the target current of the EVSE at the DC output, expressed in ampere

V_{EVSE_Out} = the present voltage at the DC output, expressed in volts

V_{EV_Req} = the target voltage of the EV/PHEV, expressed in volts

6.5.29.10 The Target Voltage of the EV/PHEV Is More Than the Maximum Voltage Limits

The EVSE shall continue the charge session with the applicable maximum voltage of the EVSE at the DC output or the target voltage of the EV/PHEV, whichever is less, if the target voltage of the EV/PHEV is more than the applicable maximum voltage of the EVSE at the DC output or the rated maximum voltage of the EV/PHEV. See Equation 10.

$$V_{EVSE\_Target} = MIN(V_{EV\_Req}, V_{EVSE\_MAX}) \;\; if\; V_{EV\_Req} > MIN(V_{EV\_MAX}, V_{EVSE\_MAX}) \quad \text{(Eq. 10)}$$

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where:

V_{EVSE_Target} = the target voltage of the EVSE at the DC output, expressed in volts

V_{EVSE_MAX} = the applicable maximum voltage of the EVSE at the DC output, expressed in volts

V_{EV_Req} = the target voltage of the EV/PHEV, expressed in volts

V_{EV_MAX} = the rated maximum voltage of the EV/PHEV, expressed in volts

NOTE: The EVSE can remain in CCC mode until the rated maximum voltage of the EV/PHEV is reached. See overvoltage protection in 6.5.24, which prevents overcharging the battery system.

6.5.29.11 The Present Voltage at the DC Output Is Less Than the Applicable Minimum Voltage of the EVSE at the DC Output

The EVSE shall trigger an error shutdown in 50 ms or less if the present voltage at the DC output or the target voltage of the EV/PHEV is less than the applicable minimum voltage of the EVSE at the DC output for more than 3 seconds. See Equation 11.

$$\text{Error shutdown if } MIN(V_{EVSE\_Measured}, V_{EV\_Req}) < V_{EVSE\_MIN} \text{ for more than 3 seconds} \quad \text{(Eq. 11)}$$

where:

$V_{EVSE\_Measured}$ = the present voltage at the DC output, expressed in volts

V_{EVSE_MIN} = the applicable minimum voltage of the EVSE at the DC output, expressed in volts

V_{EV_Req} = the target voltage of the EV/PHEV, expressed in volts

NOTE: This case could be detected during the pre-charge stage, as the EVSE cannot supply the correct present voltage at the DC output for pre-charge.

6.5.29.12 The Present Voltage at the DC Output Is More Than the Applicable Maximum Voltage of the EVSE at the DC Output

The EVSE shall trigger an error shutdown in 50 ms or less if the present voltage at the DC output is more than or equal to the applicable maximum voltage of the EVSE at the DC output for more than 400 ms, according to 6.5.24. See Equation 12.

$$\text{Error shutdown if } V_{EVSE\_Measured} \geq V_{EVSE\_MAX} \text{ for more than 400 ms} \quad \text{(Eq. 12)}$$

where:

$V_{EVSE\_Measured}$ = the present voltage at the DC output, expressed in volts

V_{EVSE_MAX} = the applicable maximum voltage of the EVSE at the DC output, expressed in volts

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6.5.29.13 Limitations Due to the Applicable Minimum Power of the EVSE at the DC Output

The EVSE shall enable 0 A mode (see 6.5.29.2), as if the target current of the EV/PHEV were 0 A, if:

a. the target power of the EV/PHEV is less than the applicable minimum power of the EVSE at the DC output; or

b. for more than 3 seconds, the present voltage at the DC output multiplied by the target current of the EV/PHEV is less than the applicable minimum power of the EVSE at the DC output.

See Equation 13.

$$I_{EVSE\_Target} = 0\,A \quad if\ P_{EV\_Req} < P_{EVSE\_MIN},\ or \qquad \text{(Eq. 13)}$$

$$I_{EVSE\_Target} = 0\,A \quad if\ V_{EVSE\_Measured} \times I_{EV\_Req} < P_{EVSE\_MIN}\ for\ more\ than\ 3\ seconds$$

where:

I_{EVSE_Target} = the target current of the EVSE at the DC output, expressed in amperes

I_{EV_Req} = the target current of the EV/PHEV, expressed in amperes

$V_{EVSE\_Measured}$ = the present voltage at the DC output, expressed in volts

P_{EV_Req} = the target power requested of the EV/PHEV, expressed in watts

P_{EVSE_MIN} = the applicable minimum power of the EVSE at the DC output, expressed in volts

NOTE: P_{EVSE_MIN} is the internal minimum power that the EVSE can deliver, as this value is not handled by the digital communication but is restricting the present power at the DC output. The EVSE cannot know the minimum voltage and the present voltage of the battery system, as these are not communicated through digital communication.

6.5.29.14 Limitations Due to the Applicable Maximum Power of the EVSE at the DC Output

If the target power of the EV/PHEV, or target current of the EV/PHEV multiplied by the present voltage at the DC output, or target current of the EV/PHEV multiplied by the target voltage of the EV/PHEV that is more than the applicable maximum power of the EV/PHEV or the applicable maximum power of the EVSE at the DC output, then the EVSE shall continue the charging session and limit the target power of the EVSE at the DC output to the minimum of the following values:

- Applicable maximum power of the EV/PHEV.
- Applicable maximum power of the EVSE at the DC output.

See Equation 14.

$$P_{EVSE\_Target} = MIN\left(P_{EV\_MAX}, P_{EVSE\_MAX}\right) \qquad \text{(Eq. 14)}$$

$$if\ MIN\left(V_{EVSE\_Measured} \times I_{EV\_Req}, V_{EV\_Req} \times I_{EV\_Req}, P_{EV\_Req}\right) > MIN\left(P_{EV\_MAX}, P_{EVSE\_MAX}\right)$$

$$with\ P_{EV\_MAX} = MAX(P_{EV\_MAX\_CPD}, V_{EV\_MAX\_CPD} \times I_{EV\_MAX\_CPD})$$

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where:

$V_{EVSE\_Measured}$ = the present voltage at the DC output, expressed in volts

V_{EV_Req} = the target voltage of the EV/PHEV, expressed in volts

I_{EV_Req} = the target current of the EV/PHEV, expressed in amperes

P_{EVSE_Target} = the target power of the EVSE at the DC output, expressed in watts

P_{EVSE_MAX} = the applicable maximum power of the EVSE at the DC output, expressed in watts

P_{EV_Req} = the target power of the EV/PHEV, expressed in watts

P_{EV_MAX} = the applicable maximum power of the EV/PHEV, expressed in watts

$V_{EV\_MAX\_CPD}$ = the rated maximum voltage of the EV/PHEV in ChargeParameterDiscoveryReq, expressed in volts

$I_{EV\_MAX\_CPD}$ = the rated maximum current of the EV/PHEV in ChargeParameterDiscoveryReq, expressed in amperes

$P_{EV\_MAX\_CPD}$ = the rated maximum power of the EV/PHEV in ChargeParameterDiscoveryReq, expressed in watts

NOTE 1: $P_{EV\_MAX\_CPD}$ = 0 if $P_{EV\_MAX\_CPD}$ is not communicated by the EV/PHEV.

NOTE 2: According to ISO 15118-2, the P_{EV_Req} is the "EVMaximumPowerLimit" within the CurrentDemandReq messages and the P_{EV_MAX} is the "EVMaximumPowerLimit" communicated.

NOTE 3: Lowering the present power at the DC output can be achieved by limiting the target current of the EVSE at the DC output based on the present voltage at the DC output and the target power of the EVSE at the DC output, as the CPCM is not defined for system C. See also 6.5.29.4 and 6.5.29.6.

6.5.30 DC Output Load Dump

In case of a load dump, after the first 3 ms, the voltage overshoot at the DC output between DC+ and DC- shall be less than or equal to:

a. for a rated maximum voltage of the EV/PHEV, as communicated (in the last request message before t3) during the initialization phase, > 500 V: 110 % of the rated maximum voltage of the EV/PHEV.

b. for a rated maximum voltage of the EV/PHEV, as communicated (in the last request message before t3) during the initialization phase, ≤ 500 V: rated maximum voltage of the EV/PHEV plus 50 V.

See Equation 15.

$$V_{EVSE\_Out} \leq MAX\left(110\ \% \times V_{EV\_MAX\_CPD}, V_{EV\_MAX\_CPD} + 50\ V\right) \quad \text{(Eq. 15)}$$

where:

V_{EVSE_Out} = the present voltage at the DC output, expressed in volts

$V_{EV\_MAX\_CPD}$ = the maximum voltage of the EV/PHEV, communicated in the last ChargeParameterDiscoveryReq message, expressed in volts

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6.5.31 Sleep Mode and Charging Session Restart Methods

Sleep mode is an operating mode of the EVSE designed for reduced energy consumption when a charging session is not occurring. In this case, the SECC is permitted to not communicate via digital communication.

The EV/PHEV can request a pause of the charging session, after which both EV/PHEV and EVSE can enter sleep mode. Additionally, the EVSE can indicate the EV/PHEV to request a digital communication session pause due to the behavior of the supply network. See Appendix F.

NOTE: The behavior of the supply network can be influenced by, for example, smart charging profiles, supply availability, and/or distribution system operator.

To restart digital communication, the EVSE can perform a restart method as specified in sections 6.5.31.2.

The restart methods can also be used to restart digital communication after an error condition, for example, loss of digital communication.

6.5.31.1 Sleep Mode on the EVSE

The EVSE may support a sleep mode according to ISO 15118-3:2015 to minimize power consumption.

The EVSE may enter a sleep mode, if:

a. there is no digital communication (application layer messages) for more than 2 consecutive min, or

b. the EV/PHEV requests a digital communication session pause according to section 8.4.2 of ISO 15118-2:2014. See Appendix F.

During sleep mode the CP oscillator of the EVSE shall be off, while the CP voltage source is enabled (CP state x1).

See 6.4.8 on how the EV/PHEV can restart a new digital communication session.

6.5.31.2 Restart Methods for the EVSE

The EVSE shall perform the restart methods, as described in Figures 20 and 21.

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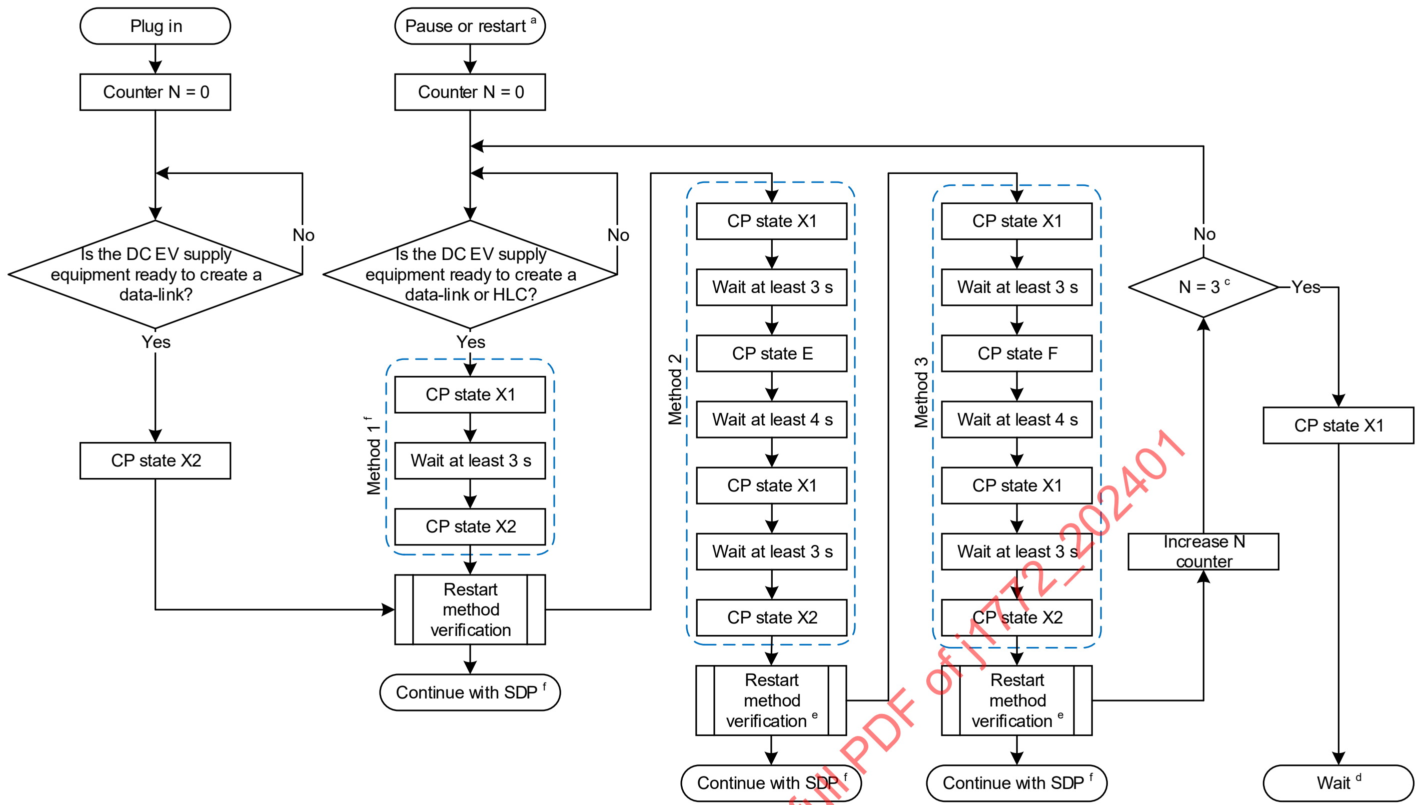

[a] *The EV/PHEV can initiate a restart by performing a B – C – B toggle.*

[b] *The EV/PHEV can react by sending a SLAC request (entering the matching process) or an SDP message, which means that the data link is established.*

[c] *The EVSE manufacturer can specify a different number of restart cycles.*

[d] *The EVSE manufacturer can decide to perform additional restarts, sleep mode, or the EV/PHEV can decide to perform a restart.*

[e] *The restart verification method described in Figure 21 can either continue with SDP or to the next restart method.*

[f] *SECC Discovery Protocol.*

Figure 20 - Restart methods sequence for the EVSE

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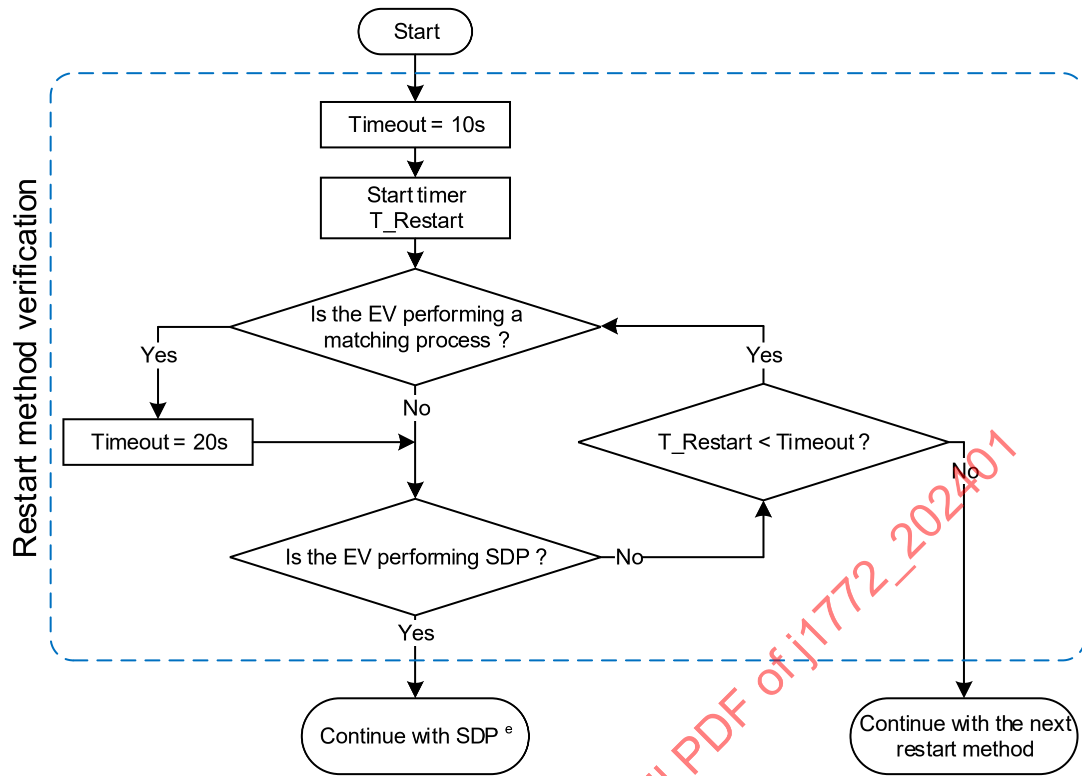

Figure 21 - Restart method verification on the EV/PHEV supply equipment

If the EVSE has turned off its CP oscillator, the EVSE shall stay in CP state x1 for 3 s or more according to sequence 9.2 of Table A.6 of IEC 61851-1:2017.

The EVSE shall wait 10 s or more between restart methods.

NOTE 1: The timeout for the EVSE to receive a matching process request is 20 seconds for DIN SPEC 70121 and ISO 15118-2:2014. Refer to Table 8 in DIN SPEC 70121:2014 and Table 111 in ISO 15118-2:2014.

The CP states E or F shall be generated for 4 s or more. See restart methods 0 and 0.

If a CP state A is detected, the EVSE should:

a. reset the Network Membership Key (NMK) if it was already used; and

b. terminate an established digital communication link,

unless specified in IEC 61851-24.

If a D-LINK_TERMINATE.request is received, the EVSE should terminate the established digital communication link, unless specified in IEC 61851-24.

If a D-LINK_TERMINATE.request or a D-LINK_ERROR.request is received, the EVSE should:

a. not change the NMK in the next matching process, unless a CP state A is detected; and

b. terminate the established digital communication link,

unless specified in IEC 61851-24.

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NOTE 2: In ISO 15118, a D-LINK_TERMINATE.request is sent if message SessionStopReq <10a> contains parameter ChargingSession="Terminate."

NOTE 3: In DIN SPEC 70121, the use of D-LINK_TERMINATE.request is not defined for message SessionStopReq <10a>, meaning the EV/PHEV or EVSE can choose to terminate the data link or not. It is recommended keep the data link active.

NOTE 4: In ISO 15118-2, a D-LINK_TERMINATE.request required to reset the NMK, but for restart purposes and other cases, this can lead to unstable matching processes. The logical network should not change if the CP state does not change to CP state A, as it is the same EV/PHEV connected to the same EVSE.

If the EVSE wants to restart a charging session, the EVSE shall perform restart method 0, as follows:

B1 – B2 transition according to sequence 3.1 of Table A.6 of IEC 61851-1:2017. See the example in Figure 22.

NOTE 5: When using DIN SPEC 70121, a charging session restart will generate a new SessionId.

NOTE 6: When using ISO 15118-2:2014, a charging session restart after a pause will maintain the previous SessionId. If a charging session is terminated, a new SessionId will be generated.

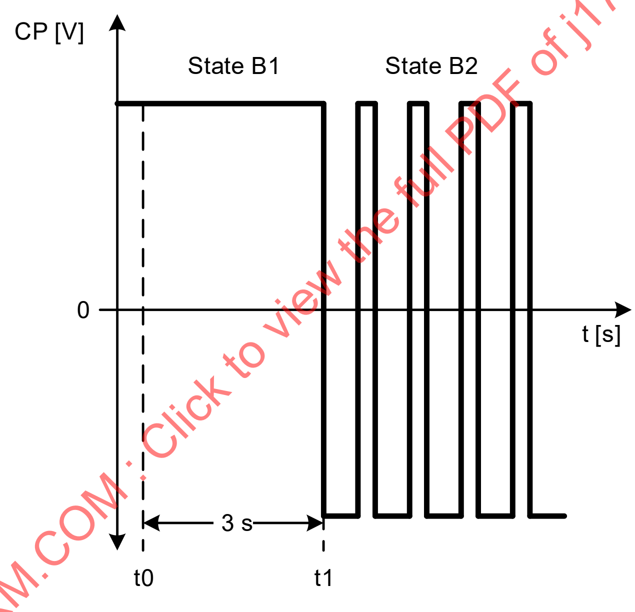

Figure 22 - Example of a B1 – B2 transition

NOTE 7: ISO 15118-2 and ISO 15118-3 require to skip restart method 1 after an error, for example, receiving a D-LINK_ERROR.request. This is not recommended, as authentication can be lost when performing restart method 2 or restart method 3 because the EVSE cannot detect an EV/PHEV disconnection based on CP monitoring. Additionally, monitoring the PP circuit is not a reliable method to determine if the EV/PHEV is connected, as the EV/PHEV can turn off the PP voltage source, for example, during sleep mode.

If the EV/PHEV does not continue with the matching process or SDP when matched after the restart sequence 1 timed out, the EVSE shall perform restart sequence 2, as follows:

B1 – E – B1 – B2 sequence as described in A.5.3 of IEC 61851-1:2017. See the example in Figure 23.

NOTE 8: CP state E requires the EVSE to set the CP voltage source to 0 V DC and without a PWM signal.

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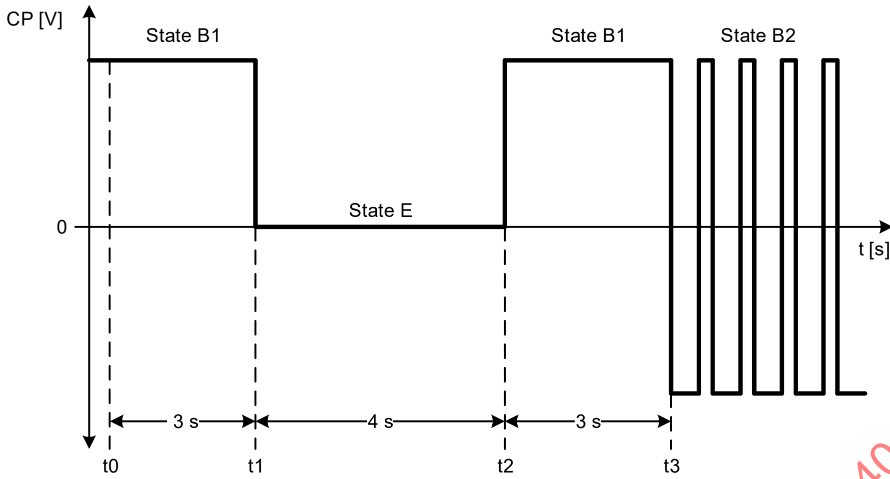

Figure 23 - Example of a B1 – E – B1 – B2 transition

If the EV/PHEV does not continue with the matching process or SDP when matched after the restart sequence 2 timed out, the EVSE shall continue with restart sequence 3, as follows:

B1 – F – B1 – B2 sequence as described in A.5.3 of IEC 61851-1:2017. See the example in Figure 24.

NOTE 9: A CP state F requires the EVSE to set PWM duty cycle of the CP voltage source to 0%, generating -12 V DC between CP and PE.

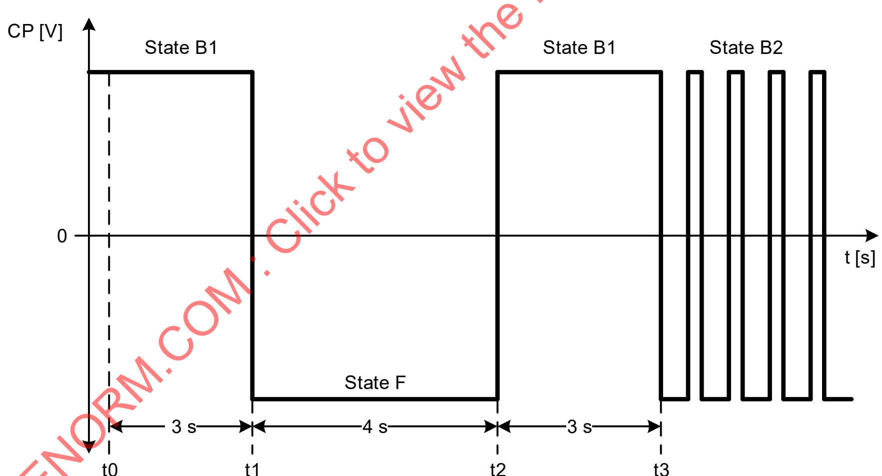

Figure 24 - Example of a B1 – F – B1 – B2 transition

If the data link is established after one of the restart methods, the EV/PHEV and EVSE shall:

a. continue with SDP; or

b. restart the matching process with a new SLAC request.

If the data link is not active after performing all the restart methods, the EVSE may perform multiple sequences of the restart methods.

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NOTE 10: If using DIN SPEC 70121, refer to section 9.6 of DIN SPEC 70121:2014 for additional requirements related to session and error handling.

NOTE 11: If using ISO 15118, refer to 7.5 of ISO 15118-3:2015 and A.5.3 of IEC 61851-1:2017 for additional information regarding the restart sequences. Also refer to 7.6 of ISO 15118-3:2015 for additional requirements related to sleep mode.

6.5.32 Loss of Electrical Continuity of the Protective Conductor

The EVSE shall trigger an emergency shutdown in 150 ms or less if a loss of electrical continuity of the protective conductor occurs anywhere from the inside of the EVSE up to the point A (see Figure 4).

6.5.33 Voltage Limitation Between DC+ and DC- and Protective Conductor

6.5.33.1 Maximum Voltage Between DC+ and DC- and Protective Conductor Under Normal Operation

Under normal operation, at the DC output, no voltage more than the present voltage between DC+ and DC- plus 50 V DC shall occur between live parts (DC+ and DC-) and protective conductor. This voltage limitation does not apply for transient overvoltage. See Figures 25 and 26.

Components of the EVSE, for example, an IMD, may superimpose a common mode voltage to protective conductor onto the present voltage at DC output. This may shift the voltage between DC output live parts (DC+/DC-) and the protective conductor up to present voltage at DC output plus 50 V DC.

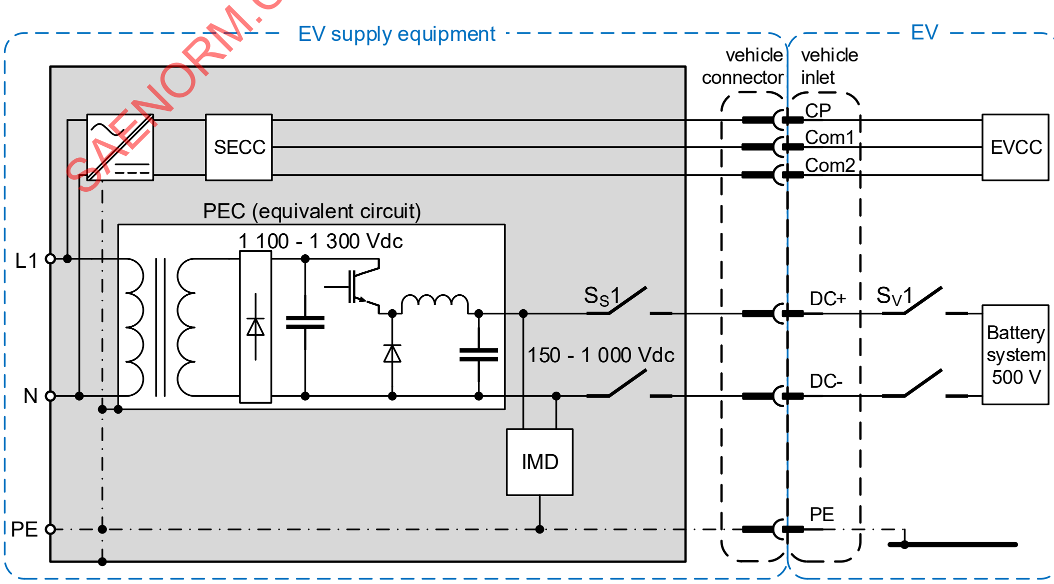
Components of the EVSE, for example, resistors, may shift each DC output live part (DC+/DC-) up to protective conductor through a resistor, which results in a large common mode DC output voltage swing.

The measurement circuits might introduce a larger common mode voltage offset if connected to an intermediate bus voltage. These circuits shall not cause a voltage shift that is more than the requirements in this clause.

The EVSE may employ passive and/or active techniques to minimize the touch impulse current, possibly in coordination with the IMD or earth fault monitor of the EVSE.

NOTE 1: To minimize the touch impulse current, the voltages between DC output live parts (DC+/DC-) and the protective conductor must stay close to symmetrical.

Figure 25 shows an example of a correct implementation and Figure 26 shows an example of an incorrect implementation.



a) Typical IMD implementation

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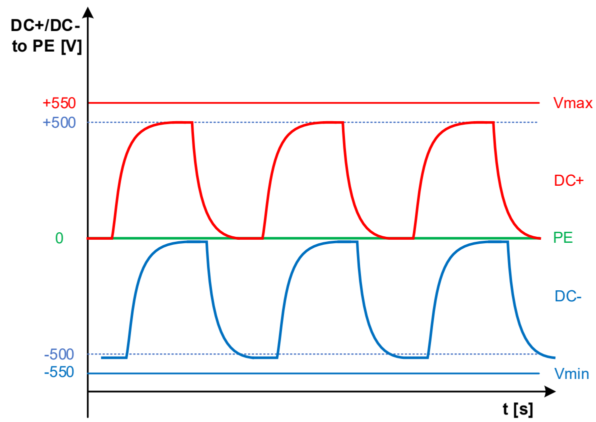
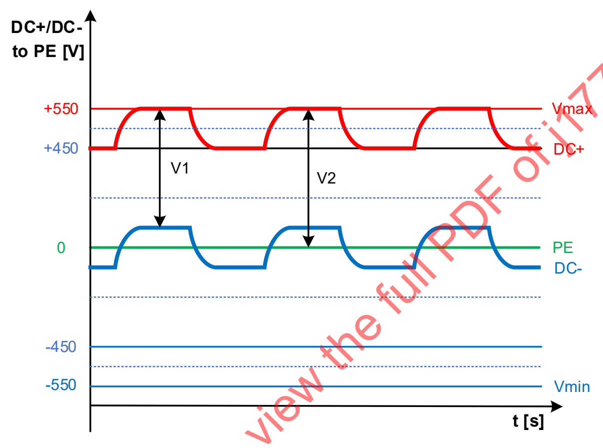


b) Waveform of an IMD implementation with a Switched Resistor



c) Waveform of an IMD implementation with a Pulsed Signal

Key

V1: Voltage at DC output between DC+ and DC-

V2: Maximum common mode voltage (with reference to PE) including IMD

Vmax: Upper voltage limit for DC+ and DC-

Vmin: Lower voltage limit for DC+ and DC-

NOTE 1: If the voltage between DC+/DC- and protective conductor is >704 V DC, the required C1 impulse current limitation specified as special protection in 6.5.4.5.5 cannot be met.

NOTE 2: Relatively low earthing resistance for earth leakage current monitoring and large offset shown does not occur in normal operational condition.

Figure 25 - Typical voltages between DC output DC+ and DC- and protective coupler under normal operation

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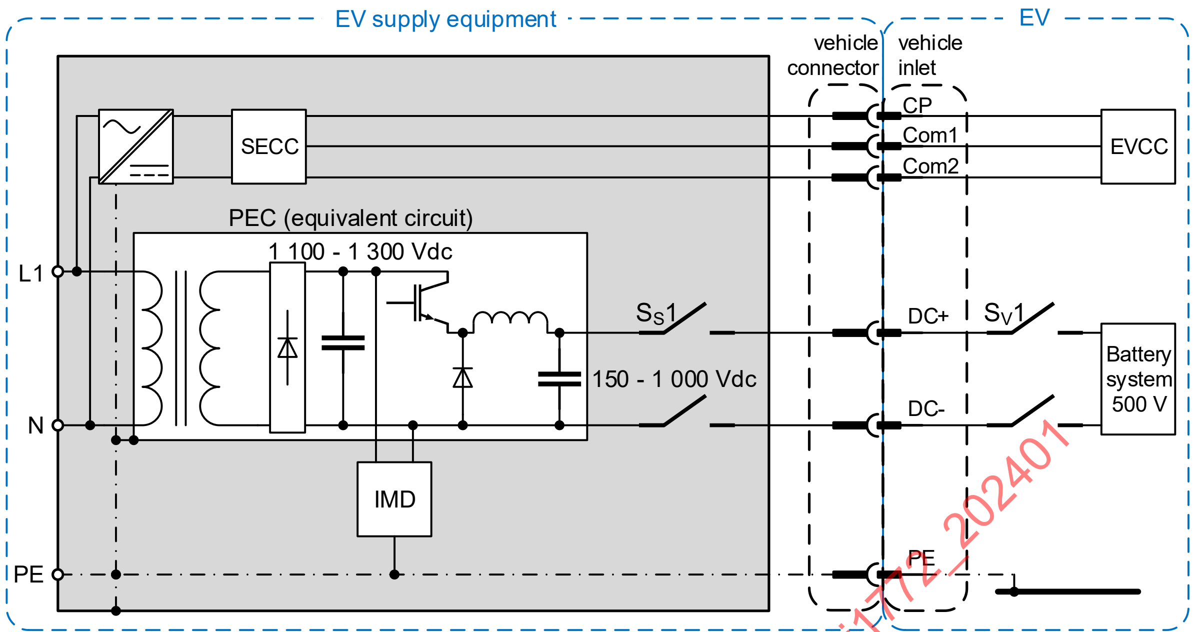
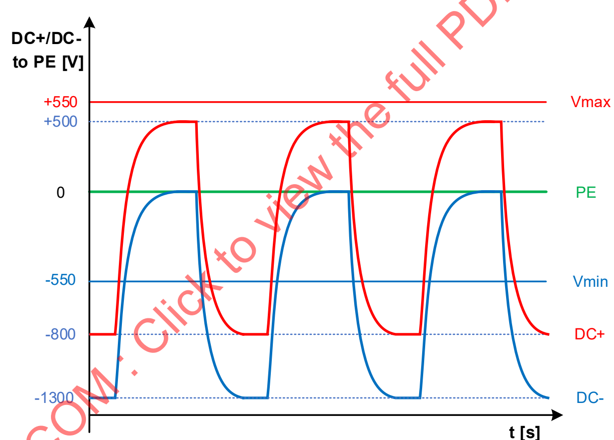


a) Incorrect IMD implementation



b) Waveform of an Incorrect IMD implementation

Key

Vmax Upper voltage limit for DC+ and DC- and PE conductor

Vmin Lower voltage limit for DC+ and DC- and PE Conductor

Figure 26 - IMD connection which results in a voltage more than the maximum voltage limits

6.5.33.2 Maximum Voltage Between DC Output (DC+ and DC-) and the Protective Conductor in Case of an Insulation Fault at DC Output to the Protective Conductor

The insulation requirements between DC output of the EVSE and the protective conductor, excluding the DC output cable assembly, depend on the working voltage. See 6.5.4.5.5.

Case 1: For a DC output with a working voltage of ≤550 V DC, basic protection shall be provided between this part of the circuit and the protective conductor.

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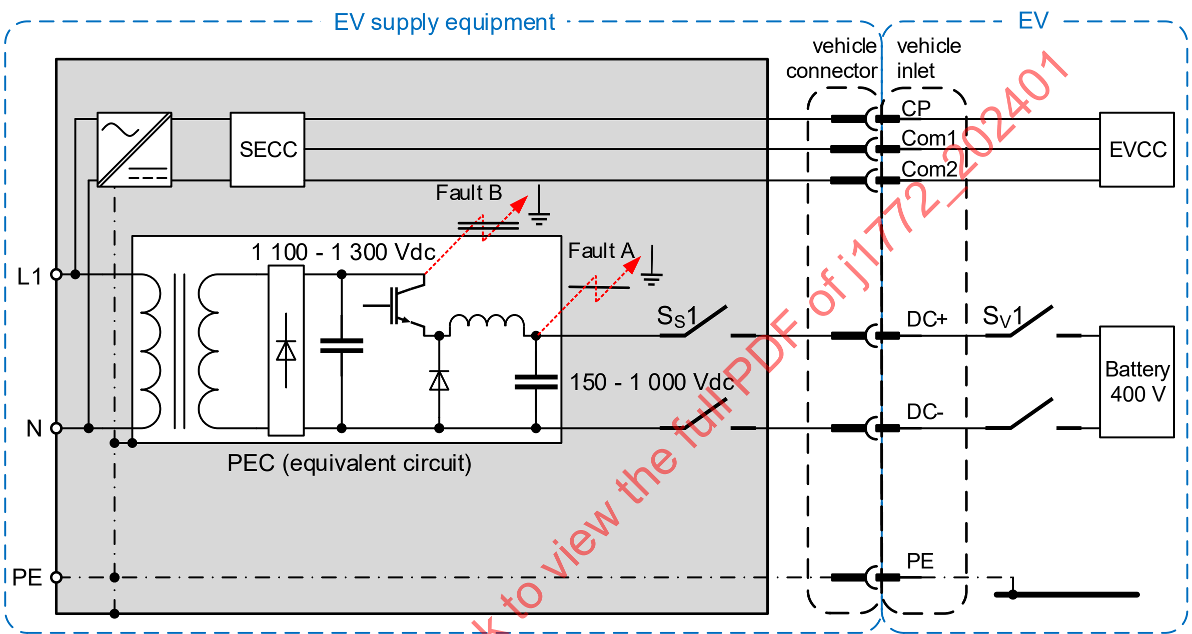
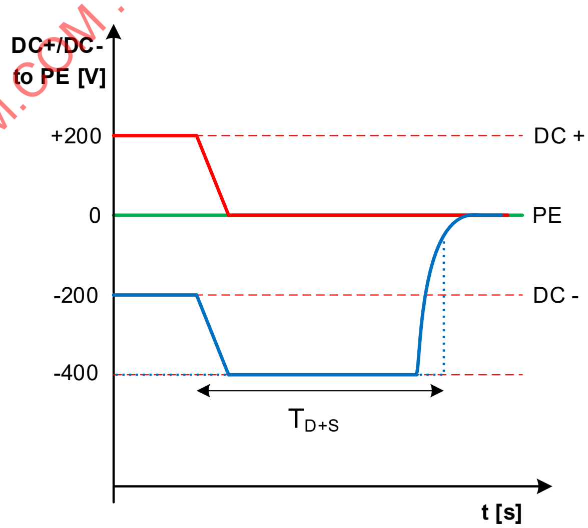
Case 2: For a DC output with a working voltage of >550 V DC, if a fault to the protective conductor causes a voltage between DC output live parts (DC+/DC-) and protective conductor of less than or equal to 110% of the present voltage at the DC output, basic protection shall be provided between this part of the circuit and the protective conductor. See fault A in Figure 27.

Case 3: For a DC output with a working voltage of >550 V DC, if a fault to the protective conductor causes a voltage between DC output live parts (DC+/DC-) and the protective conductor of more than 110% of the present voltage at the DC output between DC+ and DC-, double or reinforced protection shall be provided between this part of the circuit and the protective conductor. See fault B in Figure T105.

NOTE 1: Threshold of 550 V DC is due to backward compatibility with IEC 61851-23:2014.



a) Fault Locations



b) Waveform fo Fault A

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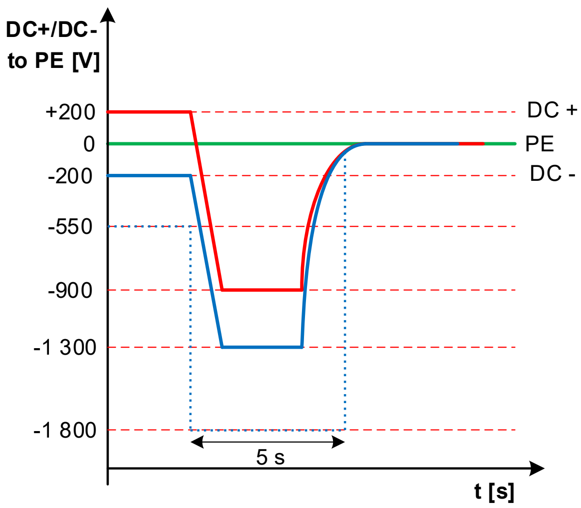

c) Waveform of Fault B

Key

PE	Protective conductor (protective earth)
TD+S	Detection time of the IMD/earth-leakage current monitoring device plus the error shutdown time
(single-line)	Basic insulation (see Fault A)
(double line)	Double insulation or basic insulation and electrically protective screening (shielding) or reinforced insulation (see Fault B)

Figure 27 - Examples of faults between the secondary circuit and the protective conductor

The following requirements apply under a fault to the protective conductor:

For EVSE based on Case 3, with a rated maximum voltage of the EV/PHEV supply equipment at the DC output of ≤500 V DC: if a voltage >550 V DC is present for more than 1 second between DC output live parts (DC+/DC-) and the protective conductor, the EVSE shall trigger and complete an error shutdown in 4 seconds or less. See Figure 27.

For EVSE based on Case 3, with a rated maximum voltage of the EV/PHEV supply equipment at DC output of >500 V DC and ≤1000 V DC: if a voltage more than 110% of the present voltage at DC output between DC+ and DC- is present for more than 1 second between DC output live parts (DC+/DC-) and the protective conductor, the EVSE shall trigger and complete an error shutdown in 4 seconds or less. See Figure 27.

In 5 seconds or less after a fault to the protective conductor, the EVSE shall limit the temporary overvoltage Vtov between DC output live parts (DC+/DC-) and the protective conductor to 1800 V DC.

NOTE 2: DC output voltages between DC+ and DC- >1000Vdc are under consideration.

6.6 Charge Coupler Requirements

As defined in 4.8.

The general contact sizes at the coupler interface shall comply with the dimensions as specified in Table 25.

Couplers for all DC charging methods shall implement the connector locking requirements in APPENDIX B, sheets B-1 through B-3 and the vehicle inlet lock zone defined in APPENDIX D, sheet D-1.

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Table 25 - Contact size and electrical ratings

Contact #	Function	Size (mm)	Current Rating (Amps)	Voltage Rating
1	+ DC Level 1 Power	3.6 diameter	up to 80 A	600 VDC
2	- DC Level 1 Power	3.6 diameter	up to 80 A	600 VDC
3	Equipment/chassis ground	2.8 diameter	Fault rated	
4	Control pilot	1.5 diameter	2 A	30 VDC
5	Proximity	1.5 diameter	2 A	30 VDC
6	+ DC Level 2 Power	8.0 diameter	up to 400 A	1000 VDC
7	- DC Level 2 Power	8.0 diameter	up to 400 A	1000 VDC

6.6.1 Retention Force

The coupler and indicated components shall not have any mechanical damage that will affect the functionality after performing the following tests.

6.6.1.1 Axial Force

Per IEC 61300-2-6, magnitude of force 753 N ± 1 N. Rate of force application 2 N/s. Duration of force application 60 seconds.

6.6.1.2 Torque

Per IEC 61300-2-7, magnitude of torque at the reference plane 20 Nm ± 1 Nm. Rate of torque application 0.2 Nm/s. Direction of torque application vertical and horizontal. Duration of torque application 60 seconds.

6.6.1.3 Cable Retention

Per IEC 61300-2-4, the vehicle connector shall be retained in such a manner so that the following force is applied to the cable retention mechanism and not applied to the coupling mechanism.

Magnitude of force 753 N ± 1 N. Rate of force application 5 N/s. Duration of force application 120 seconds.

6.6.2 Breaking Capacity

The coupler DC contacts are not rated for current interruption.

6.7 Vehicle Inlet

Standard configurations shall be capable of DC Level 1 or AC Level 2 charging.

Vehicle inlet lock function zone is defined in APPENDIX D, sheet D1.

6.7.1 DC Level 1

The contact requirements for DC Level 1 shall be as specified in Table 25, contacts 1 through 5.

Vehicle inlet dimensional requirements are defined in APPENDIX A, sheet A1.

6.7.2 DC Level 2

The contact requirements for DC Level 2 shall be as specified in Table 25, contacts 3 through 7.

Vehicle inlet dimensional requirements are defined in APPENDIX C, sheets C1 and C2.

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6.7.3 Inlet Contact Area Temperature Monitor

The inlet shall provide a means to measure (directly or indirectly) the inlet internal DC terminal contact area temperature. See 6.4.6.

6.8 Vehicle Connector

The connector shall be fitted with a cord corresponding to its intended usage and shall meet the requirements specified in NEC Article 625 for the power conductors, and UL 2251, Table 15.1 for ground conductors.

6.8.1 DC Level 1

The contact requirements for DC Level 1 shall be as specified in Table 14, contacts 1 through 5.

Vehicle connector dimensional requirements are defined in APPENDIX A, sheet A2 and APPENDIX B, sheets B-1 through B-3.

6.8.2 DC Level 2

The contact requirements for DC Level 2 shall be as specified in Table 14, contacts 3 through 7.

Vehicle connector dimensional requirements are defined in APPENDIX C, sheet C3 and C4.

6.8.3 Connector Contact Area Temperature Monitor

The connector shall provide a means to measure (directly or indirectly) the connector internal DC terminal contact area temperature. See 6.5.21.

7. NOTES

7.1 Revision Indicator

A change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

PREPARED BY SAE HYBRID - EV COMMITTEE

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APPENDIX A - CHARGE COUPLER DIMENSIONAL REQUIREMENTS (NON-LOCKABLE)

A.1 SCOPE

This appendix provides dimensional requirements for a non-lockable coupler vehicle inlet (Sheet A-1), connector (Sheet A-2), and vehicle inlet access zones (Sheet A-3). Dimensional requirements to implement an optional coupler locking mechanism is found in APPENDIX B, Sheets 1 to 3.

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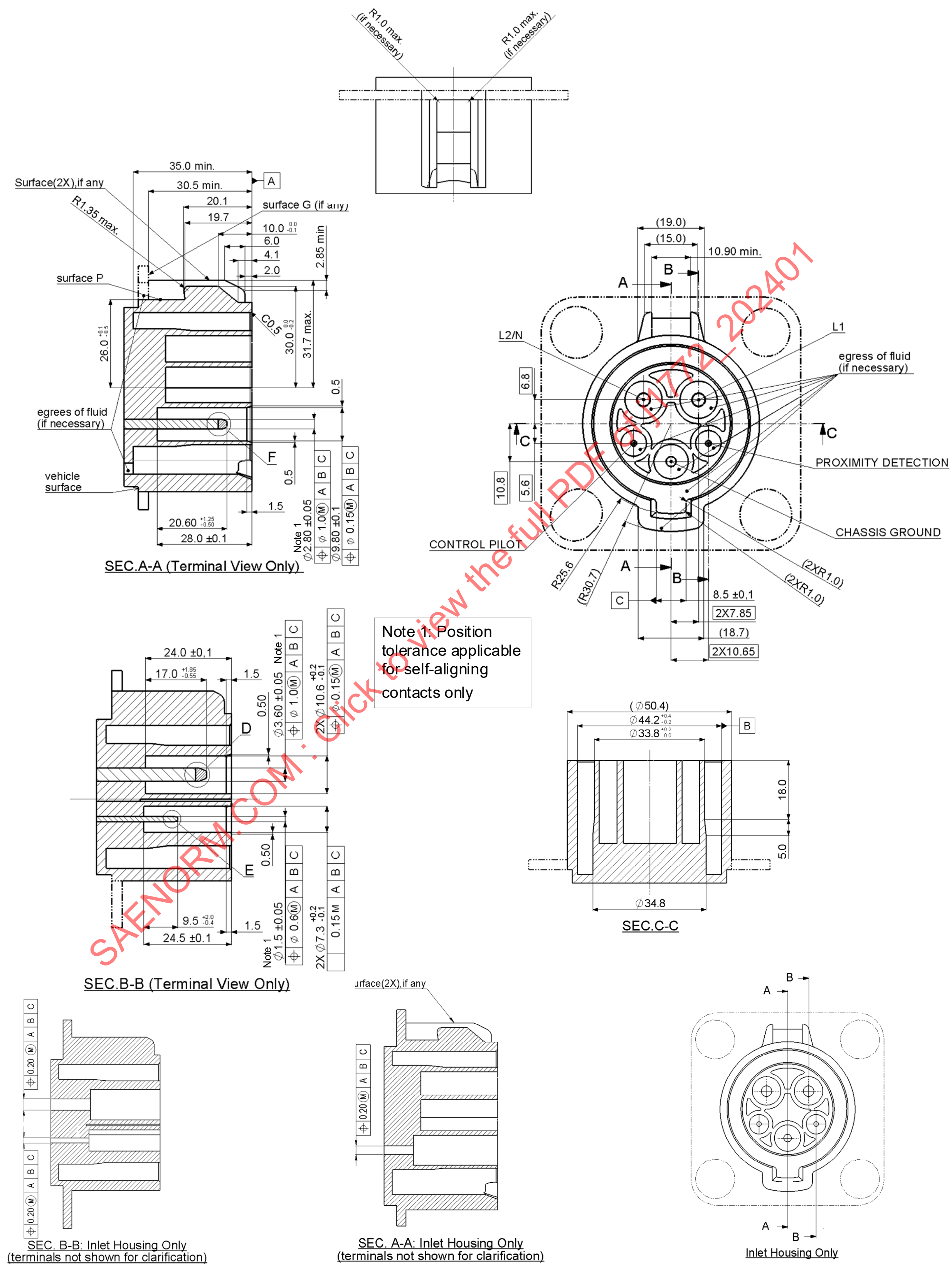
Sheet A-1 - Vehicle inlet



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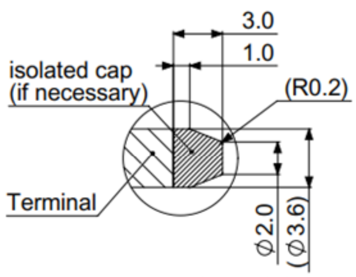
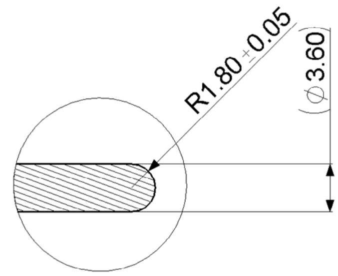
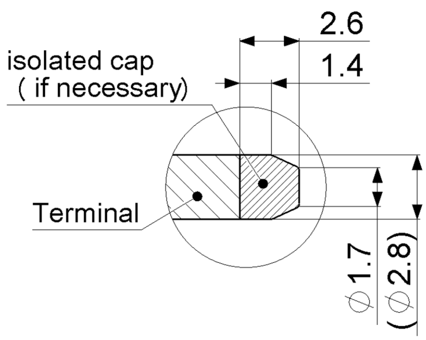
Sheet A-1 - Pin details



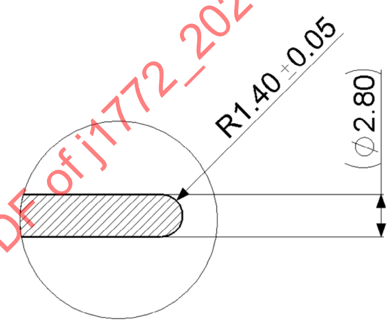
DETAIL D(L1,L2/N)



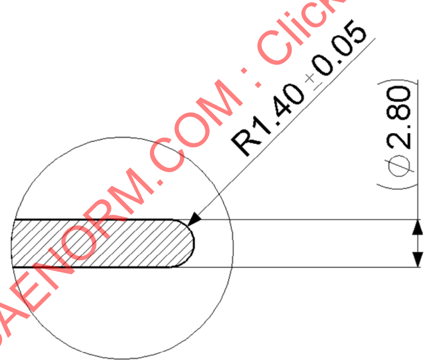
OPTIONAL CONSTRUCTION
(L1, L2/N)



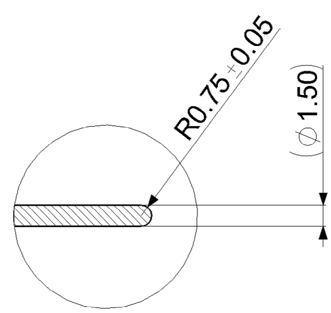
DETAIL F(Chassis Ground)



OPTIONAL CONSTRUCTION
(Chassis Ground)



OPTIONAL CONSTRUCTION
(Chassis Ground)



OPTIONAL CONSTRUCTION
(Control Pilot, Proximity Detection)

GENERAL TOLERANCE			
10 MAX	50MAX	100MAX	ANGLE
±0.15	±0.2	±0.3	±30'

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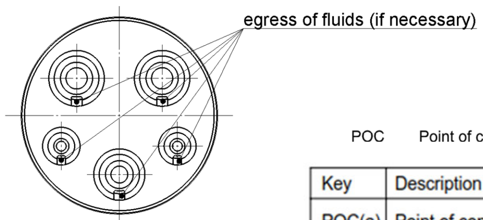
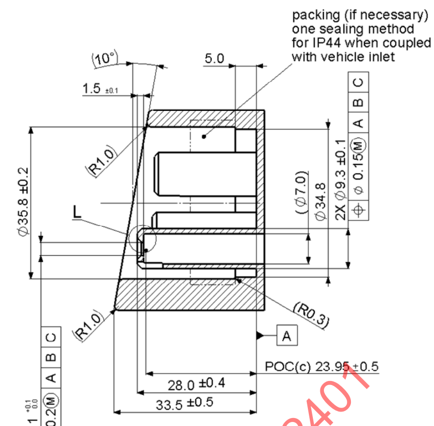
Sheet A-2 - Vehicle connector



DETAIL K

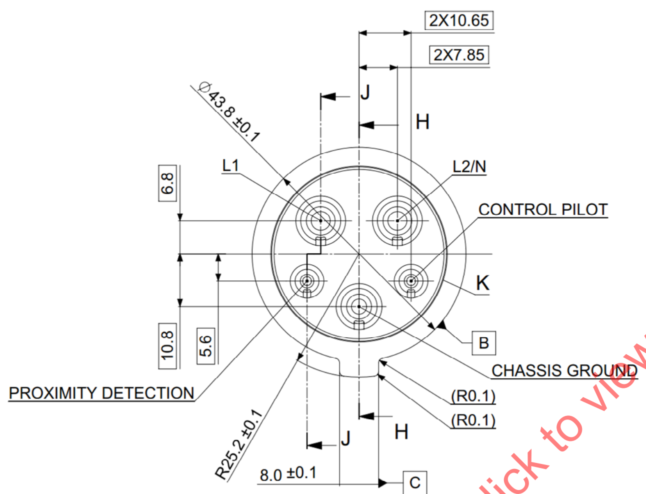
POC Point of contact

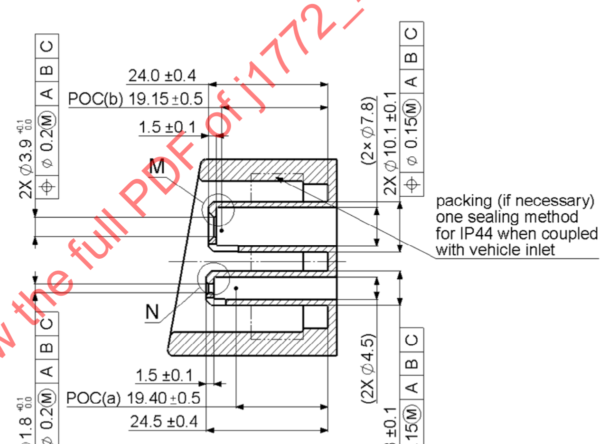
Key	Description
POC(a)	Point of contact for signal
POC(b)	Point of contact for power
POC(c)	Point of contact for PE



SEC.H-H

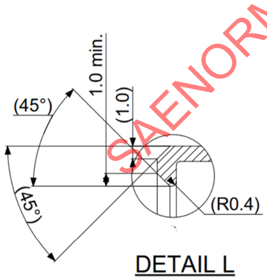
POC Point of contact



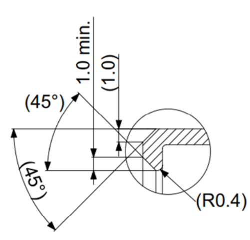


SEC.J-J

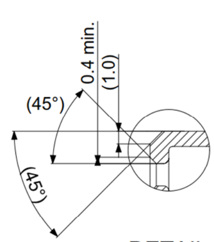
POC Point of contact



DETAIL L



DETAIL M



DETAIL N

Third angle projection
Dimensions in millimeters
Values in parenthesis is for reference

GENERAL TOLERANCE			
10MAX	50MAX	100MAX	ANGLE
±0.15	±0.20	±0.30	±30'

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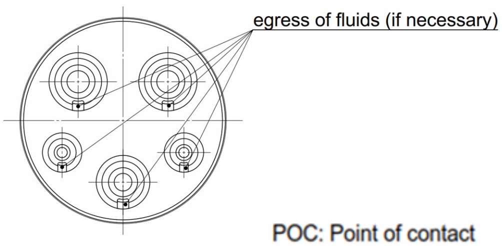
Sheet A-2 (continued) - Vehicle connector optional contact point



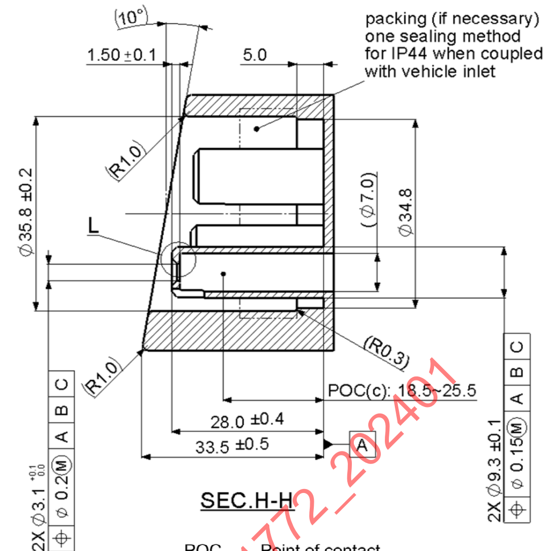
DETAIL K

POC: Point of contact

Each POC shall fulfill below equations

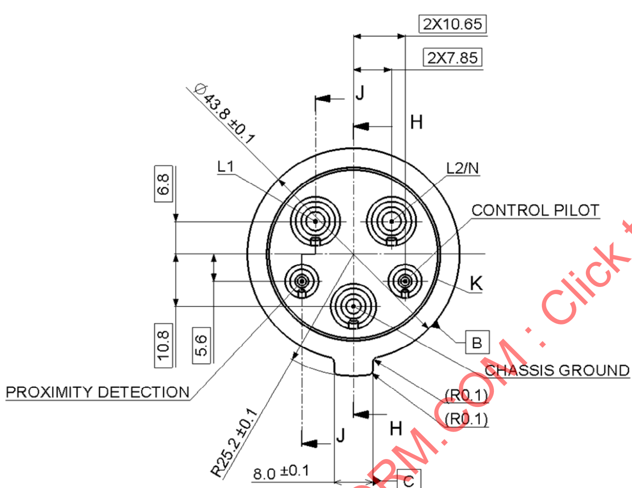
- POC(a) max. - POC(b) min. ≤ 2.9
- POC(c) min. - POC(b) max. ≥ 2.9

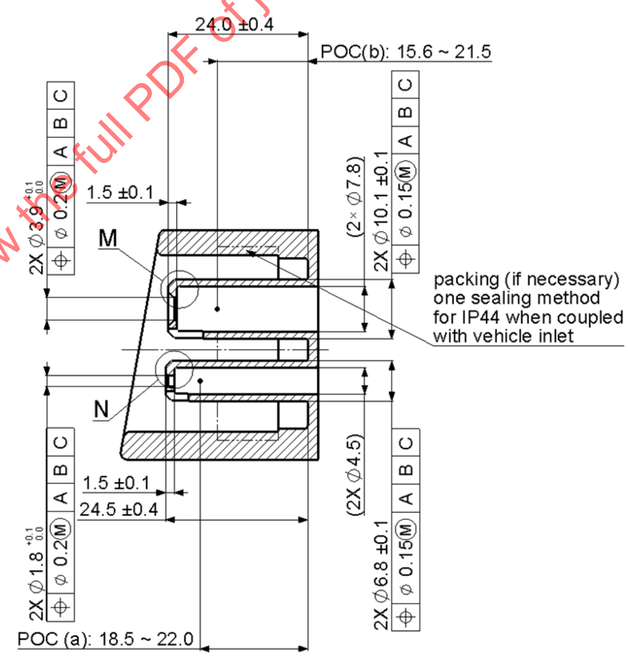
Key	Description
POC(a)	Point of contact for signal
POC(b)	Point of contact for power
POC(c)	Point of contact for PE



SEC.H-H

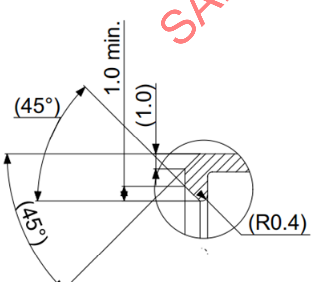
POC Point of contact



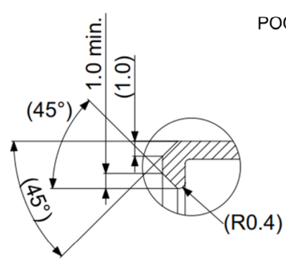


SEC.J-J

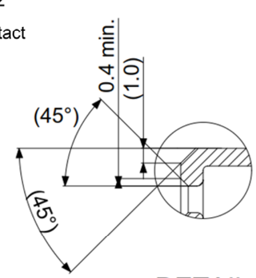
POC Point of contact



DETAIL L



DETAIL M



DETAIL N

Third angle projection
Dimensions in millimeters
Values in parenthesis is for reference

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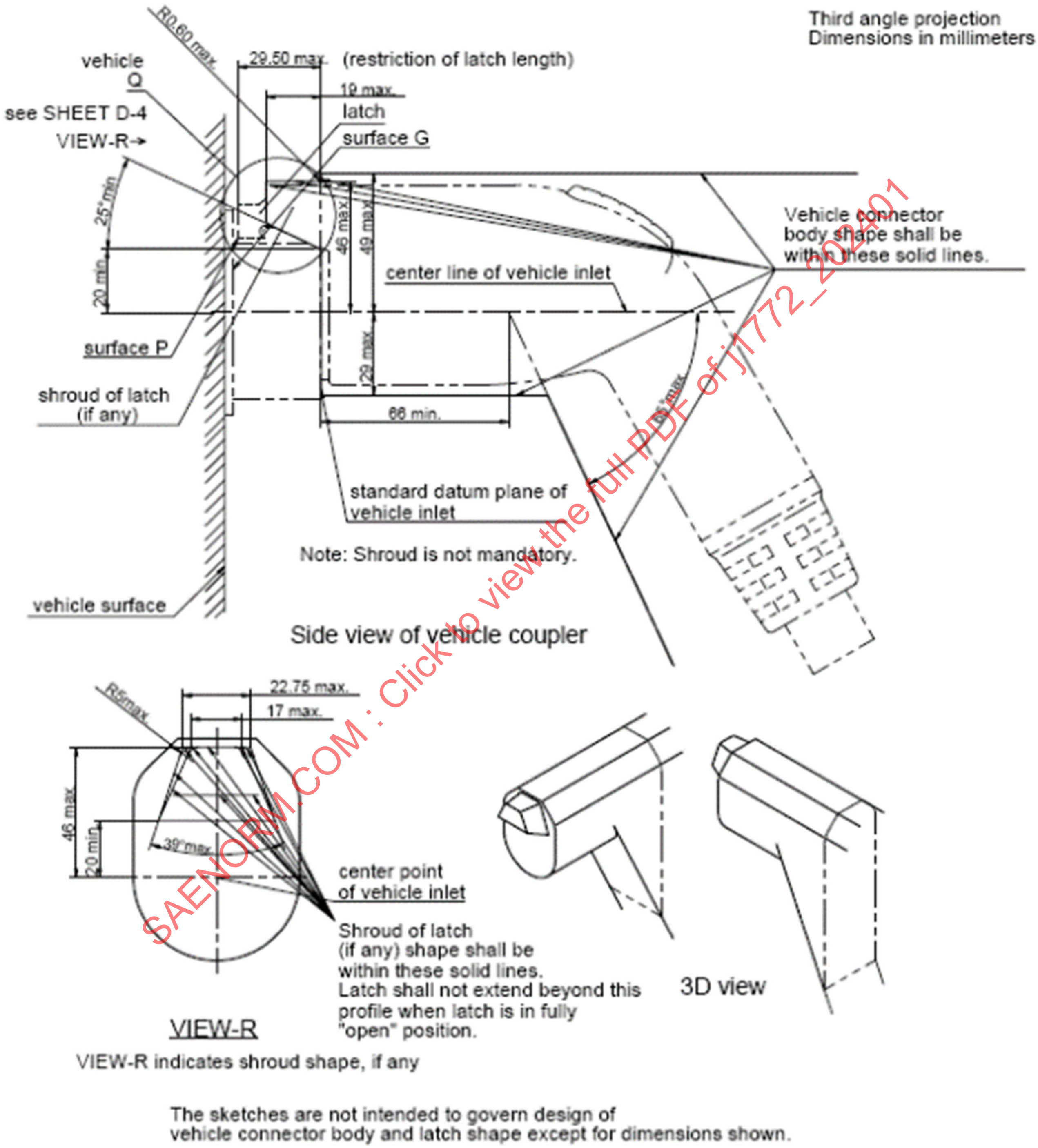
Sheet A-3 - Latch shown in latched position

NOTE: Not recommended for new coupler designs.
See Sheets B-1 to B-3.



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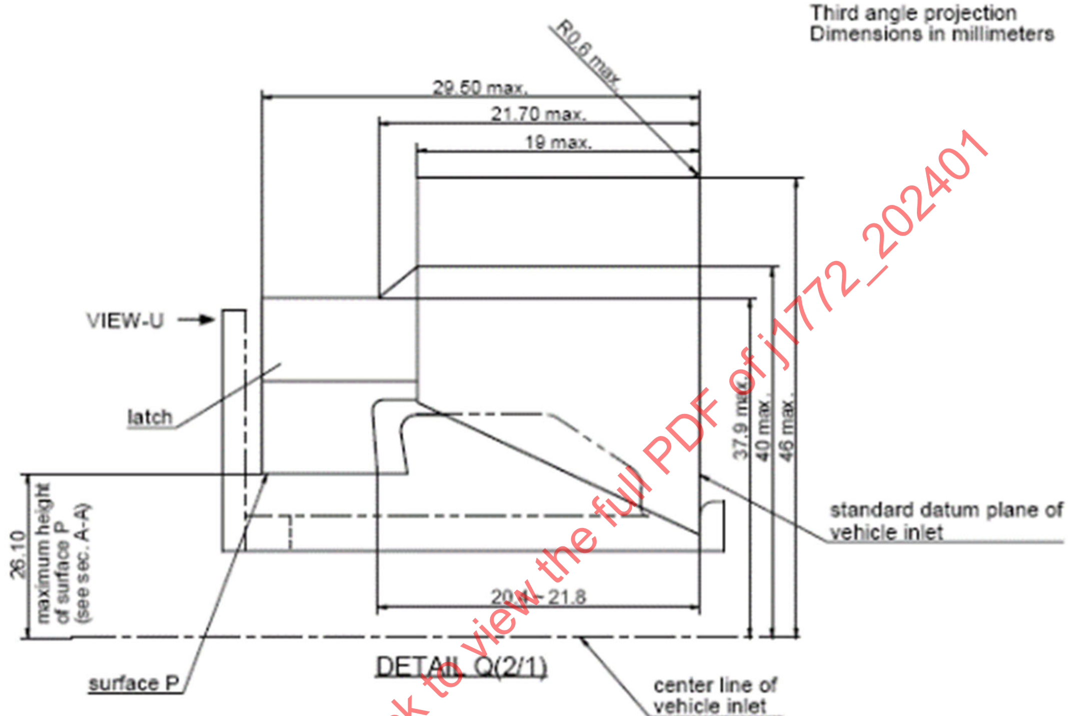
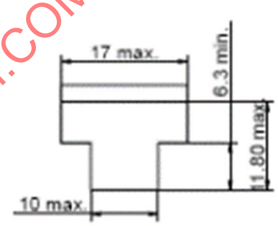
Sheet A-4 - Maximum outline of latch

Latch shown in touching surface P.
NOTE: Not recommended for new coupler designs.
See Sheets B-1 to B-3.





VIEW-U (indicates maximum outline of latch)

3D view

The sketches are not intended to govern design of latch shape except for the dimensions shown.

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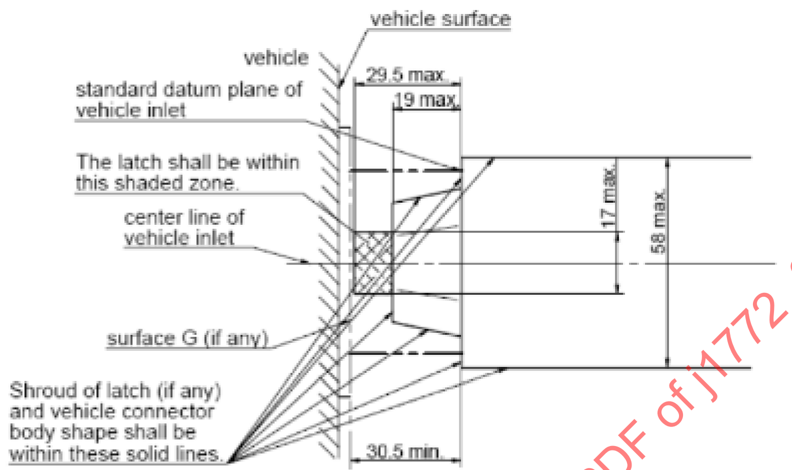
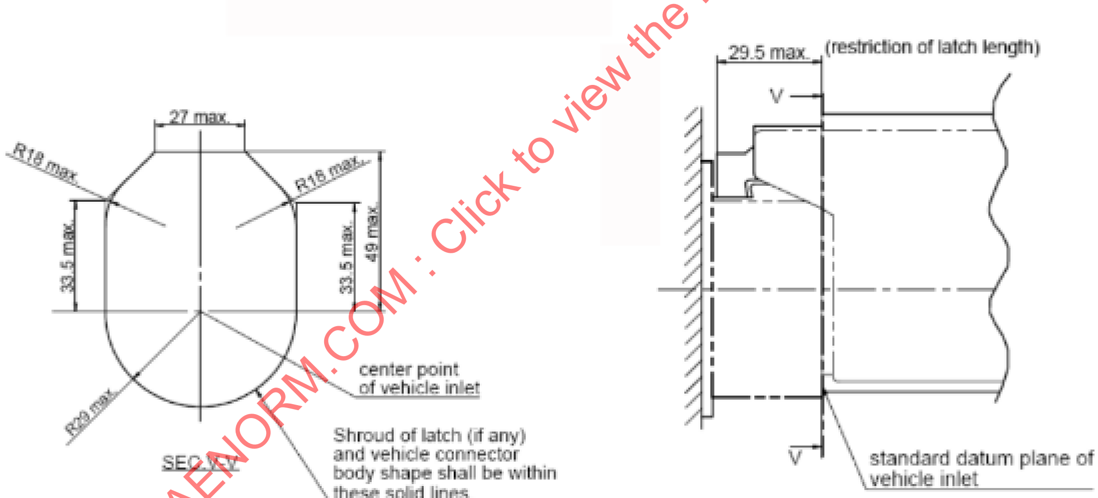
Sheet A-5 - Maximum dimensions of vehicle connector body and latch outline

NOTE: Not recommended for new coupler designs
See Sheets B-1 to B-3.

Third angle projection.
Dimensions in millimeters





The sketches are not intended to govern design of vehicle connector body and latch shape except for the dimensions shown.

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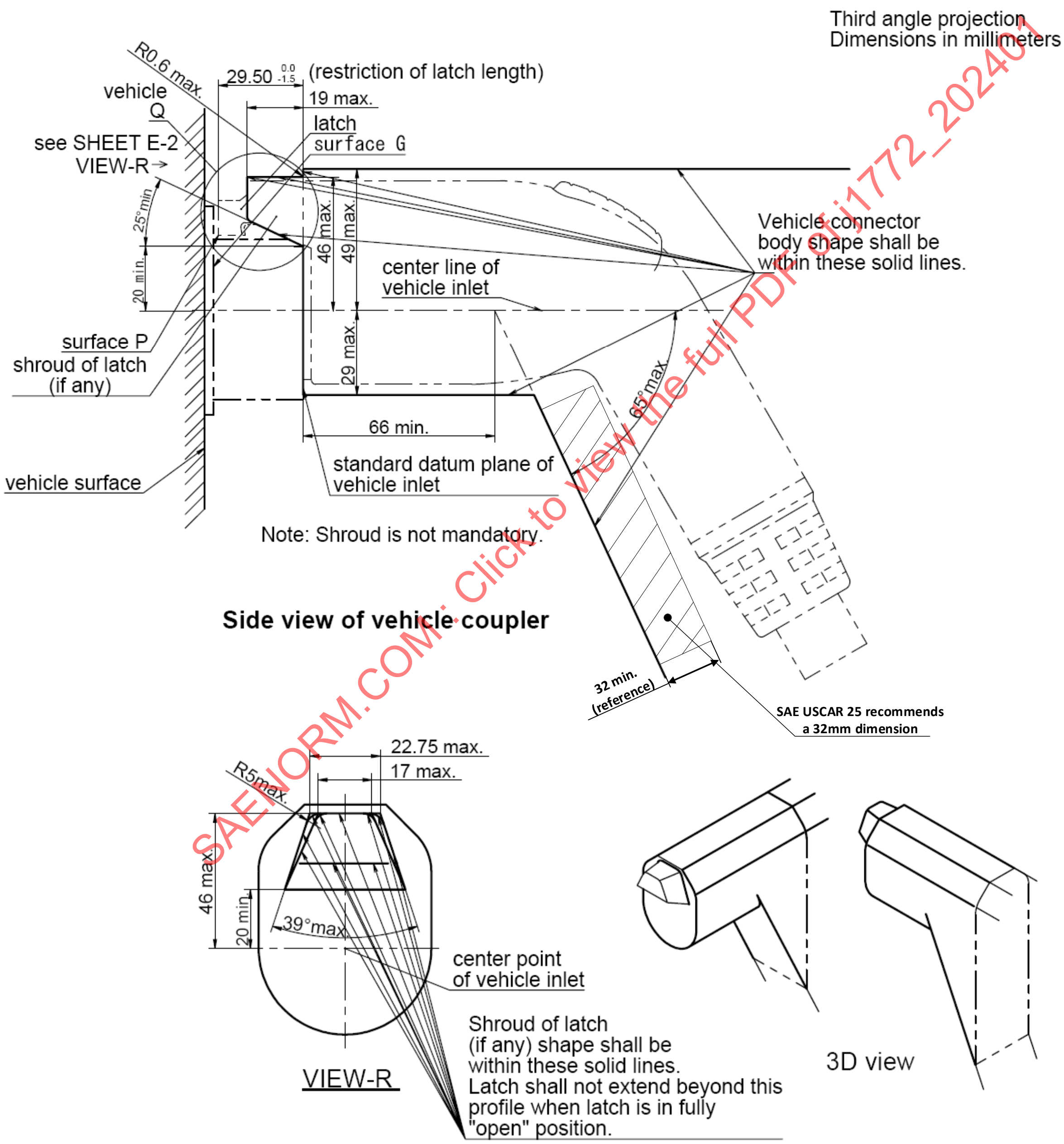
APPENDIX B - CHARGE COUPLER DIMENSIONAL REQUIREMENTS (LOCKABLE)

B.1 SCOPE

This appendix provides vehicle inlet access zone dimensional requirements for an optional lockable vehicle coupler. See Sheets B-1 to B-3. Note the no-fly zone (area between the “Vehicle connector body shape” solid lines) should accommodate (95th percentile gloved hand - SAE/USCAR 25 recommends a 32-mm dimension) user’s hand during mating and un-mating of the connector and inlet.

Sheet B-1 - Latch shown in latched position



VIEW-R indicates shroud shape, if any

The sketches are not intended to govern design of vehicle connector body shape and latch shape except for the dimensions shown.

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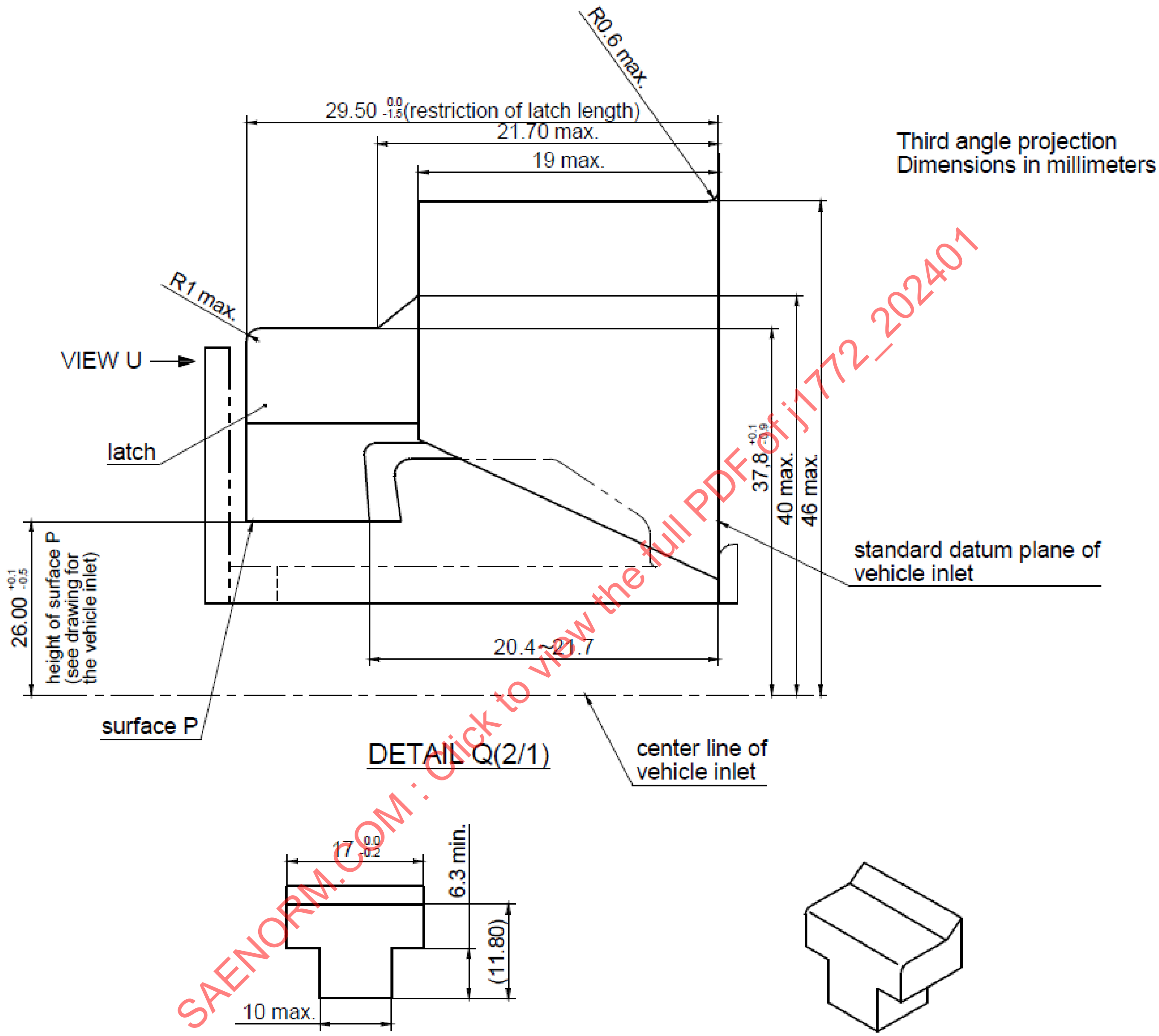
Sheet B-2 - Maximum outline of latch

Latch shown in touching surface P.



VIEW-U (indicates outline of latch.)

3D view

The sketches are not intended to govern design of latch shape except for the dimensions shown.

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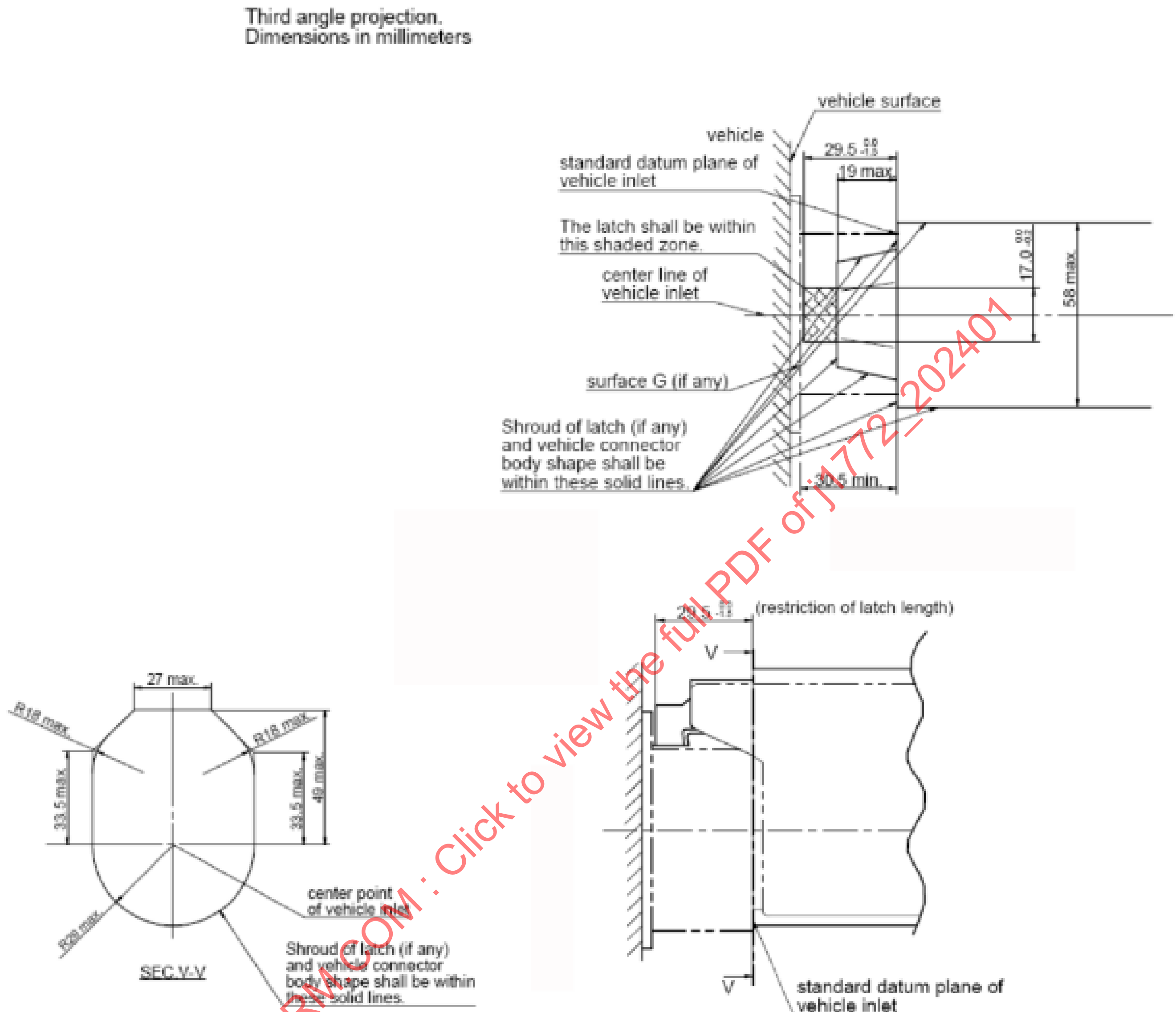
Sheet B-3 - Maximum dimensions of vehicle connector body and latch outline



The sketches are not intended to govern design of vehicle connector body and latch shape except for the dimensions shown.

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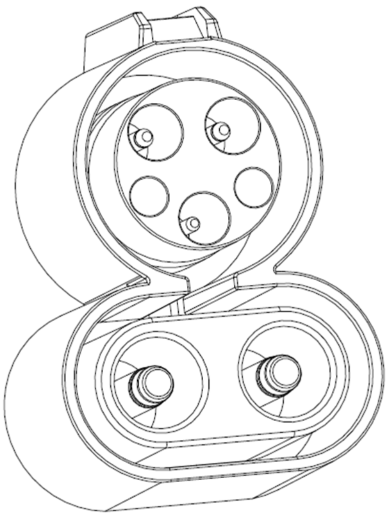
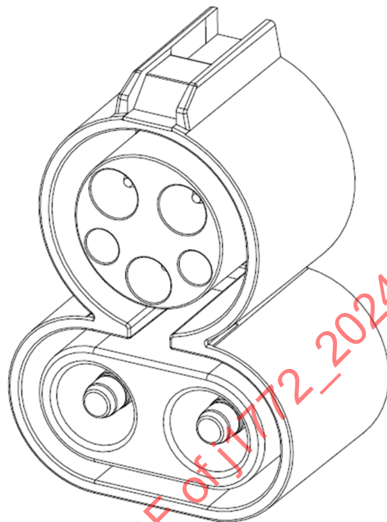
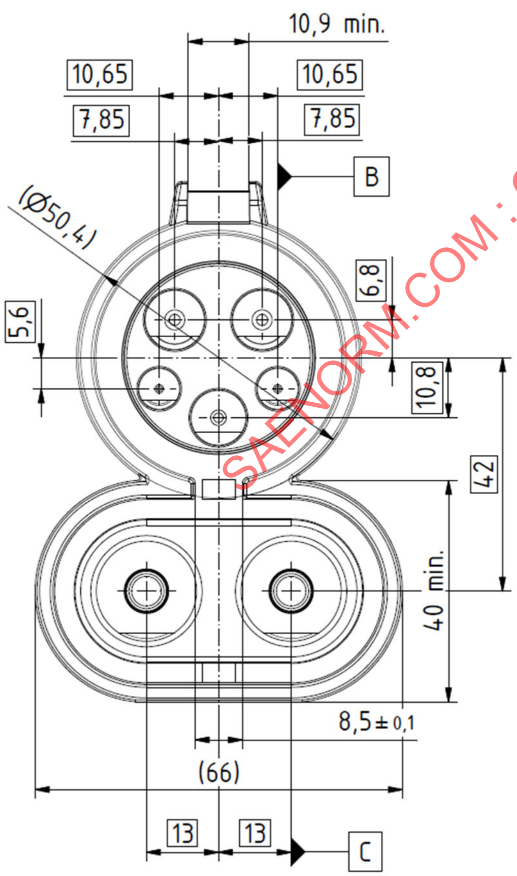
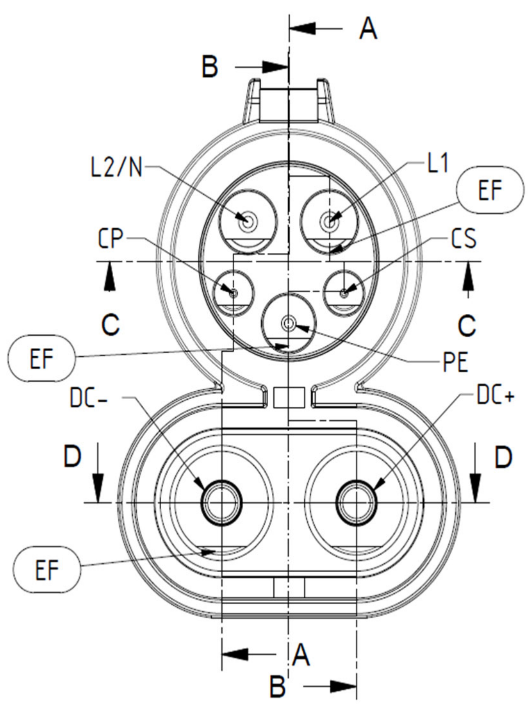
APPENDIX C - DC LEVEL 2 COUPLER

Sheet C-1 - Vehicle inlet









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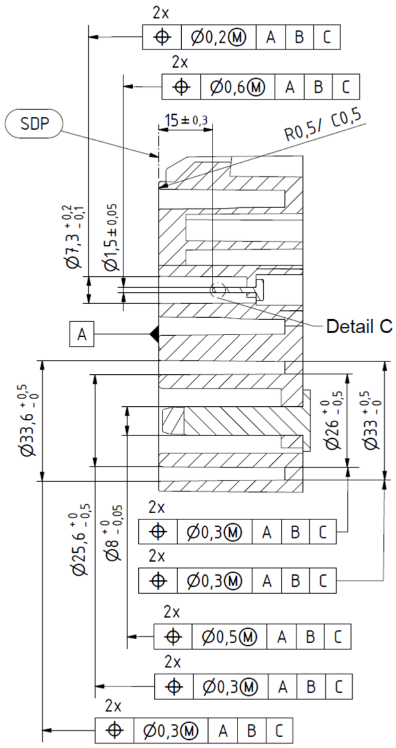
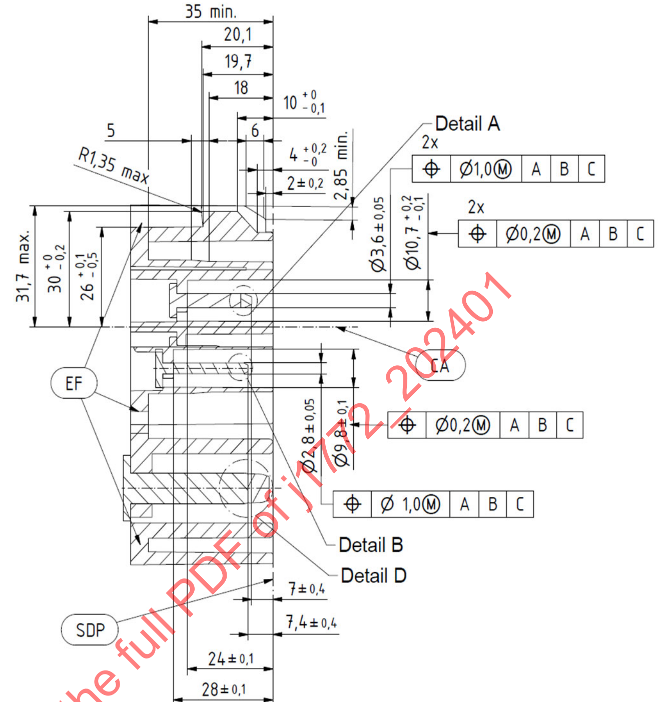
Sheet C-2 - Vehicle inlet (continuation of Sheet C-1)

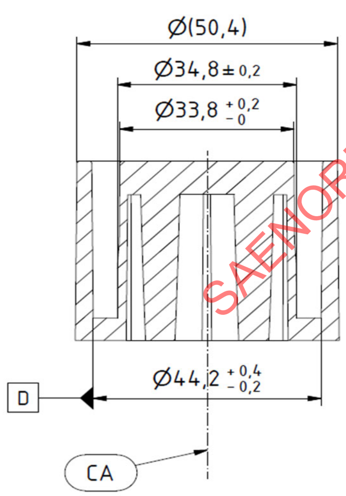
A-A (1 : 1)



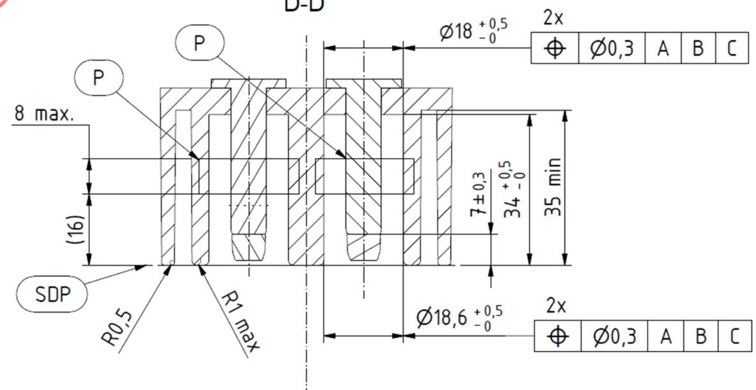
B-B (1 : 1)



C-C (1 : 1)



D-D



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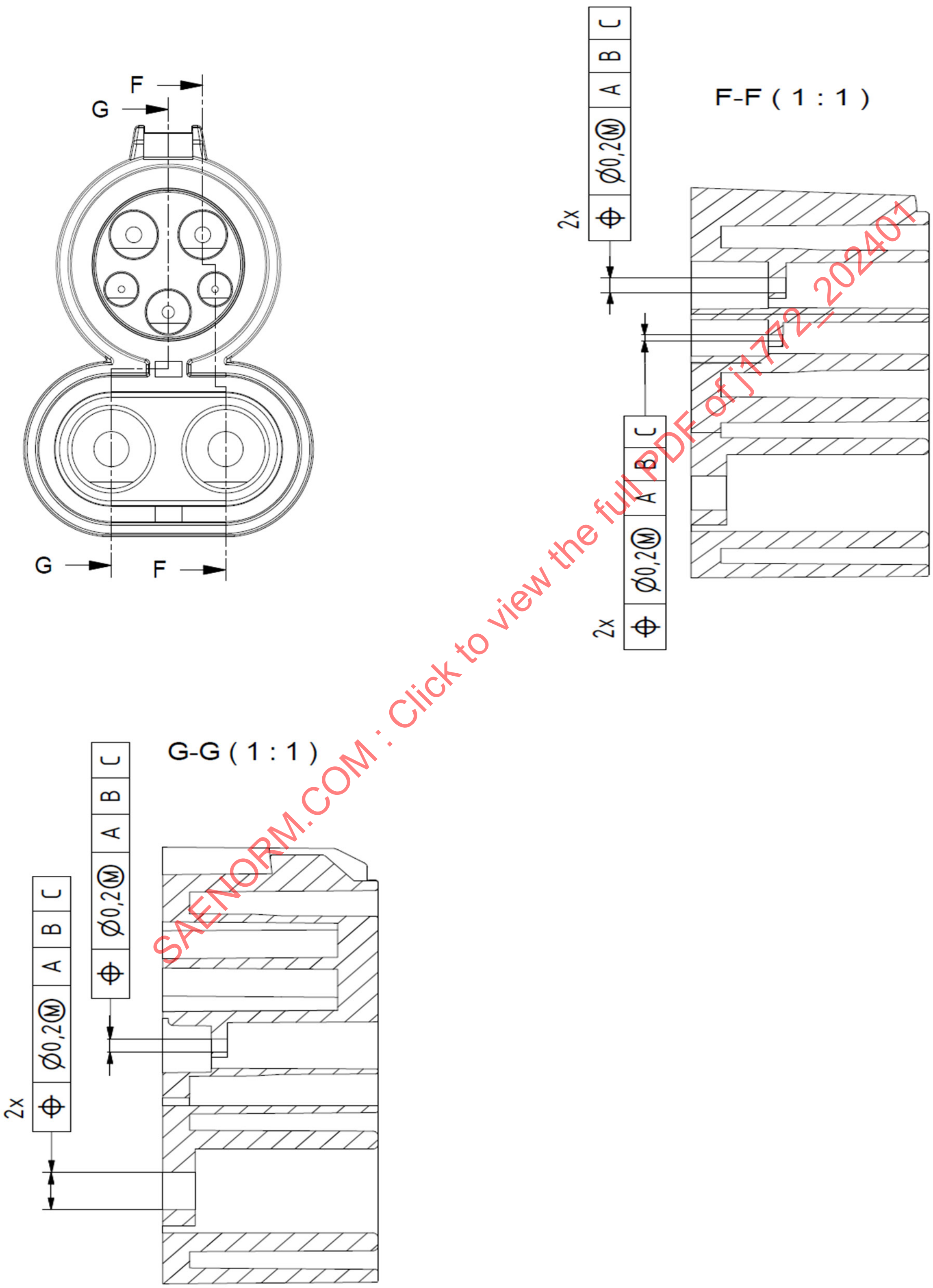
Sheet C-3 - Vehicle Inlet (continuation of Sheet C-2)



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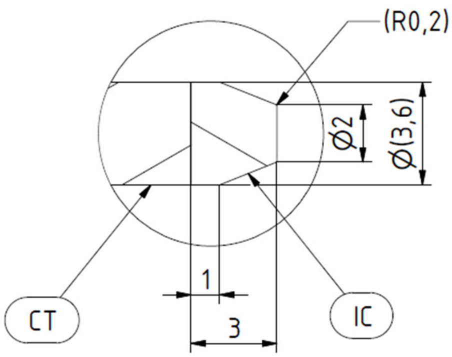
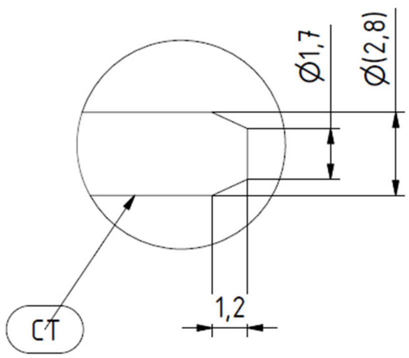
Sheet C-4 - Vehicle inlet - Sheet 4 (continuation of Sheet C-3)

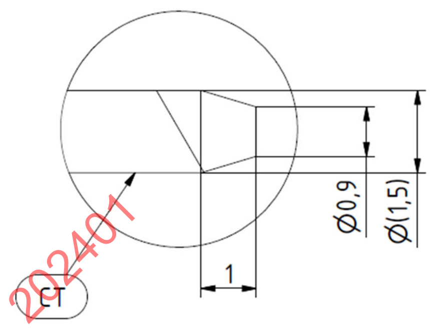
Detail A (5 : 1)
(L1, L2, N)



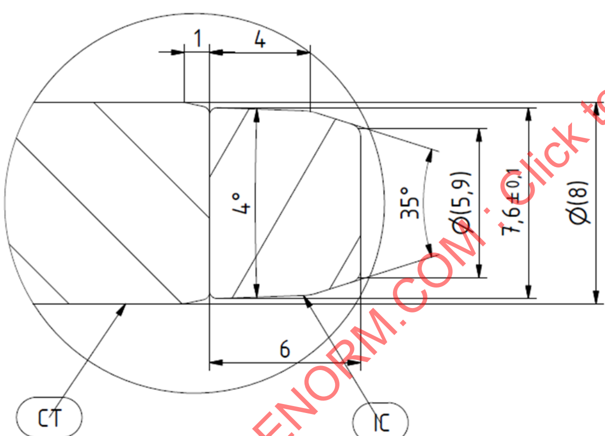
Detail B (5 : 1)
(PE)



Detail C (10 : 1)
(CS,CP)



Detail D (5 : 1)
(DC)



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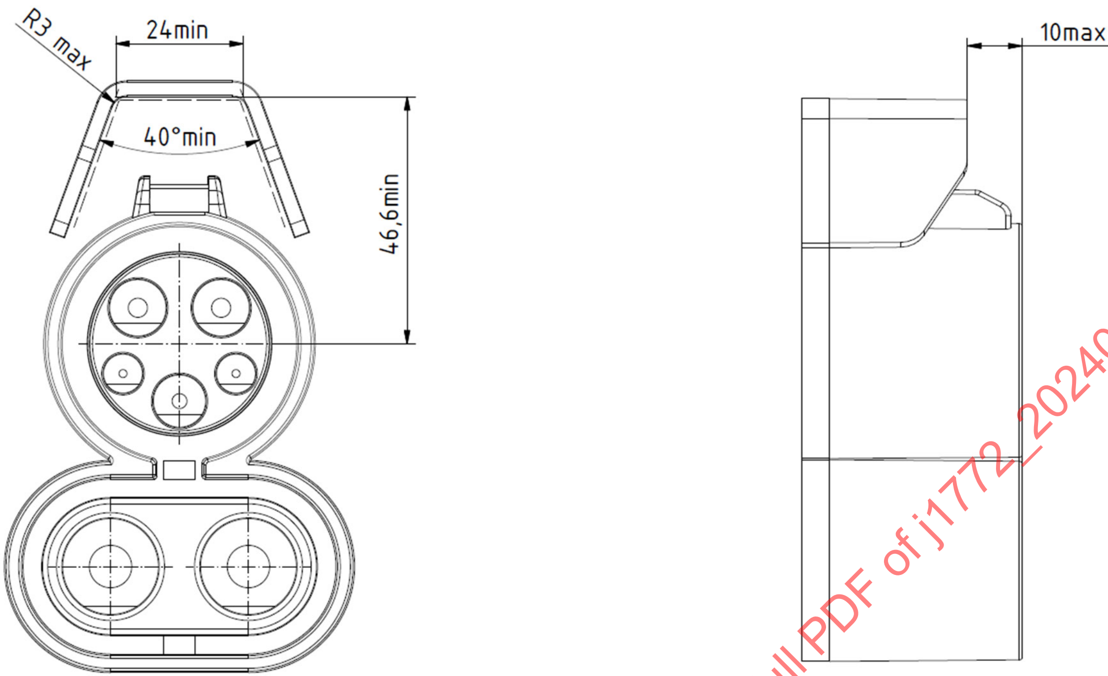
Sheet C-5 - Vehicle inlet (continuation of Sheet C-4)



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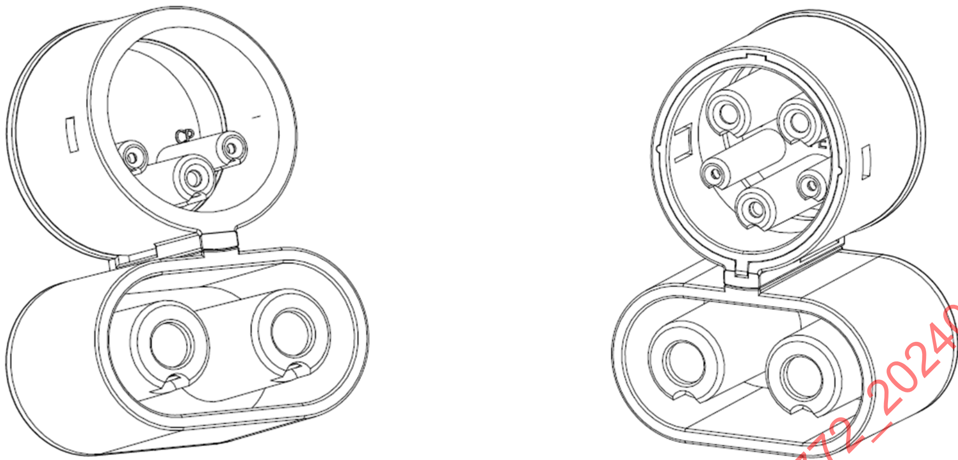
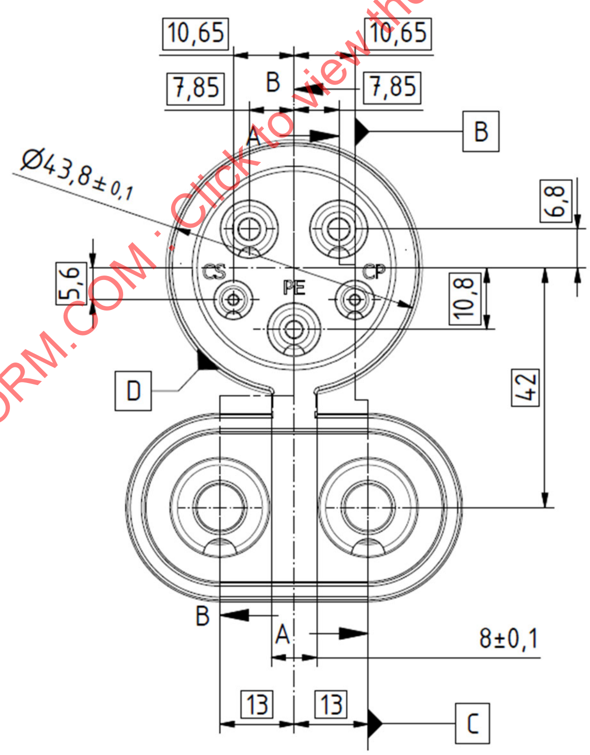
SDP - Standard Datum Plane
POC - Point of Contact
P - Packing one of sealing method (if any)
EF - Egress of fluids (if necessary)
CA - Center axis (Z-axis of AC portion)
CT - Contact
IC - Insolation Cap
G - Surface G
FIT - Latch Lock geometry shall not come outside this area
LLZ - Latch Lock Area, where some geometry of the locking device has to be for save funktion

(old: out of 2x Ø8,5)

Sheet C-6 - Vehicle connector





1 3 5 6

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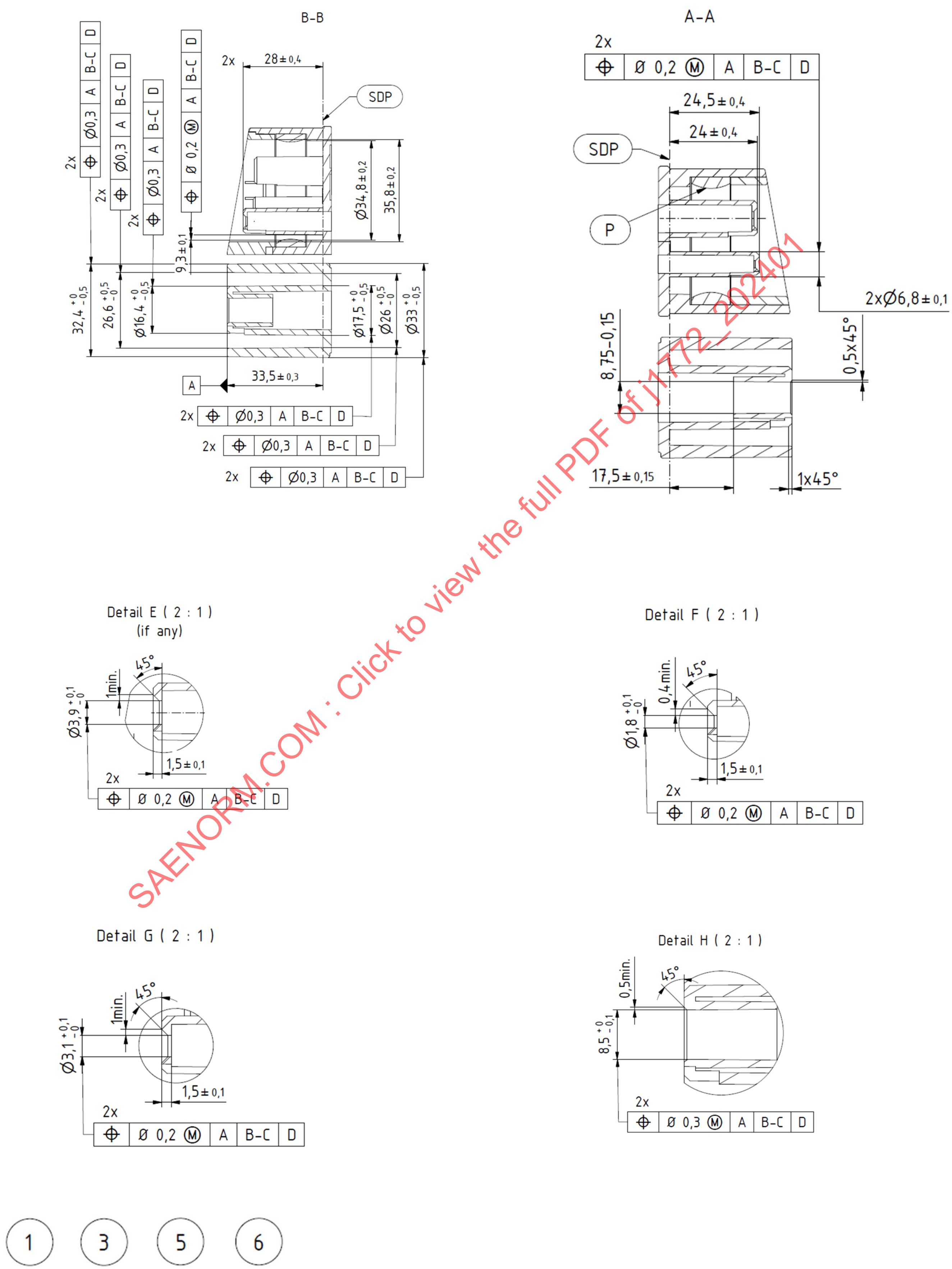
Sheet C-7 - Vehicle connector (continuation of Sheet C-6)



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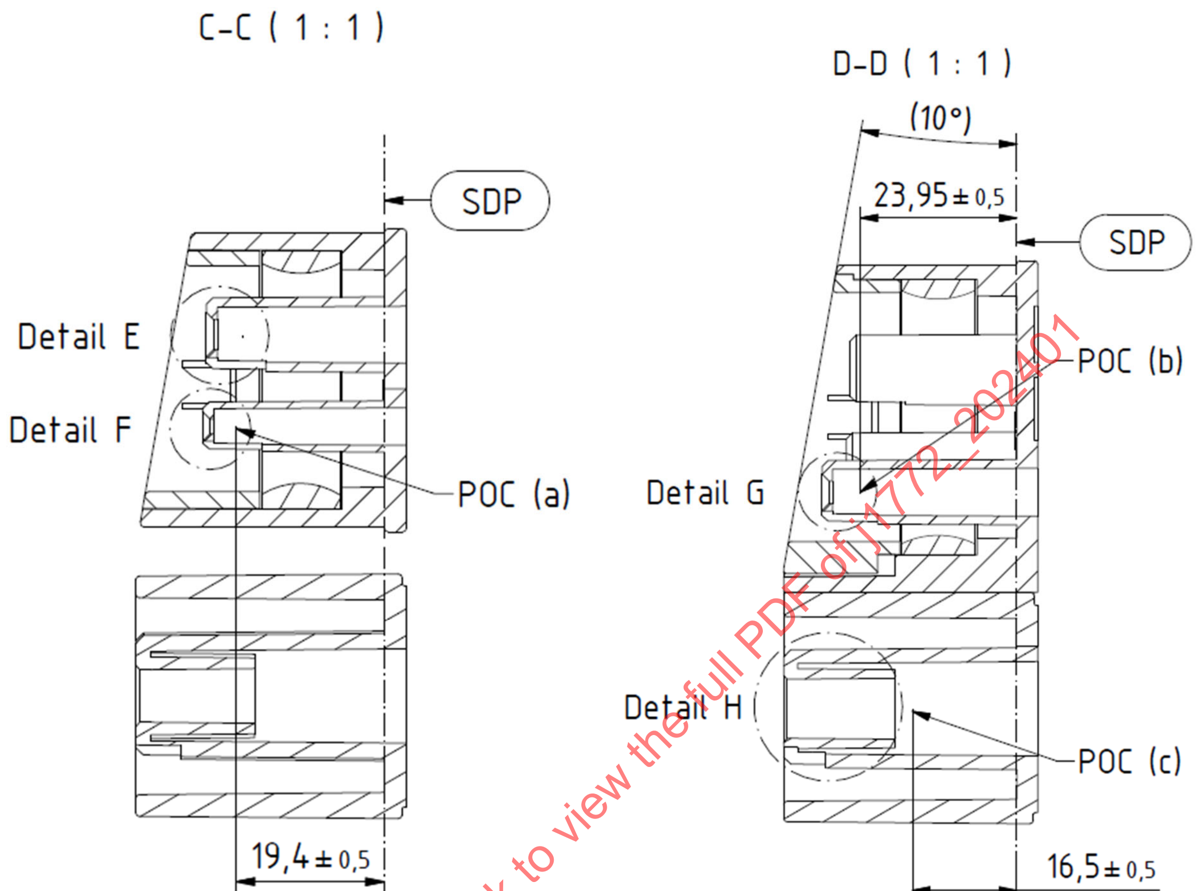
Sheet C-8 - Vehicle connector (continuation of Sheet C-7)



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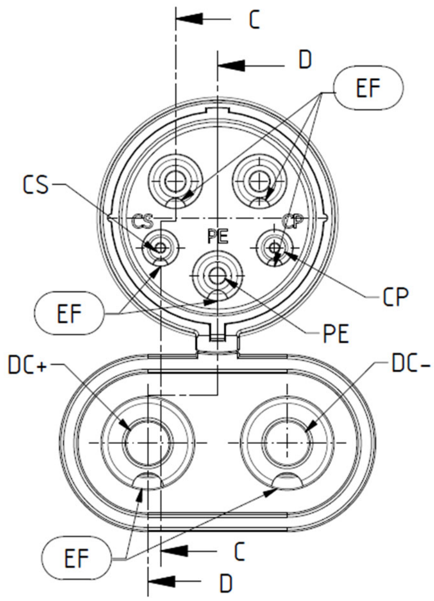
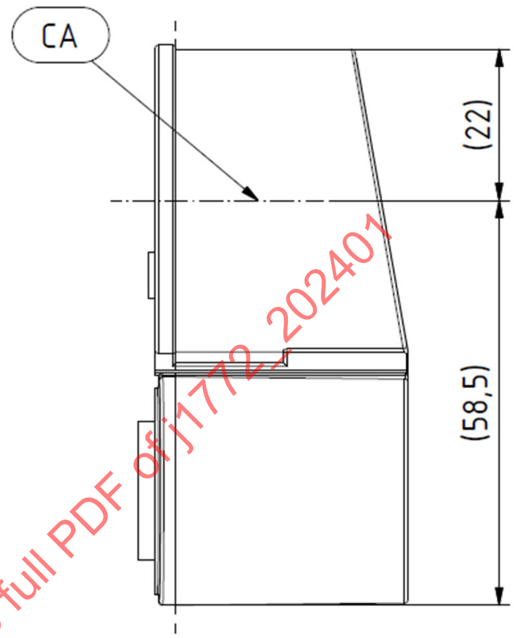
1 3 5 6

Sheet C-9 - Vehicle connector (continuation of Sheet C-8)





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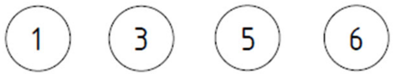
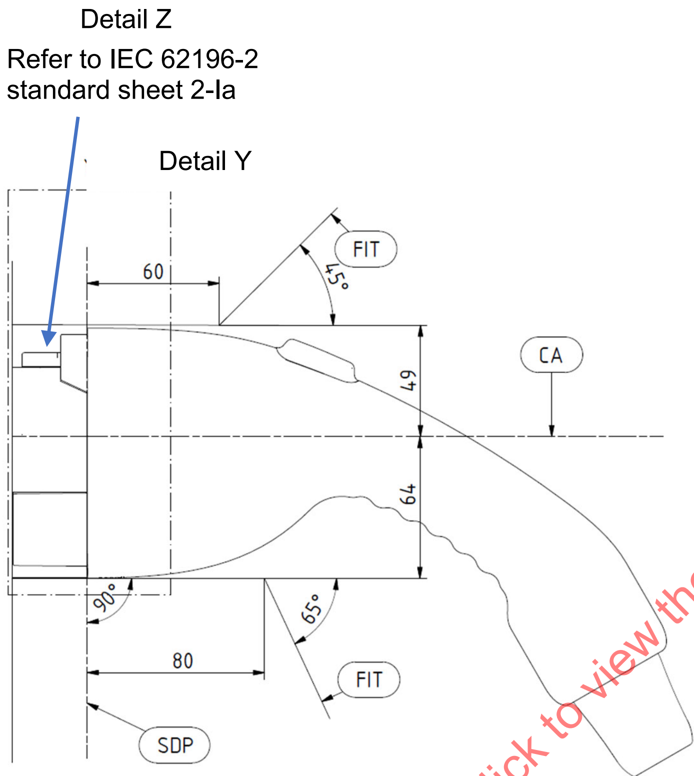
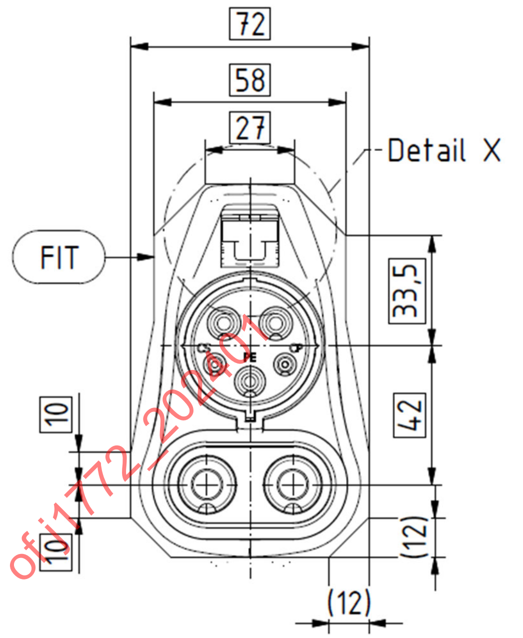
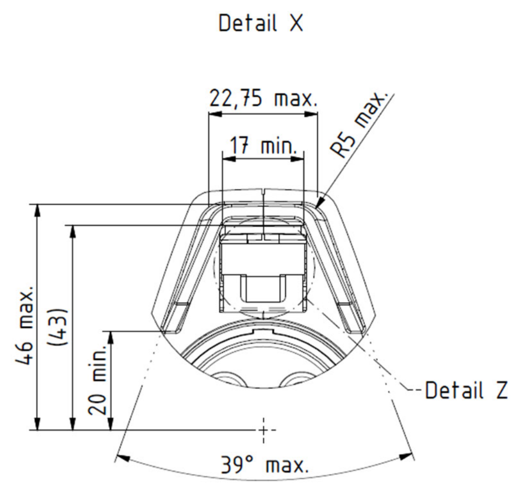


Sheet C-10 Vehicle connector (continuation of Sheet C-9)







1 3 5 6

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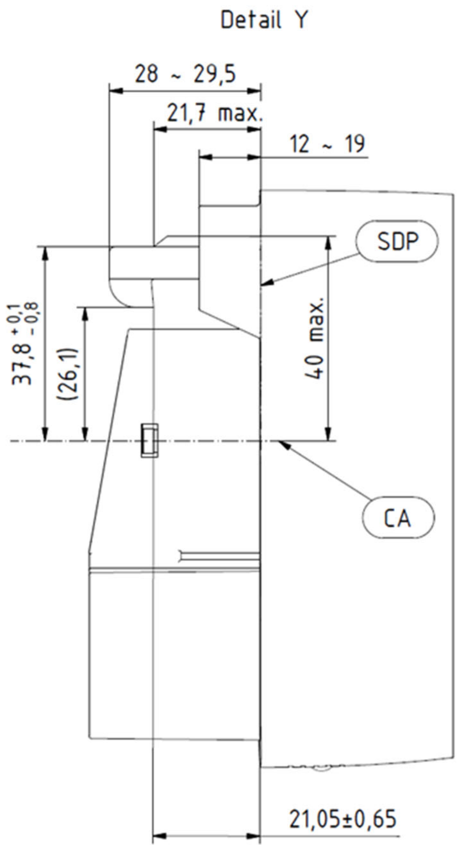
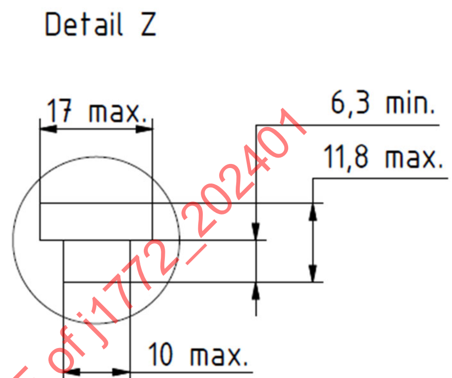
Sheet C-11 - Vehicle connector (continuation of Sheet C-10)





1 3 5 6

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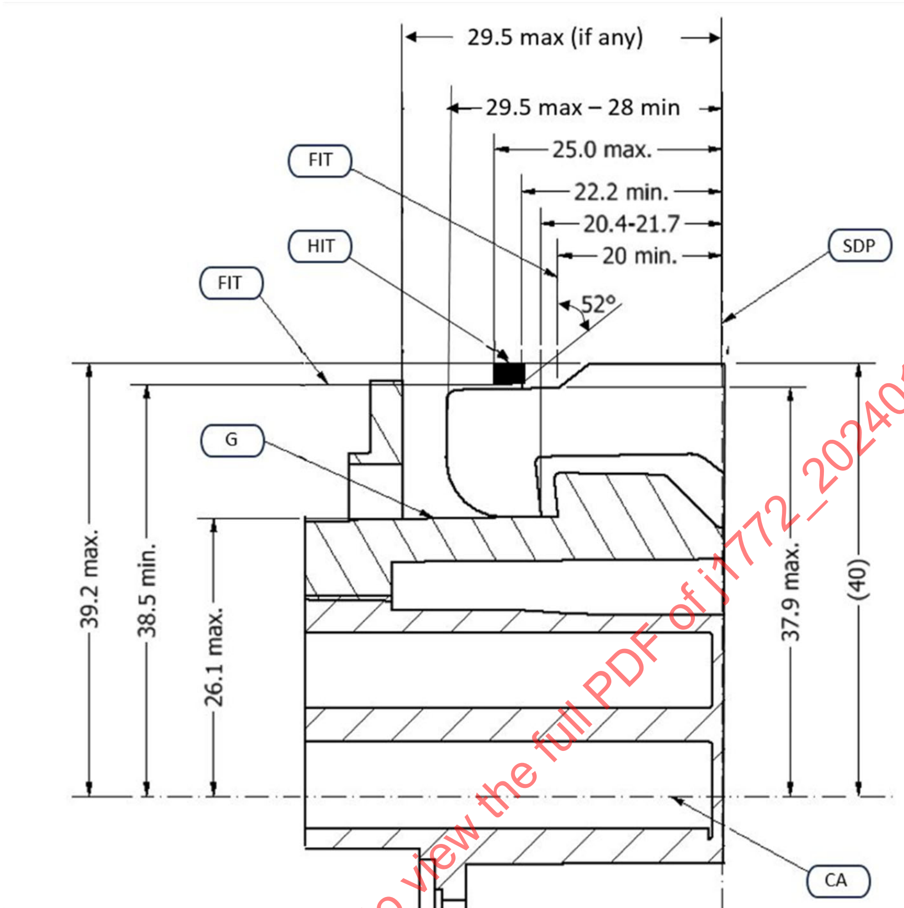
1	all dimensions in millimeters
2	(not used)
3	general tolerances DIN ISO 2768-mH
4	standard datum plane
5	dimensions in parenthesis for reference
6	(not used)
7	center line (z-axis) of AC part
8	space for optional face sealing
9	L1 and L2/N not used
10	Vehicle connector shall fit into this area
11	Egress of fluids (if needed)
12	Dimensions for CP contact sequence
13	Locking devices shall be inside this area
14	(not used)
15	(not used)
16	(not used)

SDP	Standard Datum Plane
POC(a)	Point of Contact Power
POC(b)	Point of Contact Signal
POC(c)	Point of Contact PE
POC(d)	Point of Contact DC
P	packing sealing (if any)
EF	egress of fluids (if necessary)
CA	center axis of AC part
FIT	area connector shall fit inside

Sheet C-12 - Latching lock details (mated situation)



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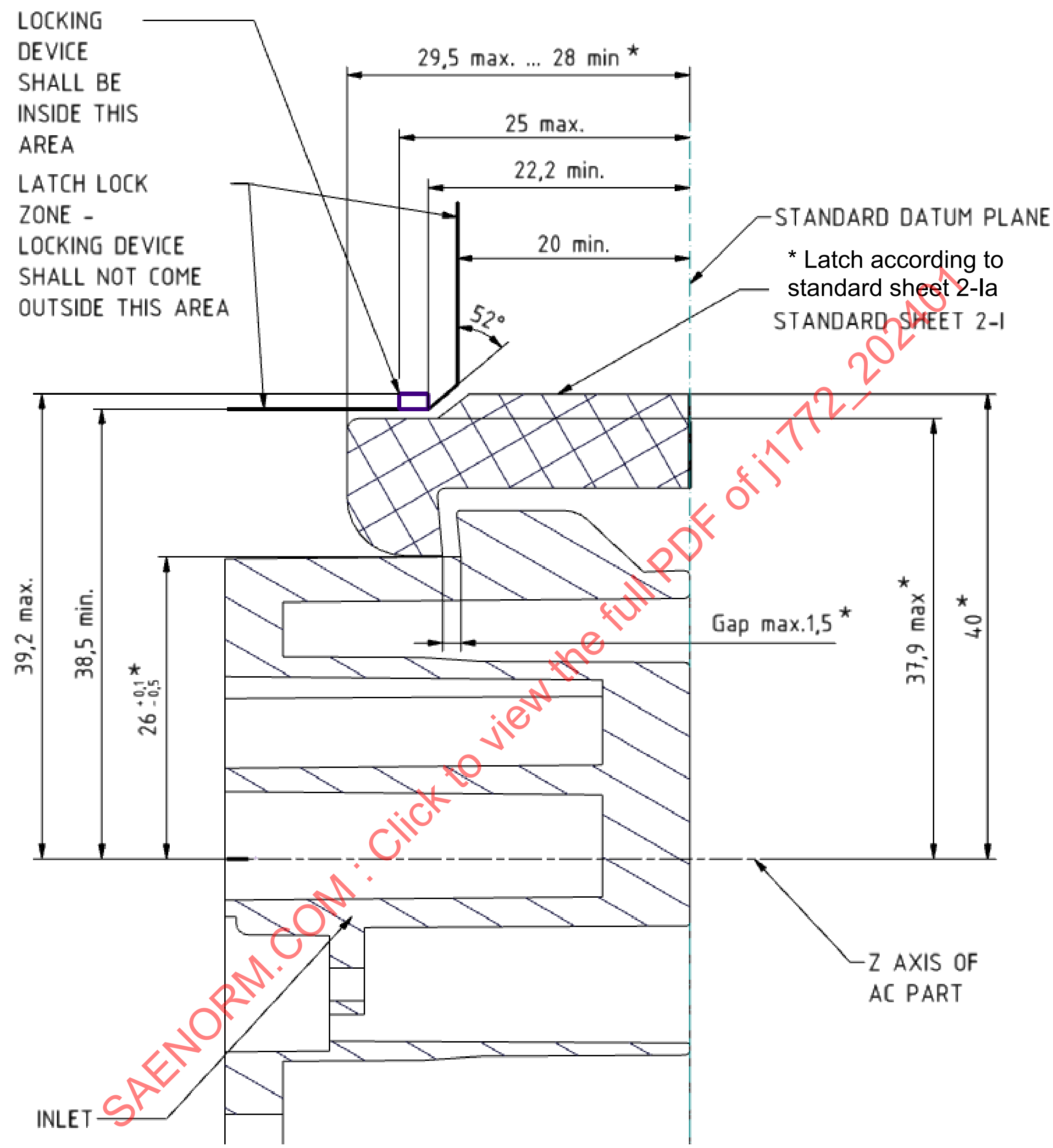
Key

17	all dimensions in millimeters
18	(not used)
19	general tolerances DIN ISO 2768-mH
20	standard datum plane
21	center line (z-axis) of AC part
SDP	Standard Datum Plane
CA	center axis of AC part
FIT	area connector shall fit inside
HIT	locking latch must be within this area
G	surface

APPENDIX D - VEHICLE INLET LOCK FUNCTION ZONE DEFINITION

Sheet D-1



All dimensions in mm.

* Reference dimensions according to IEC 62196-2 standard sheet 2-Ia.

Vehicle connector switch – S3: Switch should not abort while pressing button during charging process.

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APPENDIX E - EVSE AND EV/PHEV SEQUENCE AND RESPONSE TIME SPECIFICATIONS

E.1 START UP SEQUENCE

The charge process shall commence sequentially according to the following steps as the connector is inserted into the vehicle inlet:

a. The control pilot activates the EV/PHEV charge controller; the proximity detection activates the drive interlock.

b. Verification of EV/PHEV connection is detected by EVSE, by detecting a change from State A to State B1. During this state change, the oscillator is off. See switch S1.

c. EVSE indicates that it is ready to supply energy by turning on the oscillator and supplying PWM pilot signal to the EV/PHEV, State B2. See switch S1.

d. The EV/PHEV vehicle determines the nature of and available current from the EVSE according to one of the following three conditions by measuring the duty cycle of the signal and proceeding as follows (see 4.2.1.4.1 to 4.2.1.4.5 and Table 6):

    1. If the pilot duty cycle is between 10 and 96%, calculate available line current from the duty cycle and proceed to the next step.

    2. If the pilot duty cycle is between 3 and 7%, calculate available line current from the digital data link and proceed to the next step. See 5.2.3.

    3. If the digital data link cannot be established as described in 5.2.3, the process shall be terminated, and a fault condition displayed by the EVSE

e. The EVSE determines that the equipment grounding conductor to the EV/PHEV chassis ground is in place by detecting the high side of the Pilot is in State B1, B2, C, or D, while the low side is at -12 V.

f. The EVSE determines that the EV/PHEV pilot control circuitry is correctly configured by verifying the presence of the diode. The low side of the pilot pulse shall be within the range specified in Table 4.

g. EV/PHEV indicates that it is ready to accept energy from the EVSE by closing switch S2 and providing vehicle ventilation information to the EVSE, State C or State D.

h. The EVSE determines if indoor area ventilation is required or not. If indoor charging area ventilation is not required, then proceed to the next step. If indoor charging area ventilation is required, then three conditions can exist with corresponding EVSE responses. They are:

    1. Condition 1: If the EVSE is listed for indoor charging of all vehicles, turn on the indoor area ventilation system and proceed to the next step.

    2. Condition 2: If the EVSE is listed for outdoor charging of all vehicles, proceed to the next step.

    3. Condition 3: If the EVSE is listed for vehicles not requiring indoor charging area ventilation, terminate the process and do not allow energization.

i. The EVSE may now energize the system by closing the main power contactor and charging may commence at power levels up to the rated maximum continuous current of the EVSE for continuous rated conditions, or up to the rating of the protective circuit breaker for noncontinuous conditions, or up to the maximum rated current of the EVSE for DC charging as provided by the digital data link. A continuous load is defined as operating at a given level for more than 3 hours.

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j. The pilot signal shall be monitored, and charge current adjusted accordingly, continuously during the charge process. If pilot signal is lost or the pulse width goes outside of the allowable range, the EVSE shall terminate the charge process by opening the main contactor and turning off the pilot oscillator. The EVSE should also display a fault condition.

k. To terminate the charge process, turn the EVSE on/off switch to the off position and/or remove the connector from the vehicle inlet (see 4.2.2).

E.2 RESPONSE TIME SPECIFICATIONS

Table E1 - EVSE and EV/PHEV response time specifications for AC charging

Transition	Initial Condition[(1)(2)(3)]	New Condition	EVSE Response Time	EV/PHEV Response Time	Specification or Condition
1	State = x OSC = off	State = x OSC = on	No max		Delay until pilot oscillator will be turned on by EVSE.
2	State = x OSC = x	State = A OSC = x	100 ms max		Delay from disconnect until the contactor opens and terminates AC energy transfer.
3	State = x OSC = x	State = E or State = F OSC = x		5 seconds max	Delay until EV/PHEV opens battery isolation contactor.
4	State = x OSC = on	State = A OSC = off	2 seconds max		Delay until oscillator is turned off after EV/PHEV is disconnected.
5	State = B2 OSC = on	State = C or State = D OSC = on	3 seconds max		Delay until contactor closes and initiates AC energy transfer in response to S2 closed.
6	State = C or State = D OSC = on	State = B2 OSC = on	3 seconds max		Delay until contactor opens and terminates AC energy transfer in response to S2 opened.
7	State = x OSC = x	State = A or State = E or State = F OSC = x		4 seconds max; timed from the invalid pilot condition	EV/PHEV shall have reduced charge to 1 A or less (I ≤1.0 A @ t ≤4.0 seconds).
8	State = x OSC = x	State = E or State = F OSC = x	3 seconds max		Delay from EVSE setting invalid pilot until termination of AC energy transfer.
9	State = B2 or State = C or State = D OSC = on	Vehicle senses pilot frequency not within +/- 10% of 1000 Hz		4 seconds max; timed from the invalid pilot frequency condition	EV/PHEV shall have reduced charge to 1A or less within 4 seconds (I ≤1.0 A @ t ≤4.0 seconds).
10	State = x OSC = x	External signal to EVSE	10 seconds max		Delay from external load management signal until EVSE modifies pilot signal state, duty cycle, or other required response.
11	State = C or State = D OSC = on	Change in pilot duty cycle		5 seconds max	EV/PHEV modifies max current draw for on-board battery charger in response to pilot signal duty cycle modification.
12	State = C OSC = on	State = D OSC = x	3 seconds max		EVSE response to change of ventilation request.
13	State = C or State = D S3 closed	State = C or State = D S3 open		100 ms max	EV/PHEV should terminate charge due to Proximity circuit opening (pressing of S3). (I ≤1.0 A @ t ≤100 milliseconds).
14	State = B1 OSC = off	State = B2 OSC = on	No max		EVSE transitions from not ready to supply energy to ready to supply energy.

(1) Current State from Tables 15 and 16 defining pilot voltage and vehicle state.
(2) OSC = off for pilot oscillator turned off, OSC = on for pilot oscillator turned on.
(3) x for state or oscillator indicates any condition or unknown condition.

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NOTES: (Note that numbers correspond to Transition column in Table E1):

1. The pilot signal oscillation indicates that the EVSE is ready to supply energy. Regardless of the state transition, there is no guarantee that the EVSE will be ready to supply AC energy within a minimum time period.

2. The transition from any State to State A indicates the vehicle connector has been removed. For safety reasons, it is important to de-energize the connector.

3. The transition from any State to State E or State F is an indication that the connector has been removed or that the EVSE is not available.

While in State F, the EVSE may optionally attempt to automatically restart the charge sequence while connected to an EV/PHEV. The EVSE shall limit the optional restarts to a maximum of 20 with a 15-minute minimum time interval between restart attempts. If the charge cycle does not restart within the maximum of 20 optional restarts, user intervention is required to reset the EVSE to restore normal operation.

4. After a transition from any State to State A, the EVSE should turn off the oscillator (S1). For the purpose of filtering and reasonable control response time, the EVSE shall not turn off the oscillator immediately. The connector may be immediately reinserted into the vehicle, and the EV/PHEV could see State C or State D with the oscillator turned on and no AC energy transfer for the listed maximum time before the oscillator is turned off.

5. After the vehicle closes S2 in order to request AC energy transfer, the vehicle can expect the contactor to close within a specified time period.

6. After the vehicle opens S2, in order to stop requesting AC energy transfer, it can expect the contactor to open within a specified time period.

7. The vehicle should respond to the pilot signal voltages. In this case, the EVSE could be experiencing a power outage, ground fault, or other condition that requires termination of the AC energy transfer mode. The vehicle shall reduce charge to 1 A or less within 4 seconds timed from the invalid pilot condition. (I ≤1.0 A @ t ≤4.0 seconds).

8. If the EVSE transitions to State E or F, the EVSE shall open the contactor in less than 3 seconds.

9. The vehicle should respond to a pilot signal frequency that is significantly out of tolerance. The frequency of the EVSE oscillator is used to verify connection to a compatible EVSE and proper operation of the EVSE. If the frequency is incorrect, the vehicle shall reduce charge to 1 A or less within 4 seconds. (I ≤1.0 A @ t ≤4.0 seconds). The tolerance shall be ±10%, 1100 to 900 Hz.

10. It is common for EVSE equipment to support an input signal for the purpose of external load control (utility service interrupt signal, etc.). This input is used for various purposes including off-peak charging support, utility load shedding, and building load management controllers. A maximum response time should be specified to guarantee universal compatibility with the external controlling equipment.

11. The EVSE may modify the pilot signal duty cycle at any time, commanding the EV/PHEV to increase or decrease the maximum AC current draw. The vehicle shall adhere to the maximum response time in order guarantee universal compatibility with the external controlling equipment. (See Table 15, Transition 11.)

12. *The EVSE shall respond to ventilation state changes of the control pilot.*

13. Switch S3 opens when the connector latch lever is actuated. This opens the proximity circuit. The EV/PHEV should terminate charge prior to connector disconnect to prevent connector contact arc damage. Charge resumption after S3 closing is OEM specific. The vehicle should reduce charge to 1 A or less within 100 milliseconds timed from the S3 opening. (I ≤1.0 A @ t ≤100 milliseconds).

14. State B1 is used by the EVSE to indicate that the EVSE is not ready to supply energy. State B1 may be used by the EVSE to maintain the current charge session during load management, fee transaction, or other events. This state may last for an extended period of time. The EV/PHEV may enter a sleep mode during this state and wake upon detection of the EVSE turning on the oscillator and entering State B2.

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Examples of charge scenarios making use of the B1 to B2 transition:

1. EVSE Scheduled Charge

- Customer desires the EVSE to delay the vehicle charging process and the vehicle does not include this function. The customer knows when they need the vehicle next and may want to use controls in the EVSE to delay the start of charging until a lower price becomes available for the charge session that is still within the overall time it is connected. They may also desire to delay the start of a charge if they know they have other high loads and don't want to stress the electrical system by charging at the same time.

  - It is expected the customer would have a means to program this so it is automatic, but still could be overridden if desired. In this case, the EVSE would stay in State B1 until the time to allow charge, and then move to B2. The vehicle would initially wake up, see State B1, time out, and go to sleep until B2 is obtained, where it would wake up and then move to State C to allow charge.

- Utility sends a Demand Response Load Control (DRLC) signal to the home to delay or curtail charging loads. The utility includes an actual DRLC device in the circuit to home air-conditioners, hot water heaters, pool pumps, and other DRLC-related devices as agreed to by the customer. This device could also be on the EVSE circuit so the utility could transmit a command according to the requirements to keep the grid stable.

  - For the load delay case, if the vehicle was charging in State C when the DRLC command is received, the EVSE would switch to State B1 and stop the charge. The vehicle would time out and go to sleep until the delay period passes, then the EVSE would go back to B2 and the vehicle would wake up and move to State C to resume charging. If the DRLC is only a curtailment (reduction), the EVSE would reduce the control pilot PWM down to the 10% minimum value allowed for AC charging and the system would stay in State C and charge at a lower rate. As in the case of other DRLC devices, the customer has a means to "opt out" and not participate in a particular event, but could have consequences on energy cost depending on the agreed-to program.

- Some EVSEs include a "Stop" and "Start" button. These do not need to be used unless desired. If the EVSE connector is inserted in the vehicle inlet as normal, the system would move from State B2 to State C and charging could start, without pressing either button. If the Stop button is then pressed, the EVSE changes to State B1 and charging stops. The vehicle would time out and waits for State B2. The customer would need to press the "Start" button to change the EVSE while still connected to the vehicle, to change back to State B2, then the vehicle would wake up, change to State C, and charging would resume.

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2. PEV Scheduled Charge

- If only the vehicle has a scheduled charge and connects to an EVSE that does not have scheduled charge (e.g., the PEV scheduled charge is at 2 am but is connected to a workplace EVSE at 8 am, the next morning), the EVSE will stay in State B2 when connected, and the vehicle initially wakes up, then goes to sleep until the vehicle scheduled charge time is obtained, then the vehicle will wake up and move to State C.

  - To override the vehicle scheduled charge, one approach used by OEMs is to "double-plug" or connect the EVSE connector, remove it quickly, then reconnect. This could be included in the vehicle programming to override the PEV scheduled charge and "charge now."

- Another approach is to include a switch in the vehicle interior (or on the center stack display), or on a phone app, that commands the vehicle to "charge now."

3. EVSE and PEV Scheduled Charge

- If both the EVSE and PEV have scheduled charges applied when connected, (e.g., the PEV scheduled charge is at 2 am, but is connected to a workplace EVSE at 8 am, the next morning) assuming the EVSE scheduled charge time is at 2 pm, the vehicle would not charge at the workplace EVSE until 2 am, the next day. The EVSE would stay in State B1 from 8 am to 2 pm, and then move to State B2 at 2 pm, but the PEV would still not move to State C until 2 am. If charge-now is desired when connected, the EVSE needs the "start" button to override its scheduled charge and the vehicle needs customer intervention as noted it item 2 above.

- Exceptions to B1 to B2 Toggle
    - Some EVSEs toggle the pilot during shutdown, if the vehicle has completed a charge session (in State C) and transitions to State B2. If the EVSE stops the pilot PWM to perform some diagnostics or other functions (State B2 to B1), then returns to state B2 within a second, the vehicle should ignore this B1 to B2 transition and not proceed back to State C. EVSEs designed to this standard should maintain B2 state with no B2-B1-B2 toggle at end of charge.

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E.3 CHARGE START SEQUENCE

Figures 28 through 31 illustrate a charge start sequence.

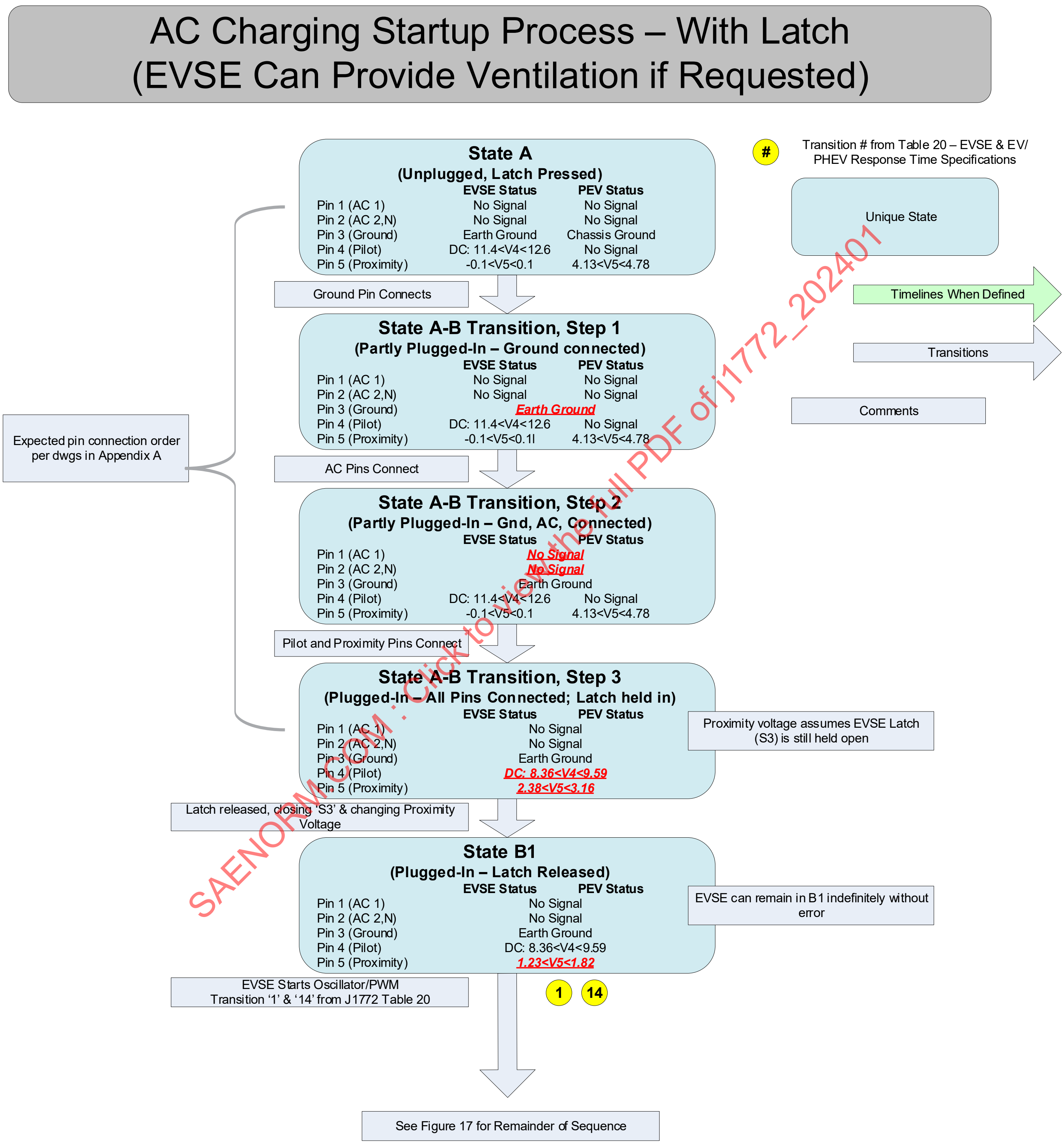

Figure E1 - Part A - Charge start sequence - EVSE capable of supporting ventilation

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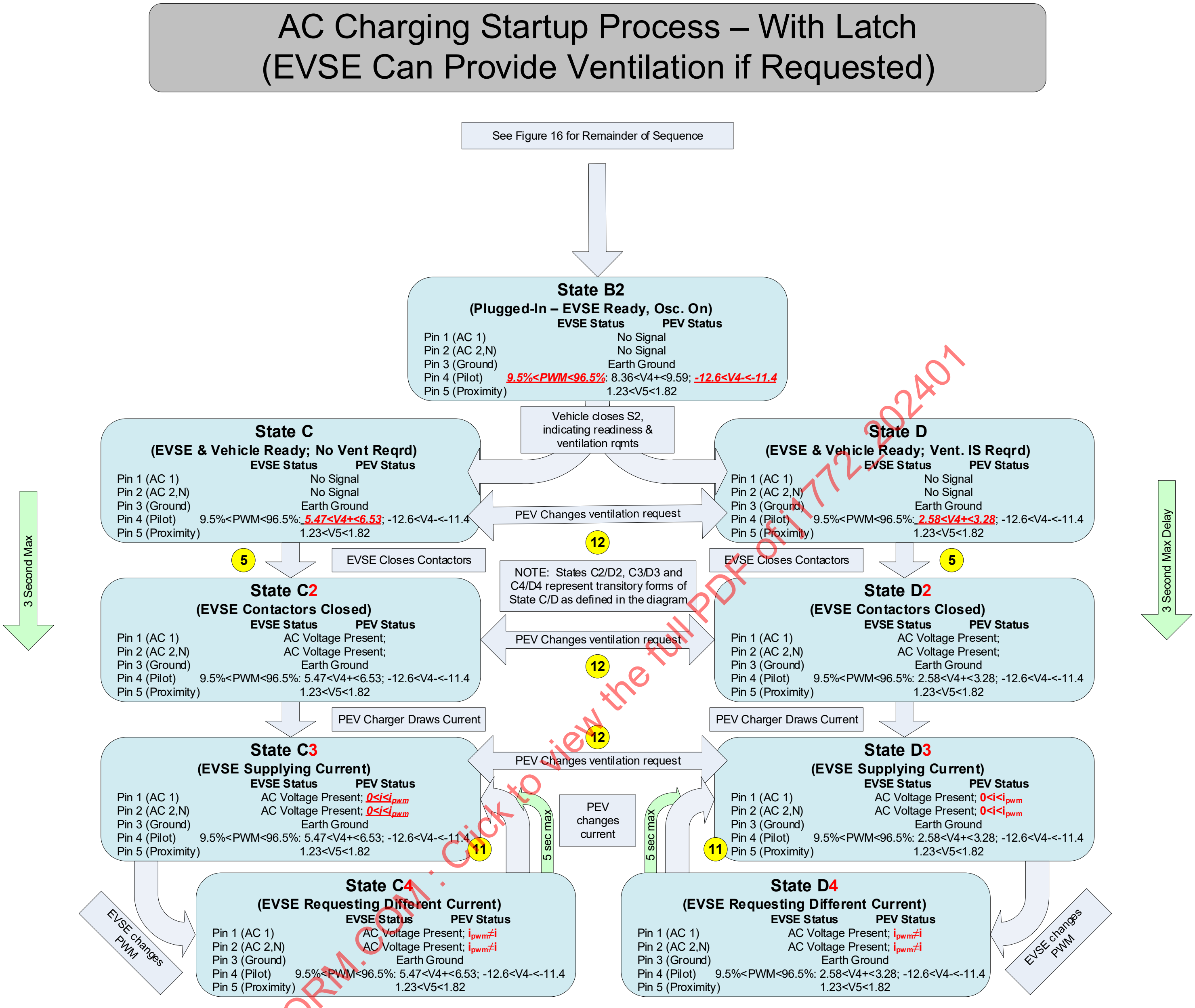

Figure E2 - Part B - Charge start sequence - EVSE capable of supporting ventilation

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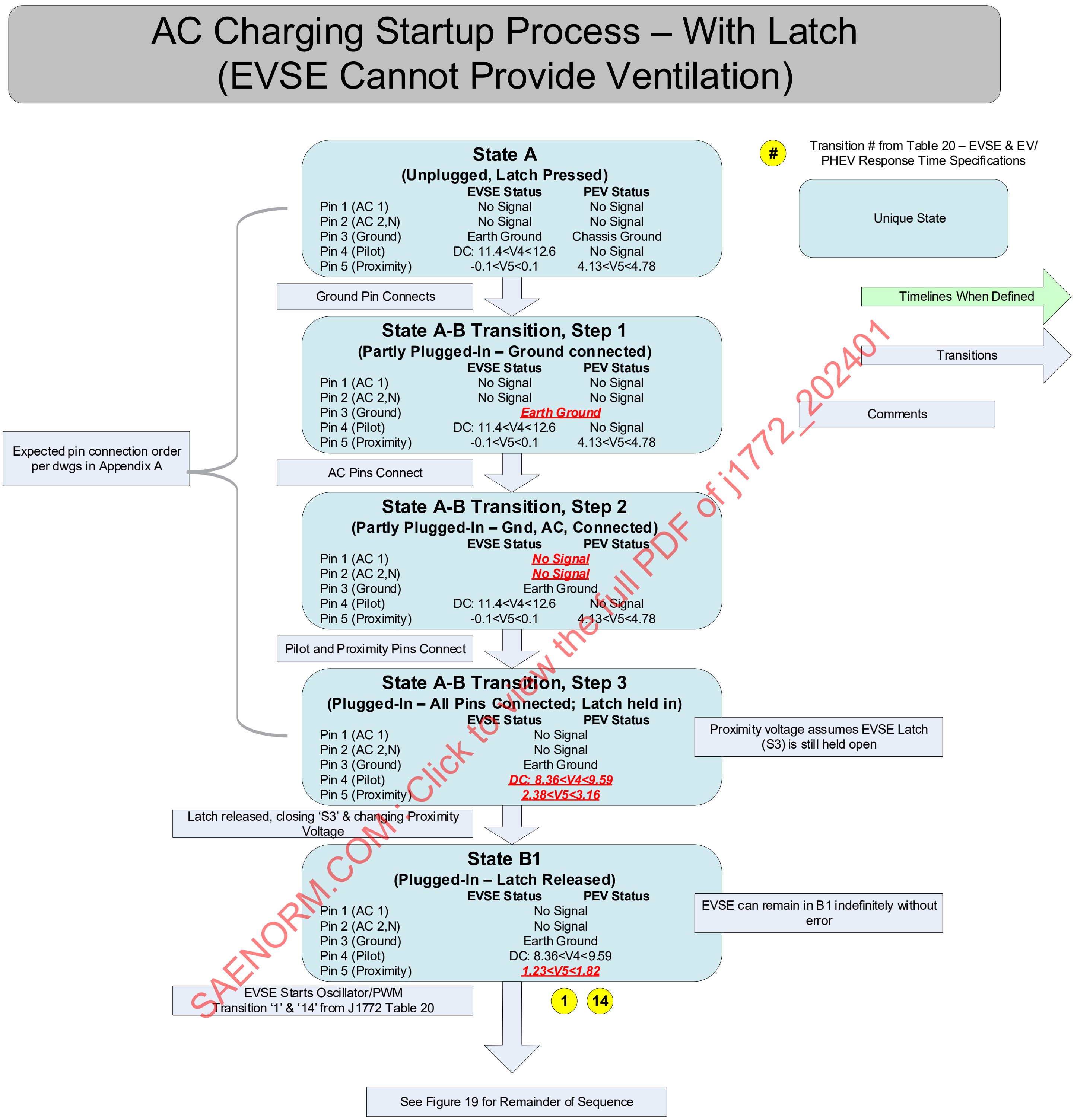

Figure E3 - Part A - Charge start sequence - EVSE does not support ventilation

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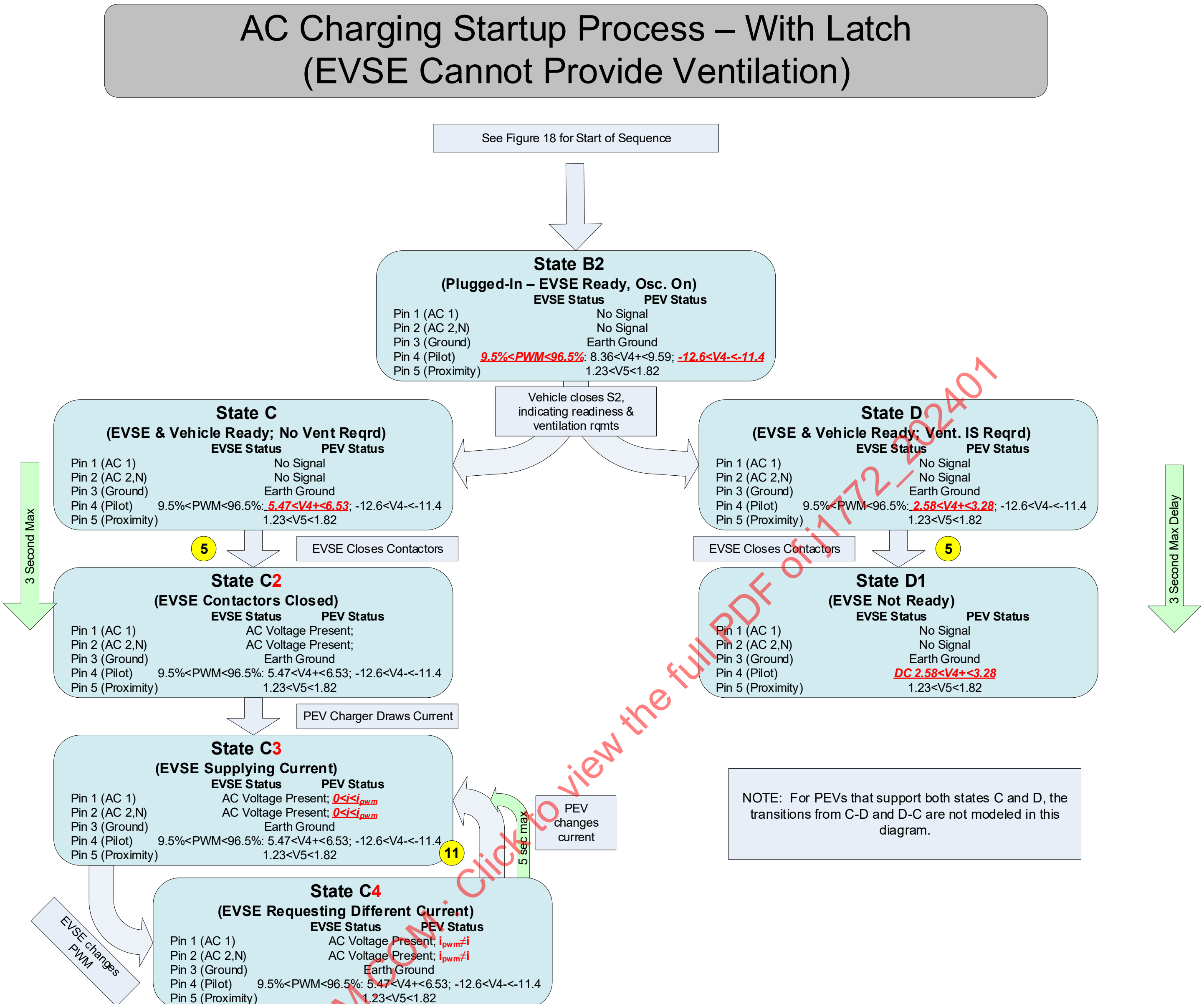

Figure E4 - Part B - Charge start sequence - EVSE does not support ventilation

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E.4 CHARGE TERMINATION SEQUENCE

Figures 32 and 33 illustrate a charge termination sequence. The sequence assumes the vehicle is charging and charging is terminated by activation of the connector latch release.

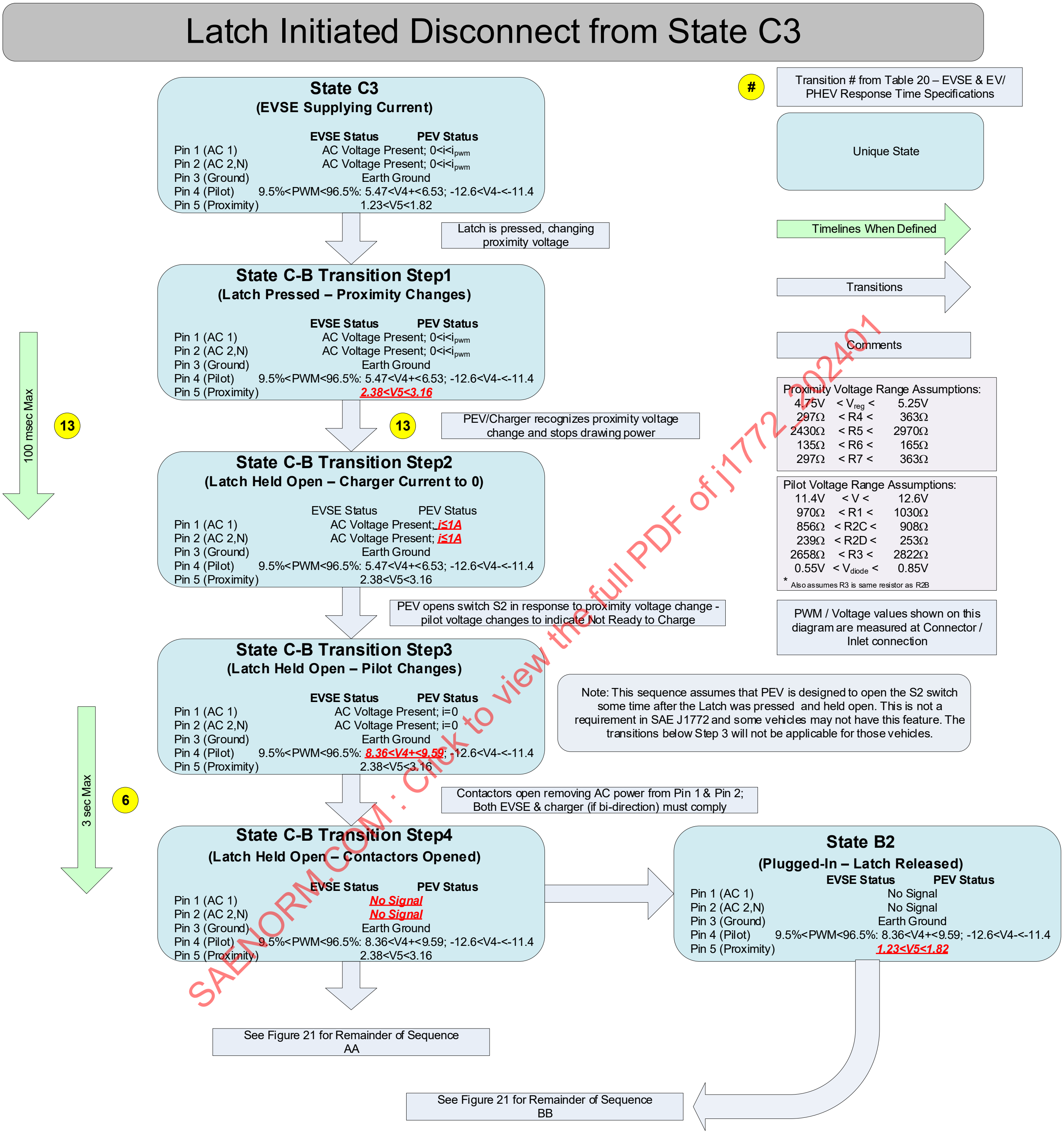

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Figure E5 Part A - Charge termination sequence

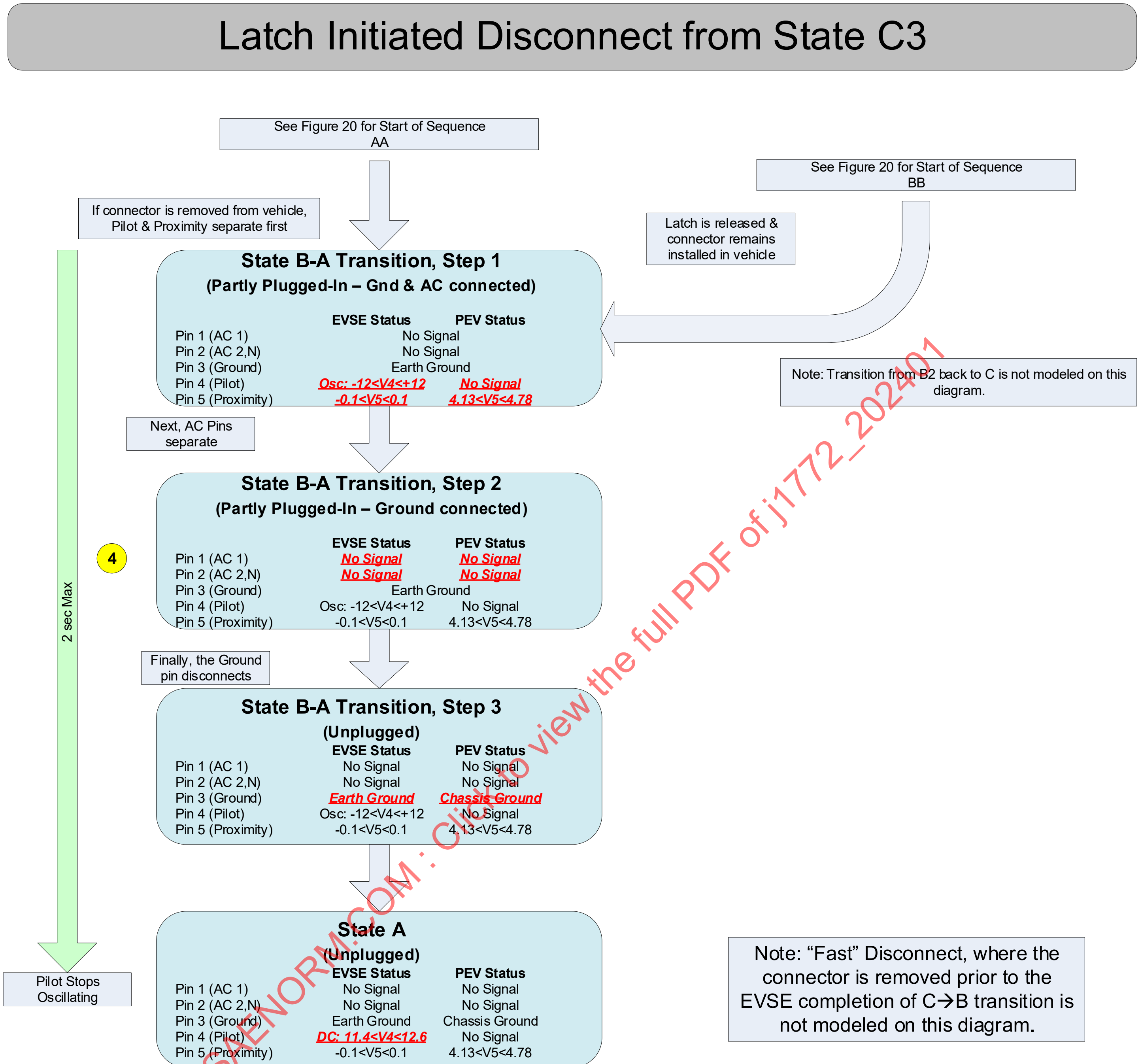

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Figure E6 - Part B - Charge termination sequence

APPENDIX F - DC EVSE AND EV/PHEV SEQUENCE AND RESPONSE TIME SPECIFICATIONS

F.1 NORMAL CHARGING SESSION

A charging session is defined as the period when a connector is inserted in a vehicle inlet until the connector is removed from the vehicle inlet. Each charging session has three phases:

F.1.1 Handshaking (Initialization)

During this phase, the EV/PHEV and EVSE exchange their operating limits and parameters for the upcoming charging session. Some signals are required, such as the voltage and current limitations. Each side uses these values to perform a compatibility check and to ensure that the limits are maintained during the charge session.

After negotiating the charging session parameters, the EV/PHEV shall lock the connector to the vehicle inlet if the two systems are compatible. If incompatible, the information broadcasted can be used by a display unit on either the EVSE or EV/PHEV to inform the customer. The connector lock shall be released by the EV/PHEV when the on-board sensors determine that voltage and currents at the vehicle inlet are within safe limits.

To ensure no damage (welding) to the EV/PHEV side contactors, the EVSE must be enabled and controlled to a voltage that the EV/PHEV can measure. Closing of EV/PHEV side contactors when there is a voltage differential present could result in damaged or welded contactors. EV/PHEV side welding of the contactor is a reliability concern. When the contactors are welded, high voltage could be exposed at the finger proof DC vehicle inlet pins.

Using the Vehicle Maximum Voltage Limit signal, the EV/PHEV shall control the pre-charge process. The power is delivered by the EVSE to reduce the voltage difference between the EV/PHEV RESS and the EVSE output. When the EV/PHEV determines the voltage measured at the EVSE is within acceptable difference to the RESS (exact tolerance threshold is at the discretion of the OEM), the EV/PHEV can then close contactors in the EV/PHEV to connect the EVSE output to the RESS.

When all the Initialization and pre-charge steps have completed, the system (EV/PHEV and EVSE) shall transition to the Energy Transfer phase. The EV/PHEV charging algorithm may establish maximum current, voltage, and power limits at a fixed value at the beginning of the charging session, and proceed through the whole charge session without changing the limits. This method might be used if the algorithm uses a fixed voltage controlled charging algorithm.

F.1.2 Energy Transfer

During Energy Transfer, the EV/PHEV and the EVSE shall continuously monitor the voltage and current readings independently to ensure that the system remains within the negotiated limits. The EV/PHEV may reduce consumption to protect the RESS. The EVSE may reduce the output level to ensure that its voltage and current limits will not be violated.

The EVSE shall indicate the status of the energy transfer and will be able to signal to the EV/PHEV when it is operating at its maximum output capability. The EV/PHEV shall communicate the expected charge completion time so the information can be presented to the user on a display in the EVSE.

There are two modes of energy transfer: Bulk Charging and Full Charging. During Bulk Charging, the EV/PHEV shall request energy transfer at or near the negotiated limitations of the charging session. This will continue for the requested charging session time. When the Bulk threshold has been reached, the EV/PHEV shall end the charging session, or it shall reduce the energy consumption to allow charging the RESS to full. While charging to Full, the energy transfer requests shall be limited by the EV/PHEV to ensure the maintenance of the RESS. Charging to Full may last for a duration that continues for several hours.

The EV/PHEV shall control charge level based on EV/PHEV RESS and other EV/PHEV conditions. When the EV/PHEV determines that the charging session is complete, it shall send a unique signal to the EVSE. At that point, the EV/PHEV shall reduce its requested energy transfer to near zero, and may open the charging contactors in the EV/PHEV.

When the EV/PHEV has determined that it has reached Full or Bulk charge level, the system shall transition to Normal Shutdown. It is up to the EV/PHEV manufacturer when to switch from bulk to full charge.

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F.1.3 Normal Shutdown

Normal shutdown occurs when the RESS reaches the desired State of Charge limit and any accessory load consumption of the EV/PHEV has completed. After completion of the charge session, the Shutdown phase allows the EV/PHEV and EVSE to return to a safe condition so the user can remove the connector from the vehicle inlet. The EV/PHEV shall have reduced its charge current request to zero, and shall indicate Charge complete. When the current is near zero (exact tolerance threshold is at the discretion of the OEM), the EV/PHEV shall open its on-board charge contactors, and wait for the inlet voltage to drop to a safe level. Once at the safe level (below 60 VDC as defined by SAE J2344), the connector may be unlocked by the EV/PHEV. The user can then remove the connector from the vehicle inlet.

The EV/PHEV and EVSE may exchange some signals that may be used for energy reporting and consumption displays.

Normal shutdown may be entered by an action from the user. For example, a "Stop" button on the EVSE could have been pressed which will immediately cause the EV/PHEV to reduce the request even if the RESS has not reached Full or Bulk level. The EV/PHEV shall enter the normal shutdown state, which shall lead to the charge coupler being unlocked for the user.

Based on user preferences, the EV/PHEV shall keep the charge coupler locked in the inlet until the user is ready to remove the charge cord connector. The EV/PHEV may remain in this state for a long time period.

Some signals are transmitted during the start of the session (handshaking). Critical signals are transmitted throughout the energy delivery phase. Some messages close out the session at the end of charging process (normal shutdown).

F.1.4 Examples of Error and Emergency Shutdown

Certain fault conditions will cause the charging system to shut down before the normal shutdown. Either the EV/PHEV will initiate the shutdown, or the EVSE may initiate shutdown. The shutdown should be triggered according to the specifications for each fault. Some examples are listed below:

F.1.4.1 Energency Shutdown Due to Loss of Safety Ground

It occurs when continuity of the safety ground is lost.

F.1.4.2 Error Shutdown Due to Loss of High Voltage Isolation

It occurs when there is current leakage between the chassis and the high voltage system, including the EV/PHEV RESS.

F.1.4.3 Error Shutdown Due to Loss of Communication

In the event that reliable data communication between the EV/PEV and the EVSE cannot be established, it is understood that the EV/PHEV or the off-board EVSE shall stop energy transfer.

F.1.4.4 Error Shutdown Due to Loss of Power

It happens when the EVSE stops delivering power to the EV/PEV.

F.1.5 Examples of System Faults

Certain fault conditions will cause the charging system to shut down before the normal shutdown. Either the EV/PHEV will initiate the shutdown, or the EVSE will initiate shutdown. Some examples are listed below:

F.1.5.1 Welded Contactors

In case the EV/PHEV contactors are welded, the EV/PHEV should provide a fault indication and request zero current and voltage. The EV/PHEV may provide a means to manually unlock the connector in a safe manner. The manual unlock could open a EV/PHEV interlock that will remove HV from the vehicle inlet. The EV/PHEV should not be operated with HV present at an exposed vehicle inlet.

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F.1.6 Connector Unlocking Requirements

F.1.6.1 An EV/PHEV using an inlet according to "Sheet A-1" of this standard ("Configuration Type 1" of IEC 62196-2) or "Sheet C-1" of this standard ("Configuration EE" of IEC 62196-3"), shall unlock the connector within 3 seconds after either of the following two events occur:

a. reception of the SessionStopRes message, if the charging session has terminated as a "Normal Shutdown" as per F.1.3 of this standard, or

b. leaving Control pilot State C2 (or D2, if ventilation is required), if an "Emergency Shutdown" as per F.1.11 of this standard has been executed,

unless the voltage measured at the inlet is greater than or equal 60 VDC.

If the voltage at the inlet is greater than 60 VDC, the EV/PHEV shall continue to measure the voltage at the inlet and, as soon as the voltage decreases to 60 VDC or less, unlock the connector.

F.1.6.2 After executing a shutdown, the EV/PHEV can request a new charging session according to 6.4.8.

(NOTE: The PHEV/BEV usually does not need to resume charging after a "Normal Shutdown.")

F.1.6.3 After executing a shutdown, the EVSE shall limit the number of attempts to initiate another charging session to 20 or fewer.

(*) CP State transitions B2 -> C2 caused by the EV/PHEV during a charging session shall not constitute such an explicit interaction by the EV/PHEV indicating the EV/PHEV's intention to start another charging session.

(NOTE: The EV/PHEV should be able to resume charging after a shutdown.)

F.1.7 DC Timing Requirements

General timing requirements regarding digital communication setup, messaging, and additional error conditions are specified in:

- SAE J2847/2
- DIN SPEC 70121:2014
- ISO 15118-2:2014

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F.1.8 Normal Normal Startup Sequence

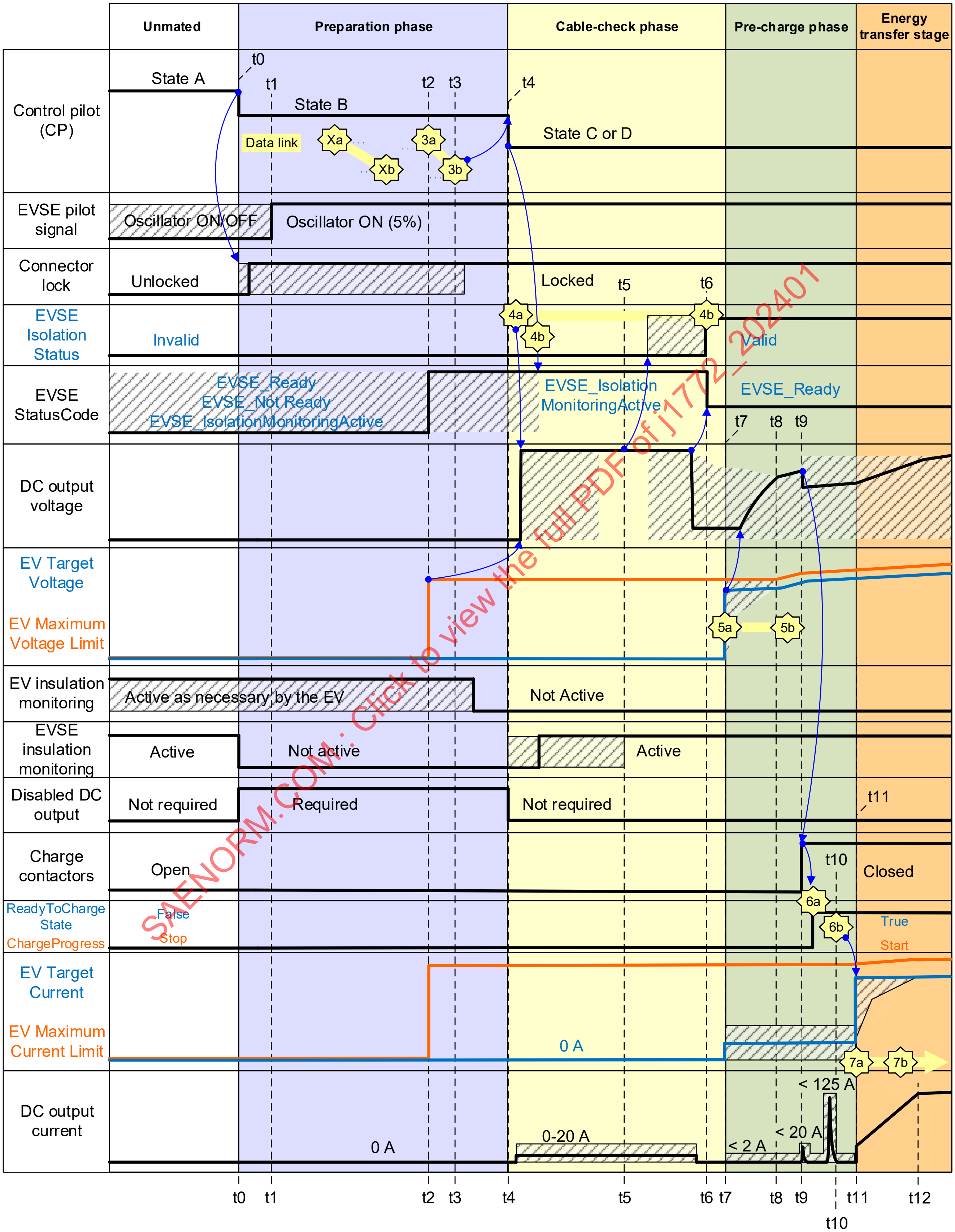

Figure F1 - Normal startup sequence

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Table F1 - Normal startup sequence description

Timestamp	Description
► t0	• The present voltage at the DC output between DC+ and DC- shall be ≤60 V DC
t0	• The vehicle connector is mated to the vehicle inlet, which changes the CP state from A to B. • After the CP state changed to B and the PP is detected (S3 closed in case of configuration EE), the EV/PHEV should lock the vehicle connector in the vehicle inlet. • After the CP state changed to B, the EVSE shall disable the EVSE IMD, disable DC output and open the EVSE disconnection device, if any. • After the CP state changed to B, the EV/PHEV may try to set up a data link as defined in IEC 61851-24.
t0 ► t3	• The EVSE shall not trigger an error shutdown due to the present voltage at the DC output (including negative voltages). NOTE: When the vehicle connector is mated to the vehicle inlet, these voltages can be caused by the EV/PHEV requirements for unmated conditions in 6.5.2 of ISO 17409:2020. EVSE based on IEC 61851-23:2014 must trigger a shutdown if the present voltage at the DC output is >60 V DC in the first ChargeParameterDiscoveryReq <3a> message.
t0 ► t4	• The EVSE shall trigger an EVSE initiated error shutdown if the present voltage at the DC output between DC+ and DC- is >60 V DC. See F.1.10.1. • If the EV/PHEV tried and failed to lock the connector, the EV/PHEV shall notify the EVSE with parameter “EVErrorCode” = ’FAILED_ChargerConnectorLockFault’ in the next communicated message that contains this parameter, according to IEC 61851-24. • The disabled DC output of the EVSE shall have equivalent electrical properties/behavior (e.g., impedance, discharge rate, etc.) as the circuit described in 6.5.27.
t0 ► t10	• The EVSE shall not perform the overvoltage protection according to 6.5.24.
t1	• The EVSE shall turn on its CP oscillator if the EVSE is ready for energy transfer and if the CP oscillator is not already on. • The EVSE shall maintain a CP duty cycle of 5% from the start of the data link setup until end of communication session, unless a certain condition requires a different CP duty cycle.
t1 ► t2	• The EV/PHEV shall establish the data link as defined in the IEC 61851-24 after it has verified that the EVSE has turned on its CP oscillator, if the data link is not already established. NOTE 1: The data link could have been previously established due to a pause or renegotiation of the communication session. • Digital communication starts by the negotiation of an appropriate application layer protocol between the EV/PHEV <Xa> and EVSE <Xb>. See Appendix G. • The EV/PHEV and EVSE exchange message pairs concerning session setup, services, authentication, payment options, and value-added services (if supported by the negotiated application layer protocol). According to IEC 61851-24, some message pairs are not necessary after a pause or renegotiation, for example, authentication or payment options. • If the EVSE wants to terminate the communication session during the initialization stage (e.g., user pressed the stop button), the EVSE shall: - send parameter "ResponseCode" = 'FAILED' in the next communicated message; - keep its CP oscillator on (unless a certain condition requires a different CP duty cycle); and - proceed to t206 in the error shutdown sequence. NOTE 2: If next communicated message is a ChargeParameterDiscoveryRes <3b> message, see t2 ► t4. • If, after the EV/PHEV has received a response message, the EV/PHEV wants to terminate the communication session, the EV/PHEV shall proceed to t107 in the normal shutdown sequence. • If, after the EV/PHEV has received a response message, the EV/PHEV receives a response message with parameter "ResponseCode" = 'FAILED,' the EV/PHEV shall proceed to t206 in the error shutdown sequence.
t2	• The EV/PHEV shall send parameters "EVMaximumVoltageLimit" and "EVMaximumCurrentLimit" (amongst other parameters) with the first ChargeParameterDiscoveryReq <3a> message.
t2 ► t3	• The EVSE shall perform a compatibility check. • The EVSE shall check if the absolute value of the present voltage at the DC output between DC+ and DC- is <60 V DC and shall send message ChargeParameterDiscovery <3b> with parameter "EVSEProcessing" = 'Ongoing' if the absolute value of the present voltage at the DC output is ≥60 V DC. • The EVSE shall send parameters "EVSEMaximumVoltageLimit," "EVSEMinimumVoltageLimit," "EVSEMaximumCurrentLimit," and "EVSEMinimumCurrentLimit" (amongst other parameters) in message ChargeParameterDiscoveryRes <3b> considering the compatibility check. • The EVSE shall send parameter "EVSEStatusCode" = 'EVSE_IsolationMonitoringActive' in the “ChargeParameterDiscoveryRes <3b>” messages, unless the EVSE wants to pause the communication session or perform a shutdown. The EV/PHEV is recommended to continue the communication session if the EVSE sends ChargeParameterDiscoveryRes <3b> messages with parameter “EVSE_StatusCode” = ‘EVSE_Ready’ or ‘EVSE_NotReady.’

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Timestamp	Description
	NOTE 1: EVSEs based on IEC 61851-23:2014 can send parameter “EVSE_StatusCode” = “EVSE_Ready,” “EVSE_NotReady,” or “EVSE_IsolationMonitoringActive” in ChargeParameterDiscoveryRes <3b> messages. • If the EVSE replies with parameters "ResponseCode" = 'OK' and "EVSEProcessing" = 'Ongoing' in message ChargeParameterDiscoveryRes <3b>, the EV/PHEV and EVSE may update the parameters sent in the next ChargeParameterDiscoveryReq/Res messages. NOTE 2: The EVSE may use "EVSEProcessing" = 'Ongoing' for other reasons. Example: load management, etc.
t2 ► t3	• If using DIN SPEC 70121:2014: If the EVSE wants to pause the communication session during the initialization stage, the EVSE shall send parameters "EVSEStatusCode" = 'EVSE_UtilityInterruptEvent' and “EVSEProcessing” = ’Ongoing’ in the next ChargeParameterDiscoveryRes <3b> message and then continue to t3 with parameter "EVSEStatusCode" = 'EVSE_Shutdown.' NOTE 3: The EVSE sends "EVSEStatusCode" = 'EVSE_UtilityInterruptEvent' and “EVSEProcessing” = ’Ongoing’ to indicate the EV/PHEV the reason for performing a normal shutdown before energy transfer. • If the EV/PHEV sends parameter "EVErrorCode" = 'FAILED_ChargerConnectorLockFault' in a ChargeParameterDiscoveryReq <3a> message, the EVSE should respond with cyclic ChargeParameterDiscoveryRes <3b> messages with parameters “EVSEProcessing” = ’Ongoing’ and “ResponseCode” = ’OK’ to give the EV/PHEV additional time to solve the fault in the locking mechanism. NOTE 4: The EVSE should inform the user how to improve the locking process. For example, by indicating how to properly mate the vehicle connector in the vehicle inlet. • According to DIN SPEC 70121:2014, the EV/PHEV must resend the identical parameters in each ChargeParameterDiscoveryReq message, however, it is recommended for the EVSE not to perform a shutdown if the EV/PHEV changes the parameters. • ISO 15118-2:2014 does not specify the possibility to update the parameters in subsequent ChargeParameterDiscoveryReq/Res messages, however, it is recommended for the EVSE not to perform a shutdown if the EV/PHEV changes the parameters. • To improve interoperability, the EVSE shall tolerate the EV/PHEV changing CP state to C/D during cyclic ChargeParameterDiscoveryReq/Res messages. If the EV/PHEV changes back to CP state B, the EVSE shall trigger an EVSE initiated emergency shutdown. See F.1.11. NOTE 5: Requirement [V2G2-912] in ISO 15118-2:2014 and a similar requirement in outdated versions of SAE J1772 don’t specify that the EV/PHEV must receive a ChargeParameterDiscoveryRe <3b> with parameter “EVSEProcessing” = ‘’Finished’’ before changing the CP state from state B to state C/D, leading to this unwanted behavior.
t2 ► t4	• If the EVSE wants to terminate the communication session during the initialization stage (e.g., user pressed the stop button), the EVSE shall send parameter "EVSEStatusCode" = 'EVSE_Shutdown' in the next communicated message and proceed to t107 in the normal shutdown sequence. If using ISO 15118-2:2014, the EVSE shall also send parameter “EVSENotification” = ‘StopCharging.’ • If, after the EV/PHEV has received a response message, the EV/PHEV wants to terminate the communication session, or if the EV/PHEV receives a response message with parameter “EVSEStatusCode” = ‘EVSE_Shutdown’ (and, if using ISO 15118-2:2014, parameter “EVSENotification” = ‘StopCharging’), the EV/PHEV shall proceed to t107 in the normal shutdown sequence.
T3	• If the absolute value of the present voltage at the DC output is <60 V DC, the EVSE shall send the EV/PHEV the result of the compatibility check in message ChargeParameterDiscoveryRes <3b> using parameters “EVSEStatusCode” = ‘EVSE_IsolationMonitoringActive,’ “EVSEProcessing” = ‘Finished,’ and: - “ResponseCode” = ‘OK’ if the compatibility check was successfully completed, or - “ResponseCode” = ‘FAILED_WrongChargeParameter’ if the compatibility check was completed and failed, triggering an EVSE initiated error shutdown. NOTE 1: A ChargeParameterDiscoveryRes <3b> message with "ResponseCode" = 'FAILED_WrongChargeParameter' and parameter "EVSEProcessing" = 'Ongoing,' will trigger an EVSE initiated error shutdown. See error handling specifications for the digital communication standards in IEC 61851-24. NOTE 2: EVSEs based on IEC 61851-23:2014 can send parameter “EVSE_StatusCode” = “EVSE_Ready,” “EVSE_NotReady,” or “EVSE_IsolationMonitoringActive” in ChargeParameterDiscoveryRes <3b> messages. The EV/PHEV is recommended to continue the communication session if the EVSE sends ChargeParameterDiscoveryRes <3b> messages with parameter “EVSE_StatusCode” = ‘EVSE_Ready’ or ‘EVSE_NotReady.’ NOTE 3: If the absolute value of the present voltage at the DC output is not <60 V DC at the end of the compatibility check (based on the timing requirements of IEC 61851-24), the EVSE cannot send a ChargeParameterDiscoveryRes <3b> message with parameter "EVSEProcessing" = 'Finished.' In this case, the EV/PHEV must trigger an error shutdown. • The negotiated maximum values sent by the EVSE in the last ChargeParameterDiscoveryRes <3b> shall be more than or equal to the applicable values in the CurrentDemandRes <7b> messages during the energy transfer stage.
t3 ► t4	• If the EV/PHEV and EVSE are not compatible, the EV/PHEV shall perform an EV/PHEV initiated error shutdown. See F.1.10.1. • The EV/PHEV shall lock the vehicle connector in the vehicle inlet before changing the CP to state C or D, if not already locked.

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Timestamp	Description
	• If the EV/PHEV failed to lock the vehicle connector, the EV/PHEV shall trigger an EV/PHEV initiated error shutdown with parameter "EVErrorCode" = 'FAILED_ChargerConnectorLockFault' in the next communicated message. • The EV/PHEV shall disable the EV/PHEV IMD, if any.
t3 ►	• The EVSE shall trigger an error shutdown if the present voltage at the DC output between DC+ and DC- is <-60 V DC for 400 consecutive ms or more.
t4	• After the EV/PHEV has disabled the EV/PHEV IMD and after checking that the vehicle connector is locked, the EV/PHEV shall change the CP state from B to C/D by closing S2. NOTE: The common mode and differential mode influences from the EV/PHEV (for example, welding detection, IMD, etc.) on the DC output should be removed before the EV/PHEV changes the CP state from B to C/D by closing S2 because this can interfere with the EVSE IMD. • After the CP state changed to C/D, the EVSE shall enable the DC output. The limitations of the disabled DC output of the EVSE are not required.
t4 ► t5	• After checking that the vehicle connector is locked, the EV/PHEV shall request cable-check phase before pre-charge phase with CableCheckReq <4a>. See 6.5.4.7. • The EVSE shall check if the CP state changed to state C or D before sending the first CableCheckRes <4b> message and before the present voltage at the DC output between DC+ and DC- is >60 V DC.
t4 ► t6	• The EVSE shall check the functionality of the IMD. See 6.5.4. • The EVSE shall check the insulation of the DC output and shall continuously report the insulation state with parameter "EVSEIsolationStatus" according to 6.5.4.7, "EVSEProcessing" = 'Ongoing', and "EVSEStatusCode" = 'EVSE_IsolationMonitoringActive' in message CableCheckRes<4b>. • The EVSE may perform other functions (for example, welding detection) while sending parameters "EVSEIsolationStatus" according to 6.5.4.7 and "EVSEProcessing" = 'Ongoing' in message CableCheckRes<4b>.
t4 ► t10	• If using DIN SPEC 70121:2014: If the EVSE wants to pause the communication session during the cable-check phase or pre-charge phase, the EVSE shall disable the DC output (see 6.5.27) and , if the next communicated message is: - a CableCheckRes <4b> or PreChargeRes <5b> message, the EVSE shall first send a response message with parameter “EVSEStatusCode” = ‘EVSE_UtilityInterruptEvent’ and a response message with parameter “EVSEStatusCode” = ‘EVSE_Shutdown’ in the next communicated message to proceed to t107 in the normal shutdown sequence after sending the response message. See 6.5.27. - a PowerDeliveryRes <6b> message, the EVSE shall send parameter “EVSEStatusCode” = ‘EVSE_Shutdown,’ for the EV/PHEV to initiate a normal shutdown. See F.1.9. NOTE 1: If the next communicated message is a CurrentDemandRes <7b> message, a communication session termination will result in a normal shutdown. See F.1.9. NOTE 2: Some EV/PHEV s might interpret messages with parameter "EVSEStatusCode" = 'EVSE_UtilityInterruptEvent' as "EVSEStatusCode" = 'EVSE_Shutdown.' • If the EVSE wants to terminate the communication session during the cable-check phase or pre-charge phase, the EVSE shall disable the DC output (see 6.5.27) and send parameter "EVSEStatusCode" = 'EVSE_Shutdown' (and, if using ISO 15118-2:2014, parameter “EVSENotification” = ‘StopCharging’) in the next communicated message. If the next communicated message is: - a CableCheckRes <4b> or PreChargeRes <5b> message, the EVSE shall proceed to t107 in the normal shutdown sequence after sending the response message. See F.1.9. - a PowerDeliveryRes <6b> message, the EV/PHEV shall initiate a normal shutdown. See F.1.9. NOTE 3: If the next communicated message is a CurrentDemandRes <7b> message, a communication session termination will result in a normal shutdown. See F.1.9. • If the EV/PHEV wants to terminate the communication session during the cable-check phase or pre-charge phase, after receiving a response message, the EV/PHEV shall: - if it has not yet closed the EV/PHEV charge contactors, proceed to t107 in the normal shutdown sequence. See F.1.9. - if it has already closed the EV/PHEV charge contactors, initiate a normal shutdown. See F.1.9. • If the EV/PHEV receives a response message with parameter "EVSEStatusCode"='EVSE_Shutdown' (and, if using ISO 15118-2:2014, parameter “EVSENotification” = ‘StopCharging’) during the cable-check phase or pre-charge phase, the EV/PHEV shall: -if it has not yet closed the EV/PHEV charge contactors, proceed to t107 in the normal shutdown sequence. See F.1.9. -if it has already closed the EV/PHEV charge contactors, initiate a normal shutdown. See F.1.9.
t5	• The EVSE determines that the insulation resistance of the DC output is ≥100 kΩ. See 6.5.4.7.
t6	• After completing the cable-check phase, the EVSE shall send message CableCheckRes <4b> with parameters "EVSEIsolationStatus" according to 6.5.4.7, "EVSEProcessing" = 'Finished,' and: - "EVSEStatusCode" = “Ready,” if the insulation status is 'Valid' and there are no errors, or - "ResponseCode" = 'FAILED,' if the EVSE detects an error, to trigger an EVSE initiated error shutdown.

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Timestamp	Description
	• If the EVSE detects an error, the EVSE shall trigger an EVSE initiated error shutdown by sending parameters "EVSEIsolationStatus" according to 6.5.4.7 and "ResponseCode" = 'FAILED' in message CableCheckRes <4b>.
t6 ► t7	• The EVSE may keep the present voltage at the DC output.
t7	• The EV/PHEV shall send message PreChargeReq <5a>, with parameter "EVTargetVoltage" depending on the present voltage of the battery system, to start the pre-charge phase. See 6.5.28.
t7 ► t9	• The EV/PHEV and EVSE shall perform the pre-charge phase according to 6.5.28. • The EVSE shall control the present voltage at the DC output according to the target voltage of the EV/PHEV in the PreChargeReq <5a> messages and send the corresponding PreChargeRes <5b> messages.
t8	• The present voltage at the DC output reaches the target voltage of the EV/PHEV.
t8 ► t9	• The EV/PHEV may adapt the target voltage of the EV/PHEV with cyclic PreChargeReq/Res messages to compensate for voltage deviation.
t9	• The EV/PHEV shall close the EV/PHEV charge contactors only after verifying that the absolute difference between the present voltage at the DC output and the present voltage at the battery system is <20 V DC. See 6.5.28. NOTE: The EV/PHEV should be protected against reversed polarity of the DC output.
t9 ► t10	• The EV/PHEV shall request the EVSE to disable its pre-charge current limitation by sending message PowerDeliveryReq <6a> according to IEC 61851-24, only after closing the EV/PHEV charge contactors. NOTE: When using DIN SPEC 70121:2014, use parameter "ReadyToChargeState" = 'TRUE.' When using ISO 15118-2:2014, use parameter "ChargeProgress" = 'Start.'
t10	• After disabling the pre-charge current limitation (for example, pre-charge circuit, if any), and enabling the DC output, the EVSE shall send message PowerDeliveryRes <6b> with parameter "EVSEStatusCode" = 'EVSE_Ready' to indicate that it is ready for energy transfer. • The EVSE shall start the overvoltage protection according to 6.5.24.
t11	• The EV/PHEV shall set parameter "EVTargetCurrent" in the first CurrentDemandReq <7a> message to start the energy transfer stage. • The EV/PHEV shall send CurrentDemandReq <7a> messages with parameters "EVMaximumVoltageLimit" and "EVMaximumCurrentLimit" less than or equal to the respective negotiated limits sent in the last ChargeParameterDiscoveryReq <3a> message.
t11 ► t12	• The EVSE shall adapt the DC output to the target values by the EV/PHEV in message CurrentDemandReq <7a>. • The EVSE shall respond to the EV/PHEV with the following information in message CurrentDemandRes<7b>: - the present current and voltage at the DC output, - the applicable minimum and maximum values for current, voltage, and power of the EVSE at the DC output, and - Its present status. NOTE: The EV/PHEV may change the target current and voltage of the EV/PHEV even if the present current and voltage at the DC output has not reached the previous target values.
t11 ►	• The EVSE shall continuously monitor the insulation of the DC output and update parameter "EVSEIsolationStatus" in the next communicated messages that contain this parameter. See 6.5.4.6.
t12	• The present current at the DC output reaches the target current of the EV/PHEV in the time delay (Td) or less defined in 6.5.12.
t12 ►	• The EV/PHEV adapts the target current and voltage of the EV/PHEV according to its energy transfer strategy by setting parameters "EVTargetCurrent" and "EVTargetVoltage" in cyclic CurrentDemandReq <7a> messages. NOTE: See section 6.5.29 for the handling of operating ranges.

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F.1.9 Normal Shutdown or Pause After Energy Transfer sequence

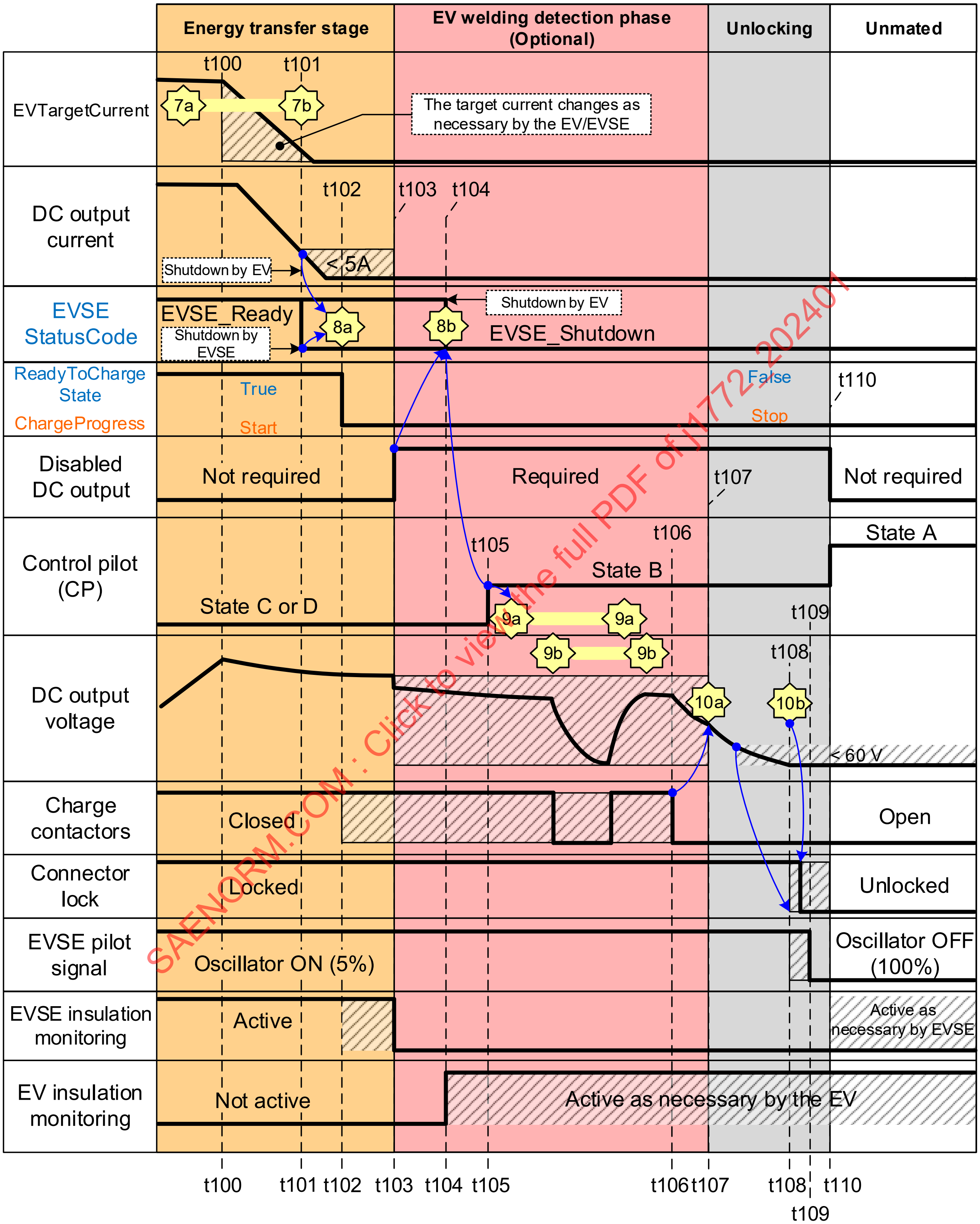

Figure F2 - Normal shutdown sequence

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Table F2 - Normal shutdown sequence description

Timestamp	Description
► t100	• Cyclic CurrentDemandReq/Res messages between the EV/PHEV (CurrentDemandReq <7a>) and EVSE (CurrentDemandRes <7b>).
t100	• If the EV/PHEV wants to stop or pause a communication session for a non-critical reason, the EV/PHEV shall request a reduction of the present current at the DC output to 0 A DC in the next CurrentDemandReq <7a> messages.
t100 ► t101	• If the EVSE wants to stop or pause a communication session for a non-critical reason (for example, user pressed the stop button), the EVSE shall: - ramp down the present current at the DC output to <5 A DC, and - adjust parameter "EVSEMaximumCurrentLimit" in the next CurrentDemandRes <7b> messages according to the present current at the DC output. See 6.5.29.4 and 6.5.29.6. NOTE 1: EV/PHEV s based on IEC 61851-23:2014 might directly go to t102 without reducing the target current of the EV/PHEV. This will be interpreted as an EV/PHEV initiated error shutdown by the EVSE (refer to section 9.7.4.1.2 in DIN SPEC 70121:2014). See Table F3. NOTE 2: The EVSE can limit the present current at the DC output ramp down to -20 A/s to avoid sudden load variations at side A (for example, supply network connection)
t101	• The present current at the DC output is <5 A DC.
t101 ► t102	• If the EVSE wants to stop or pause the communication session and the present current at the DC output is <5 A DC, the EVSE shall: - First, set parameter "EVSEStatusCode" = 'EVSE_UtilityInterruptEvent' in the next CurrentDemandRes <7b> message to pause the communication session; - Second, if the EVSE did not receive a “PowerDeliveryRes” <8a> message (t102), set "EVSEStatusCode" = 'EVSE_Shutdown' (and, if using ISO 15118-2:2014, parameter “EVSENotification” = ‘StopCharging’) in the next CurrentDemandRes <7b> message to stop the communication session.
t102	• If using DIN SPEC 70121:2014: If the EV/PHEV wants to stop the communication session or if the EVSE wants to stop or pause the communication session (that is, the EV/PHEV received a CurrentDemandRes <7b> message with parameter "EVSEStatusCode" = 'EVSE_Shutdown' or 'EVSE_UtilityInterruptEvent'), the EV/PHEV shall request the EVSE to disable the DC output by sending parameter "ReadyToChargeState" = 'FALSE' in the PowerDeliveryReq <8a> message according to IEC 61851-24, after the present current at the DC output is <5 A DC. • If using ISO 15118-2:2014: If the EV/PHEV wants to stop the communication session or if the EVSE wants to stop or pause the communication session (that is, the EV/PHEV received a CurrentDemandRes <7b> message with parameter "EVSEStatusCode" = 'EVSE_Shutdown' and “EVSENotification” = ‘StopCharging’ or 'EVSE_UtilityInterruptEvent'), the EV/PHEV shall request the EVSE to disable the DC output by sending parameter "ChargeProgress" = 'Stop' in the PowerDeliveryReq <8a> message according to IEC 61851-24, after the present current at the DC output is <5 A DC. NOTE 1: From t102 onwards, the sequences for EV/PHEV initiated normal shutdown and EVSE initiated normal shutdown are identical.
t102 ► t103	• After receiving the PowerDeliveryReq <8a> message, the EVSE shall reduce the present current at the DC output to <5 A DC in 1 second or less, if not already done. NOTE: This is needed for EV/PHEVs based on IEC 61851-23:2014. • After receiving the PowerDeliveryReq <8a> message, the EVSE shall stop the overvoltage protection according to 6.5.24.
t102 ► t105	• The EV may open the EV/PHEV charge contactors after the present current at the DC output is <5 A DC and after the message PowerDeliveryReq <8a> has been sent. In this case, the EV/PHEV shall not re-close the EV/PHEV charge contactors.
t103	• The EVSE shall disable the DC output and open the EVSE disconnection device, if any. NOTE: If the EVSE disables the DC output while the present current at the DC output is >0 A DC, the present voltage at the DC output drops to the battery system voltage because the EV/PHEV charge contactors are still closed. • The EVSE shall disable the EVSE IMD.
t103 ► t110	• The disabled DC output of the EVSE shall have equivalent electrical properties/behavior (e.g., impedance, discharge rate, etc.) as the circuit described in 6.5.27.
t104	• The EVSE shall communicate that the present current at the DC output is <5 A DC and has disabled the DC output by sending parameter "EVSEStatusCode" = 'EVSE_Shutdown' or 'EVSE_UtilityInterruptEvent' in message PowerDeliveryRes <8b>. • The EV/PHEV may enable the EV/PHEV IMD, if any.
t104 ► t107	• If the EVSE has not received a SessionStopReq <10a> message 20 seconds after sending the PowerDeliveryRes <8b> message, the EVSE shall trigger an error shutdown.
t105	• The EV/PHEV shall change the CP state to B after receiving message PowerDeliveryRes <8b>. NOTE: If the EV/PHEV decides not to perform welding detection, it proceeds to t106.

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Timestamp	Description
t105 ► t106	• The EV/PHEV may actuate the EV/PHEV charge contactors multiple times during welding detection. • The EV/PHEV may send multiple WeldingDetectionReq <9a> messages in order to read the present voltage at the DC output measured by the EVSE in the WeldingDetectionRes <9b> messages. • The EVSE shall check if the CP state changed to state B before sending the first WeldingDetectionRes <9b> message.
t106	• The EV/PHEV completes welding detection, if performed. • The EV/PHEV shall open the EV/PHEV charge contactors. NOTE: Opening of the EV/PHEV charge contactors starts the reduction of the present voltage at the DC output by passive discharge because the EVSE has not yet received message SessionStopReq <10a>.
t107	• The EV/PHEV shall send the SessionStopReq <10a> message after it has opened the EV/PHEV charge contactors. • If using DIN SPEC 70121:2014, the EV/PHEV sending the SessionStopReq <10a> message will terminate the communication session. • If using ISO 15118-2:2014, the EV/PHEV may, in message SessionStopReq <10a>, use parameter: -"ChargingSession" = 'Pause' to initiate a communication session pause, or -"ChargingSession" = 'Pause' if the EVSE sent parameter "EVSEStatusCode" ='EVSE_UtilityInterruptEvent' in one of the CurrentDemandRes <7b> messages or in the PowerDeliveryRes <8b> message; or -"ChargingSession" = 'Terminate' to terminate digital communication. Refer to IEC 61851-24.
t107 ► t108	• The EVSE shall, in 1 second or less, reduce and maintain the present voltage at the DC output between DC+ and DC- ≤60 V DC. NOTE: The EVSE can actively discharge the DC output because the EV/PHEV has opened the EV/PHEV charge contactors.
t108	• The EVSE shall send the SessionStopRes <10b> message. • If using ISO 15118-2:2014, the EVSE shall turn off its CP oscillator.
t108 ► t110	• The EV/PHEV should unlock the vehicle connector after the SessionStopRes <10b> message is received. The requirements for unlocking are defined in ISO 17409. • If supported by the EVSE, the EV/PHEV may wake up the EVSE and reinitiate a communication session (see 6.4.8). The communication session shall restart after the restart process at t1 in the normal start up sequence (see F.1.8). • If digital communication according to ISO 15118 is used, the EV/PHEV may request a pause (see F.1.12). The communication session shall restart after the pause process at t1 in the normal start up sequence (see F.1.8). • Any subsequent reinitiation of a new communication session shall use the restart sequence as specified in 6.5.31 and continue to t1 in the normal start up sequence F.1.8.
t109	• If using DIN SPEC 70121:2014, the EVSE shall turn off its CP oscillator 1.5 seconds after sending the SessionStopRes <10b> message.
t110	• Un-mating the vehicle connector changes the CP state from B to A. • The limitations of the disabled DC output are not required.

F.1.10 Error and emergency handling

The EVSE and EV/PHEV shall have means to initiate error or emergency shutdowns.

NOTE: An error shutdown is to prevent damage to the equipment. An emergency shutdown is to protect the user from a hazardous situation.

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Table F3 - Overview of error and emergency shutdown cases

Type of Shutdown	Case
Error Shutdown	Cable check errors (see 6.5.4)
	Insulation monitoring during energy transfer (see 6.5.4.6)
	Protection against overvoltage at the DC output between DC+ and DC- (see 6.5.16)
	Overtemperature handling (see 6.5.20)
	Check of the plausibility of the values provided by the thermal sensing (see 6.5.20)
	Short-circuit before energy transfer (see 6.5.18)
	Maximum voltage between DC output live parts (DC+/DC-) and the protective conductor in conditions with a single fault to protective conductor (see 6.5.33.1)
Emergency Shutdown	Loss of electrical continuity of the control pilot conductor (see 6.2.1.1)
	Loss of electrical continuity of the proximity detection conductor (see 6.2.2.5)
	Overcurrent protection (see 6.5.17)
	Protection against overvoltage at the DC output between DC+ and DC- (see 6.5.33.1)
	Control circuit supply integrity
	Loss of electrical continuity the protective conductor (see 6.4.10 and 6.5.32)
	Short-circuit protection (see 6.5.18)
	If error shutdown does not work properly (see F.1.10.1)

Other reasons for error or emergency shutdowns are specified in the respective digital communication protocol as defined in IEC 61851-24.

F.1.10.1 EVSE or EV/PHEV Initiated Error Shutdown

Sequence diagrams and descriptions for EVSE and EV/PHEV initiated error shutdown, based on ISO 15118-2:2014 and DIN SPEC 70121:2014, are shown in Figure F3 and Table F4.

If the digital communication is based on DIN SPEC 70121:2014 and an error occurs during energy transfer, the EV/PHEV can initiate an error shutdown as defined in the sequence diagram and description in Figure F4 and Table F5. In this case, the EV/PHEV can enter the welding detection phase.

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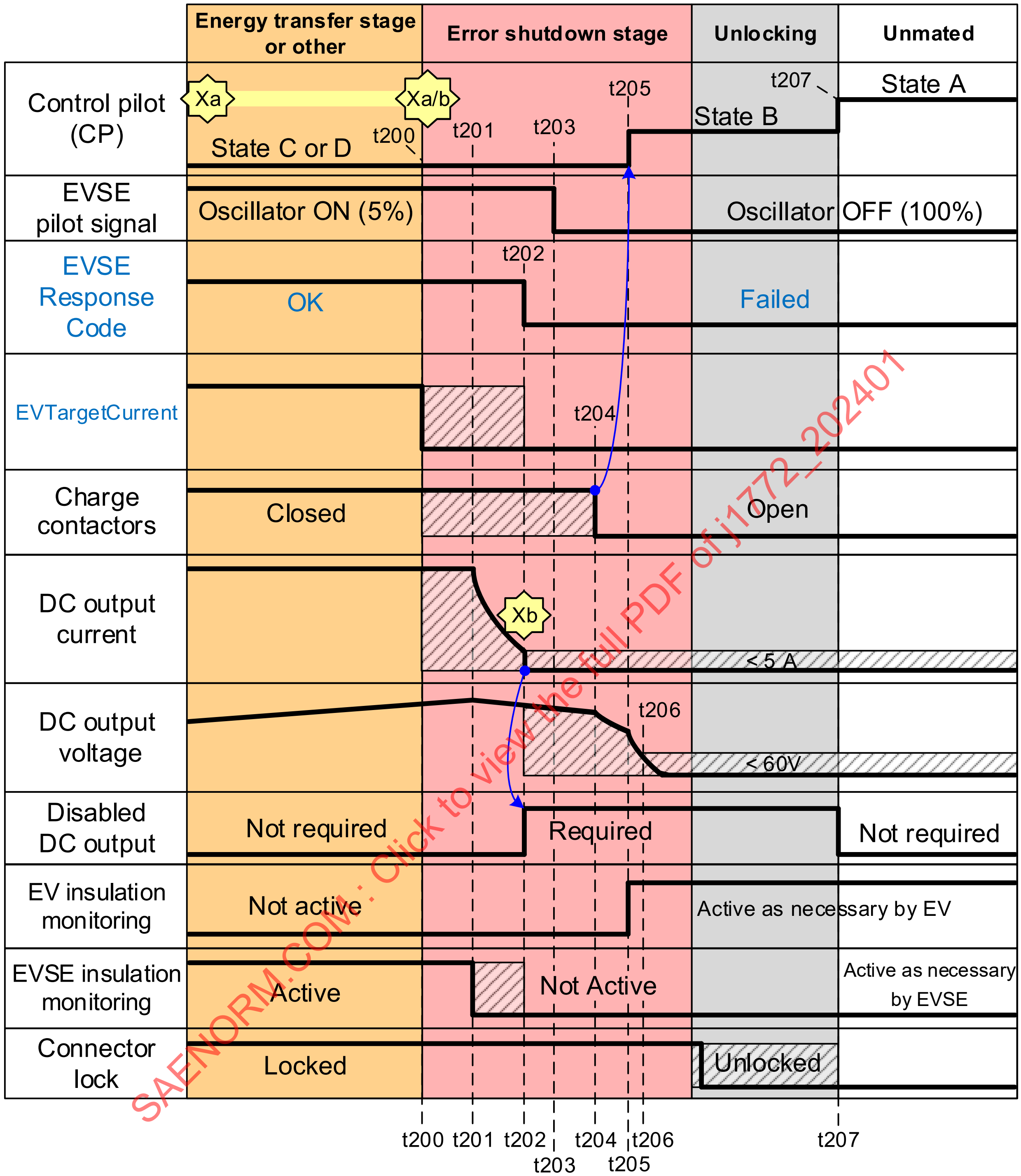

Figure F3 - Error shutdown sequence

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Table F4 - Error shutdown sequence description

Timestamp	Description
► t200	• General precondition: Any digital communication messages between the EV/PHEV and EVSE. • Preconditions for EV/PHEV initiated error shutdown: CP state B, C, or D. • Preconditions for EVSE initiated error shutdown: CP Oscillator ON.
t200	• Occurrence of error shutdown condition detected by the EV/PHEV or EVSE (for example, the EV/PHEV triggers an error shutdown via digital communication, digital communication loss, or closing of the data link/TCP connection). See Table F3. NOTE 1: When using DIN SPEC 70121:2014, if an error condition occurs before energy transfer, the EV/PHEV proceeds to t305 in Table F5, by sending a SessionStopReq <10a> message. NOTE 2: When using DIN SPEC 70121:2014, if an error condition occurs during energy transfer, the EV/PHEV proceeds to t300 in Table F5, by sending a PowerDeliveryReq <8a> message. • The trigger time starts from this moment. NOTE 3: Some trigger times for EV/PHEV initiated error shutdown depends on digital communication requirements. See IEC 61851-24. For an EV/PHEV initiated error shutdown: • The EV/PHEV may open the EV/PHEV charge contactors. In this case, the EV/PHEV shall not re-close the EV/PHEV charge contactors.
t200 ► t201	• Duration of the trigger time of the EVSE. See F.1.10 for the specific requirements for each error shutdown.
t201	• The EVSE performs the error shutdown. • The timing requirements of F.1.9.1 (performance time) starts from this moment. • The EVSE shall disable the EVSE IMD, if not already done.
t201 ► t202	• The EVSE shall reduce the present current at the DC output to <5 A DC and disable DC output in 1 second or less, if not already done.
t201 ► t206	• The EVSE shall, in 2.5 seconds or less, reduce the present voltage at the DC output to ≤60 V DC between: - DC+ and DC-, - DC+ and PE, and - DC- and PE.
t202	• The present current at the DC output shall be <5 A DC and remain <5 A DC. • If not already done, the EVSE shall stop the overvoltage protection according to 6.5.24, and then, the EVSE shall disable the DC output, and open the EVSE contactors, if any. During an EVSE initiated error shutdown: • If digital communication is still operational, the EVSE shall send parameter "ResponseCode" = 'FAILED' in the next response messages. Refer to IEC 61851-24:2014. During an EV/PHEV initiated error shutdown: • If digital communication is still operational, the EVSE shall send message SessionStopRes <10b> if message SessionStopReq <10a> was received before t202. NOTE: Refer to ISO 15118-2:2014 and DIN SPEC 70121:2014 for exception cases, if any.
t202 ► t203	• The EVSE shall turn off its CP oscillator between 300 and 500 ms after the present current at the DC output is <5 A DC.
t202 ► t207	• The disabled DC output of the EVSE shall have equivalent electrical properties/behavior (e.g., impedance, discharge rate, etc.) as the circuit described in 6.5.27.
t203	• The EVSE shall turn off its CP oscillator. NOTE: If the EVSE turns off the CP oscillator before sending a response message with parameter "ResponseCode" = 'FAILED,' the EV/PHEV will detect an EVSE initiated emergency shutdown (see F.1.10.2). The 300 ms delay should be sufficient for the EV/PHEV to send and receive the digital communication message. • If the EVSE has not turned off its CP oscillator 2.5 seconds after the error is detected (t200), the EV/PHEV and EVSE shall trigger an emergency shutdown. See F.1.11.2 for the timing requirements for the EVSE regarding the present current at the DC output, disconnection device, and CP oscillator.
t203 ► t204	• The EV/PHEV shall open the EV/PHEV charge contactors in 100 ms or less after the EVSE has turned off its CP oscillator.
t204	• The EV/PHEV shall open the EV/PHEV charge contactors, if not already open.
t205	• The EV/PHEV shall change the CP state to B when it has opened the EV/PHEV charge contactors. • The EV/PHEV may enable the EV/PHEV IMD.
t206	• The present voltage at the DC output between DC+ and DC- shall be ≤60 V DC.

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	During an EV/PHEV initiated error shutdown: • If digital communication is still operational, the EVSE shall send message SessionStopRes <10b> if message SessionStopReq <10a> was received after t202. NOTE: Refer to ISO 15118-2:2014 and DIN SPEC 70121:2014 for exception cases, if any.
t206 ► t207	• If digital communication is still operational, the EV/PHEV should unlock the vehicle connector after the SessionStopRes <10b> message is received. The requirements for unlocking are defined in ISO 17409. • Any subsequent reinitiation of a new communication session shall use the restart sequence as specified in 6.5.31 and continue to t1 in the normal start up sequence F.1.8.
t207	• Un-mating the vehicle connector changes the CP state from B to A. • The limitations of the disabled DC output of the EVSE are not required.

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F.1.10.1.1 EV/PHEV Initiated Error Shutdown During Energy Transfer Using DIN 70121:2014

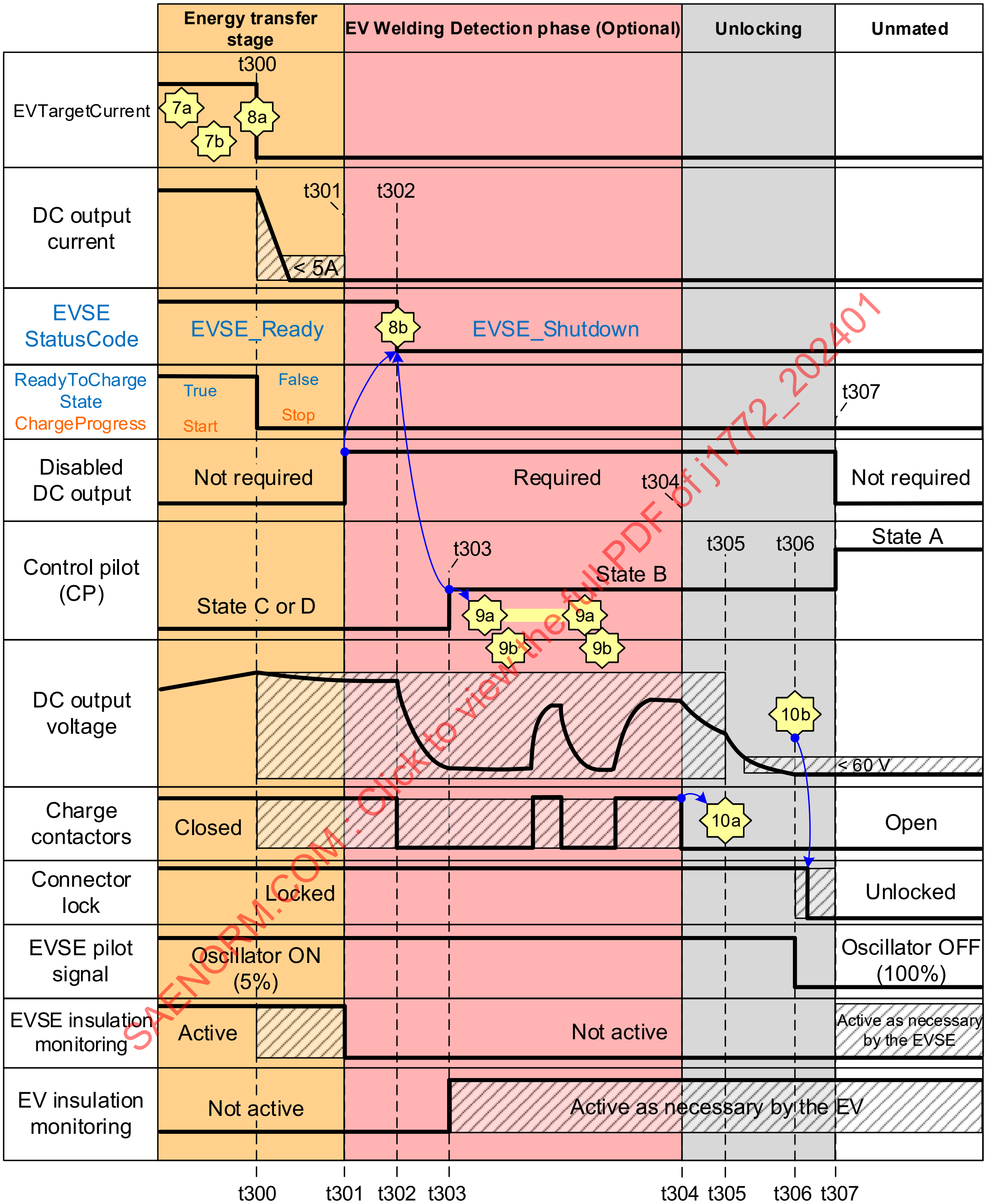

Figure F4- EV/PHEV initiated error shutdown during energy transfer using DIN 70121

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Table F5 - EV initiated error shutdown during energy transfer using DIN 70121 sequence description

Timestamp	Description
► t300	• Cyclic CurrentDemandReq/Res messages between the EV/PHEV <7a> and EVSE <7b>.
t300	• An EV/PHEV, using DIN SPEC 70121:2014 as its digital communication protocol, triggers an EV/PHEV initiated error shutdown by requesting the EVSE to disable DC output by sending message PowerDeliveryReq <8a> with parameter "ReadyToChargeState" = 'FALSE.'
t300 ► t301	• If the present current at the DC output is >5 A DC, the present current at the DC output shall be <5 A DC in 1 second or less and remain <5 A DC.
t300 ► t303	• The EV/PHEV may open the EV/PHEV charge contactors after the present current is <5 A DC and after the message PowerDeliveryReq <8a> has been sent. In this case, the EV/PHEV shall not re-close the EV/PHEV charge contactors.
t301	• If not already done, the EVSE shall stop the overvoltage protection according to 6.5.24, and then the EVSE shall disable the DC output, and open the EVSE disconnection device, if any. NOTE: If the EVSE disables the DC output while the present current at the DC output is >0 A DC, the present voltage at the DC output drops to the battery system voltage because the EV/PHEV charge contactors are still closed. • The EVSE shall disable the EVSE IMD.
t301 ► t307	• The disabled DC output of the EVSE shall have equivalent electrical properties/behavior (e.g., impedance, discharge rate, etc.) as the circuit described in 6.5.27.
t302	• The EVSE shall communicate that the present current at the DC output is <5 A DC and has disabled the DC output by sending parameter "EVSEStatusCode" = 'EVSE_Shutdown' in message PowerDeliveryRes <8b>.
t302 ► t305	• If the EVSE has not received a SessionStopReq <10a> message 20 seconds after sending the PowerDeliveryRes <8b> message, the EVSE shall trigger an EVSE initiated error shutdown.
t303	• The EV/PHEV shall change the CP state to B after receiving message PowerDeliveryRes <8b>. • The EV/PHEV may enable the EV/PHEV IMD, if any. NOTE: If the EV decides not to perform welding detection, it proceeds to t304.
t303 ► t304	• The EV/PHEV may actuate the EV/PHEV charge contactors multiple times during welding detection. • The EV/PHEV may send multiple WeldingDetectionReq <9a> messages in order to read the present voltage at the DC output measured by the EVSE in the WeldingDetectionRes <9b> messages. • The EVSE shall check if the CP state changed to state B before sending the first WeldingDetectionRes <9b> message.
t304	• The EV/PHEV completes welding detection, if performed. • The EV/PHEV shall open the EV/PHEV charge contactors. NOTE: The opening of the EV/PHEV charge contactors starts the reduction of the present voltage at the DC output by passive discharge because the EVSE has not yet received message SessionStopReq <10a>.
t305	• The EV/PHEV shall send the SessionStopReq <10a> message after it has opened the EV/PHEV charge contactors. • The EV/PHEV initiates digital communication termination by sending message SessionStopReq <10a>.
t305 ► t306	• The EVSE shall, in 1 second or less, reduce the present voltage at the DC output between DC+ and DC- to ≤60 V DC. NOTE: The EVSE can actively discharge DC output because the EV/PHEV has opened the EV/PHEV charge contactors.
t306	• The EVSE shall send the message SessionStopRes <10b>. • The EVSE shall turn off its CP oscillator according to IEC 61851-24.
t306 ► t307	• The EV/PHEV should unlock the vehicle connector after the SessionStopRes <10b> message is received. The requirements for unlocking are defined in ISO 17409. • Any subsequent reinitiation of a new communication session shall use the restart sequence as specified in 6.5.31 and continue to t1 in the normal start up sequence F.1.8.
t307	• Un-mating the vehicle connector changes the CP state from B to A. • The limitations of the disabled DC output of the EVSE are not required.

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F.1.11 Emergency Shutdown Executed by the EVSE or EV/PHEV

Both the EVSE and the EV/PHEV must communicate, by means of basic signalling, that an emergency shutdown condition was detected. In this case, the EVSE and the EV/PHEV execute the emergency shutdown independently, synchronized with basic signalling.

The diagrams show multiple scenarios for emergency shutdown conditions, as detected by the EVSE or EV/PHEV.

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F.1.11.1 Emergency Shutdown Executed by the EV/PHEV

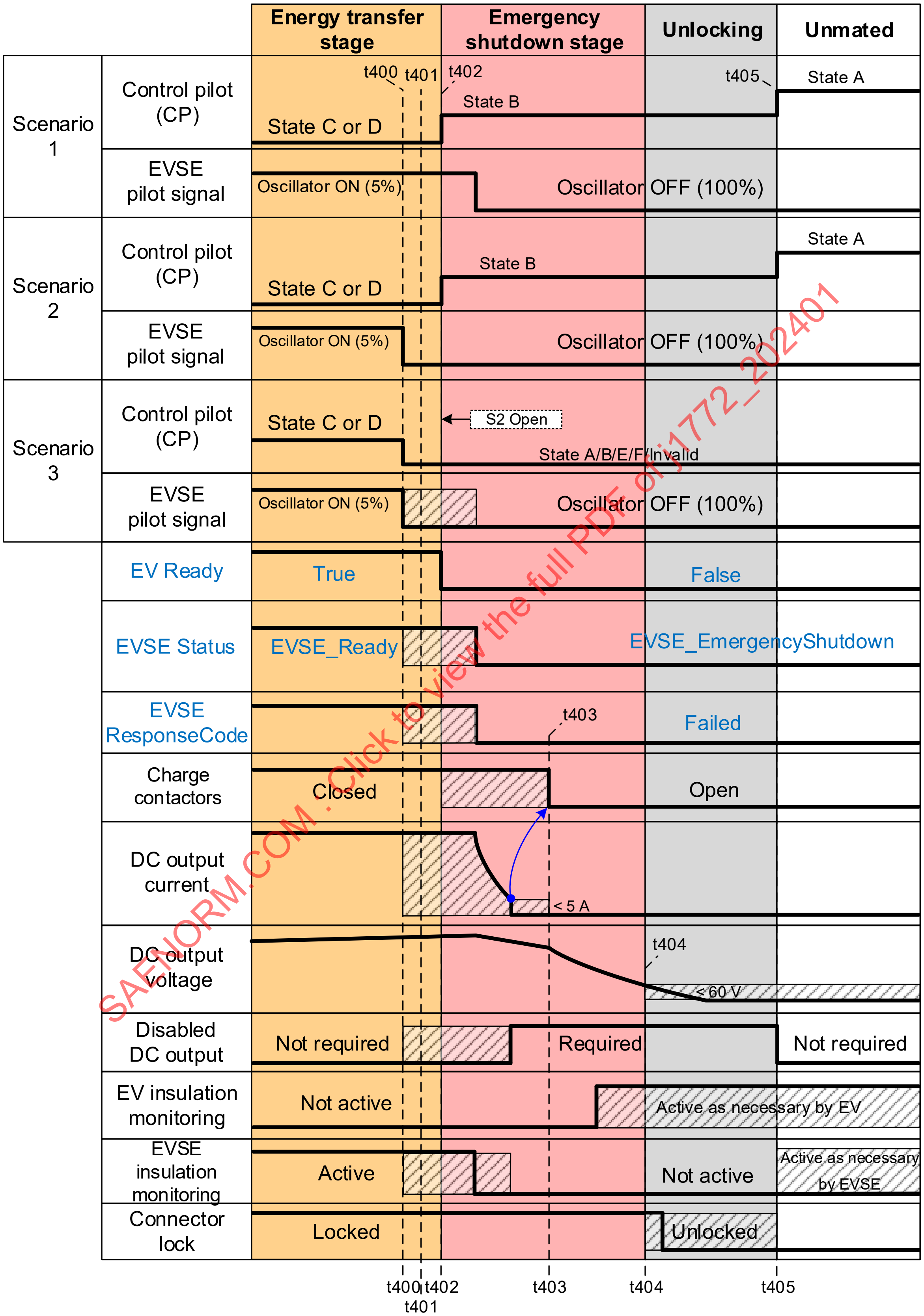

Figure F5 - Emergency shutdown executed by the EV

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Table F6 - Emergency shutdown executed by the EV/PHEV sequence description

Timestamp	Description
► t400	• General precondition: Any digital communication messages between the EV/PHEV and EVSE. • Preconditions for emergency shutdowns executed by the EV/PHEV: CP state C/D and CP oscillator on (5% PWM)
t400	• Occurrence of the first emergency shutdown condition: - Scenario 1: Occurrence of a fault that can be detected by the EV/PHEV (for example, internal fault of the EV, loss of electrical continuity of the protective conductor without leaving CP state C or D, etc.). The fault has not been detected by the EVSE. - Scenario 2: The EVSE initiates an emergency shutdown by turning off the CP oscillator (100% PWM). The fault has not been detected by the EV/PHEV. - Scenario 3: Occurrence of a fault detected by both the EV/PHEV and EVSE. For example, when S2 is closed and the CP state changes to states A/B/E/F or Invalid from the EV/PHEV perspective (for example, loss of electrical continuity of the control pilot conductor or loss of electrical continuity of the proximity detection conductor). NOTE 1: When the EV/PHEV detects an emergency shutdown condition, it must not rely on digital communication from the EVSE, as a fault condition may disturb digital communication or basic signalling between the EV/PHEV and EVSE. NOTE 2: The timing requirements in this sequence are based on the occurrence of the first emergency shutdown condition detected by the EV/PHEV. There might be subsequent emergency shutdown conditions.
t400 ► t401	Scenario 1: • In case the EV/PHEV detects an internal fault, the EV/PHEV shall open S2 as specified by the EV/PHEV manufacturer. • In case of losing of electrical continuity of the protective conductor without leaving CP state C or D (from point A to the EV/PHEV; see Figure 4), the EV/PHEV shall trigger an emergency shutdown in 150 ms or less. See 6.4.10. Scenario 2: • In case the EVSE turned off the CP oscillator, the EV/PHEV shall trigger an emergency shutdown in 50 ms or less. Scenario 3: • In case of an unexpected CP state change, the EV/PHEV shall trigger an emergency shutdown in 50 ms or less. See 6.2.1.2.
t401	• The EV/PHEV triggers the emergency shutdown.
t401 ► t402	• The EV/PHEV shall open S2 in 10 ms or less.
t402	• The EV/PHEV opens S2. • The EV/PHEV may open the EV/PHEV charge contactors. In this case, the EV/PHEV shall not re-close the EV/PHEV charge contactors.
t401 ► t403	• The EV/PHEV shall either: - open the EV/PHEV charge contactors in 100 ms or less after the present current at the DC output is <5 A DC, or - open the EV/PHEV charge contactors 1.1 seconds after triggering an emergency shutdown, Whichever results in the shortest time to open the EV/PHEV charge contactors. NOTE 1: In an emergency shutdown, the EVSE has reduced the present current at the DC output to <5 A DC in 30 ms or less after t401. The EV/PHEV has sufficient time to open the EV/PHEV charge contactors without a present current at the DC output. NOTE 2: Legacy EVSEs, according to IEC 61851-23:2014, may take up to 1 second to reduce the present current at the DC output to <5 A DC in case the CP state changes from state C/D to state B
t401 ► t405	• Both the EV/PHEV and EVSE may try to maintain digital communication. • If the EV/PHEV or EVSE send a digital communication message, the request message sent by the EV/PHEV shall contain parameter "EVReady" = 'False.'
t403	• The EV/PHEV opens the EV/PHEV charge contactors.
t403 ►	• The EV/PHEV may enable the EV/PHEV IMD, if any.
t404	• See t505 in Table F7 (Emergency shutdown executed by the EVSE)
t404 ► t405	• The EV/PHEV may unlock the vehicle connector. The requirements for unlocking are defined in ISO 17409. • Any subsequent reinitiation of a new communication session shall use the restart sequence as specified in 6.5.31 and continue to t1 in the normal start up sequence F.1.8.
t405	• Un-mating the vehicle connector changes the CP state from B to A.

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F.1.11.2 Emergency Shutdown Executed by the EVSE

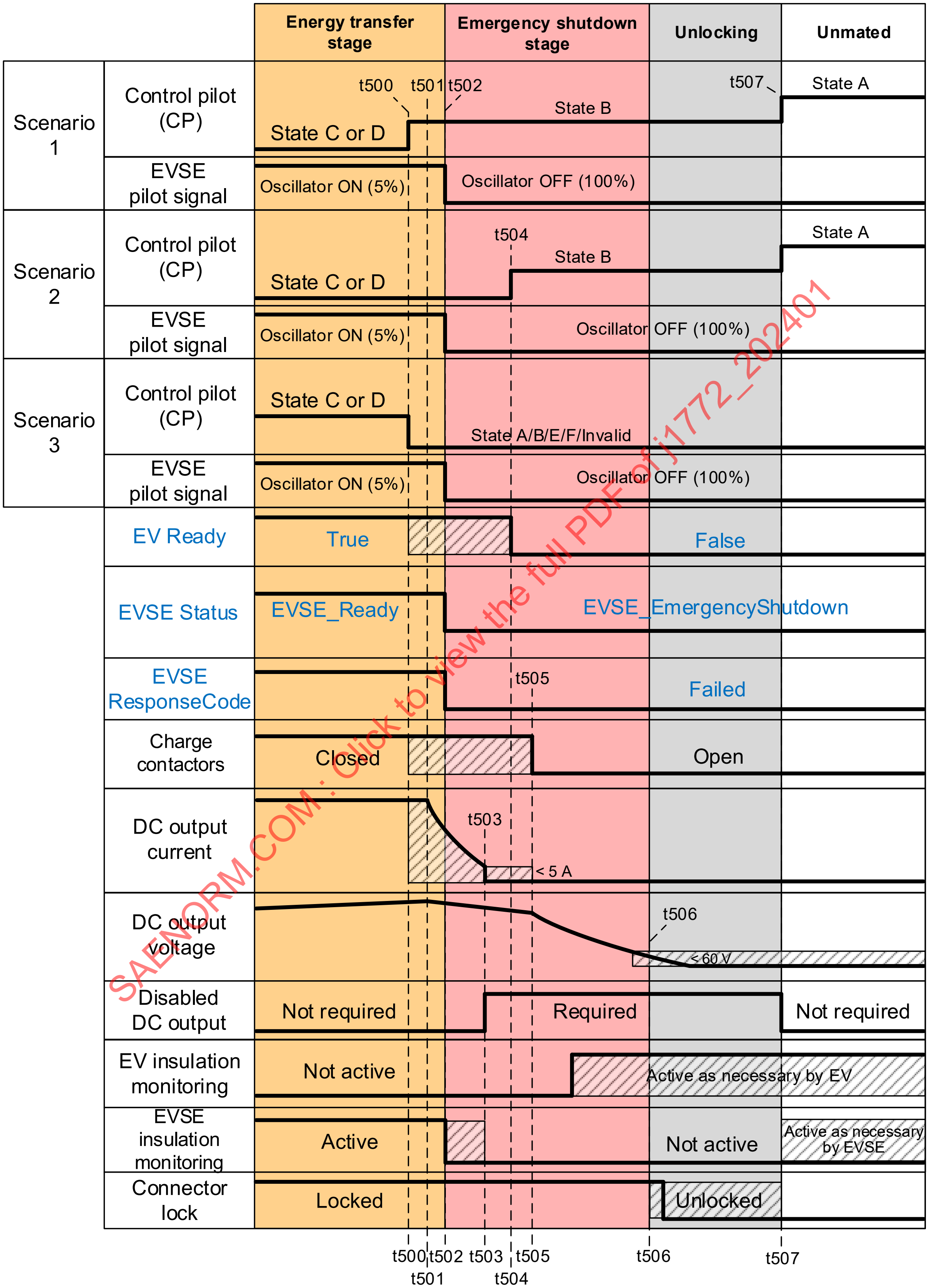

Figure F6 - Emergency shutdown executed by the EVSE

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Table F7 - Emergency shutdown executed by the EVSE sequence description

Timestamp	Description
► t500	• General precondition: Any digital communication messages between the EV/PHEV and EVSE. • Precondition for an emergency shutdown executed by the EVSE: CP oscillator on.
t500	• Occurrence of the first emergency shutdown condition: - Scenario 1: The EV/PHEV initiates an emergency shutdown by opening S2 (for example, internal fault of the EV, loss of electrical continuity of the protective conductor without leaving CP state C or D, etc.). The fault has not been detected by the EVSE. - Scenario 2: Occurrence of a fault that can be detected by the EVSE (for example, internal fault detected by EVSE). The fault has not been detected by the EV/PHEV. - Scenario 3: Occurrence of a fault detected by both the EV/PHEV and EVSE. For example, the CP state changes to states A/B/E/F or Invalid from the EVSE perspective (for example, loss of electrical continuity of the protective conductor, loss of electrical continuity of the control pilot conductor, or loss of electrical continuity of the proximity detection conductor). NOTE 1: When the EVSE detects an emergency shutdown condition, it must not rely on digital communication from the EV, as a fault condition may disturb digital communication or basic signalling between the EV/PHEV and EVSE. NOTE 2: The timing requirements in this sequence are based on the occurrence of the first emergency shutdown condition detected by the EVSE. There might be subsequent emergency shutdown conditions. NOTE 3: In an emergency shutdown executed by the EV/PHEV (scenario 1), the EV/PHEV may open the EV/PHEV charge contactors as soon as it detected the fault condition.
t500 ► t501	• The EVSE shall trigger an emergency shutdown in the trigger times or less specified for each fault. See Table F3. • In case the EVSE detects an internal fault not specified in Table F3, the EVSE shall trigger an emergency shutdown as specified by the EVSE manufacturer. NOTE: The trigger time is the time between the occurrence of a fault and the moment that an emergency has to be triggered by the EVSE. These times are specified for each fault in Table F3.
t501	• The EVSE has triggered an emergency shutdown. NOTE: Point in time that cannot be physically measured at the vehicle connector.
t501 ► t502	• The EVSE shall turn off its CP oscillator in 10 ms or less.
t501 ► t503	• The EVSE shall reduce the present current at the DC output to <5 A DC and disable DC output in 20 ms or less, if not already done.
t501 ► t506	• The EVSE shall, in 1 second or less, reduce the present voltage at the DC output to ≤60 V DC between: - DC+ and DC-, and - DC+ and PE, and - DC- and PE.
t502	• The EVSE turns off its CP oscillator to indicate an EVSE initiated emergency shutdown. NOTE: The timing requirements of F.1.9.1 (performance time) start from this moment. • The EVSE shall disable the EVSE IMD, if not already done.
t502 ► t504	Scenario 2: •The EV/PHEV must change the CP state from C/D to B by opening S2 in 50 ms or less after the CP oscillator is turned off.
t502 ► t507	• Both the EV/PHEV and EVSE may try to maintain digital communication. • If the EV/PHEV or EVSE send a digital communication message, the response message sent by the EVSE shall contain parameter "ResponseCode" = 'FAILED.'
t503	• The EVSE has reduced the present current at the DC output to <5 A DC. • If not already done, the EVSE shall stop the overvoltage protection according to 6.5.24, and then, the EVSE shall disable the DC output, and open the EVSE disconnection device, if any.
t503 ► t507	• The disabled DC output of the EVSE shall have equivalent electrical properties/behavior (e.g., impedance, discharge rate, etc.) as the circuit described in 6.5.27.
t504	Scenario 2: • The EV/PHEV opens S2. See t402 in Table F6 (Emergency shutdown executed by the EV).
t505	• See t403 in Table F6 (Emergency shutdown executed by the EV/PHEV). NOTE: The EVSE can assume the EV/PHEV opened the EV/PHEV charge contactors 160 ms after turning off the CP oscillator or after the CP state changed from state C/D to states A/BCE/F or Invalid. After this time, the EVSE can proceed to actively discharge DC output.
t506	• The present voltage at the DC output between DC+ and DC- is ≤60 V DC.
t506 ► t507	• See t404 ► t405 in Table F6 (Emergency shutdown executed by the EV) • Any subsequent re-initiation of a new communication session shall use the restart sequence as specified in 6.5.31 and continue to t1 in the normal start up sequence F.1.8.
t507	• Un-mating the vehicle connector changes the CP state from B to A.

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Timestamp	Description
	• The limitations of the disabled DC output of the EVSE are not required.

F.1.12 Pause Triggered by the EVSE Using ISO 15118-2:2014

The sequences specified in this clause are only applicable for EVSE using ISO 15118-2:2014.

F.1.12.1 Pause Before Cable Check Triggered by the EVSE Using ISO 15118-2:2014

If the EVSE does not have power available at the beginning of the charging session to do cable-check, pre-charge, and energy transfer, the EVSE can perform a pause before cable-check. The EVSE will trigger a restart of the charging session as soon as it has power available.

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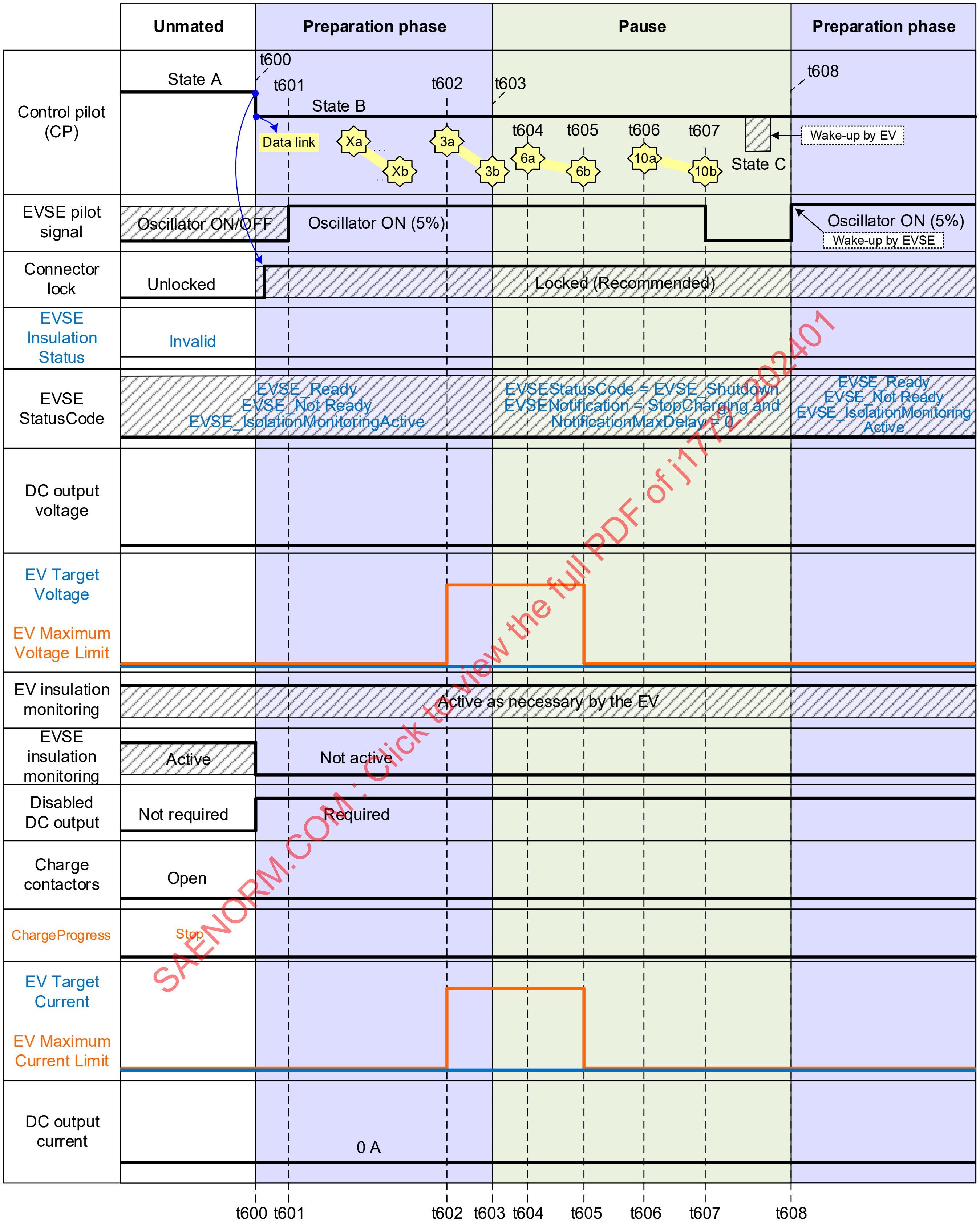

Figure F7 - Pause before cable-check triggered by the EVSE

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Table F8 - Pause before cable-check triggered by the EVSE sequence description

Timestamp	Description
► t600	• The present voltage at the DC output shall be ≤60 V DC.
t600	• The vehicle connector is mated to the vehicle inlet, which changes the CP state from A to B. • After the CP state changed to B and the PP is detected (S3 closed in case of configuration EE), the EV/PHEV should lock the vehicle connector in the vehicle inlet. • After the CP state changed to B, the EVSE shall disable the EVSE IMD, disable DC output and open the EVSE disconnection device, if any. • After the CP state changed to B, the EV/PHEV may try to set up a data link as defined in IEC 61851-24.
t600 ► t603	• The EVSE shall not trigger an error shutdown due to the present voltage at the DC output (including negative voltages). NOTE: When the vehicle connector is mated to the vehicle inlet, these voltages can be caused by the EV/PHEV requirements for unmated conditions in 6.5.2 of ISO 17409:2020. EVSE based on IEC 61851-23:2014 must trigger a shutdown if the present voltage at DC output is >60 V DC in the first ChargeParameterDiscoveryReq <3a> message.
t600 ► t604	• If the EV/PHEV tried and failed to lock the vehicle connector, the EV/PHEV shall notify the EVSE with parameter "EVErrorCode" = 'FAILED_ChargerConnectorLockFault' in the next communicated message that contains this parameter, according to IEC 61851-24.
t600 ► t608	• The disabled DC output of the EVSE shall have equivalent electrical properties/behavior (for example, impedance, discharge rate, etc.) as the circuit described in 6.5.27.
t601	• The EVSE shall turn on its CP oscillator if the EVSE is ready for energy transfer and if its CP oscillator is not already on. • The EVSE shall maintain a CP duty cycle of 5% from the start of the data link setup until end of communication session unless a certain condition requires a different CP duty cycle.
t601 ► t602	• The EV/PHEV shall establish the data link, as defined in the IEC 61851-24, after it has verified that the EVSE has turned on its CP oscillator, if the data link is not already established. NOTE: The data link could have been previously established due to a pause or renegotiation of the communication session. • Digital communication starts by the negotiation of an appropriate application layer protocol between the EV/PHEV <Xa> and EVSE <Xb>. See Appendix G. • The EV/PHEV and EVSE exchange message pairs concerning session setup, services, authentication, payment options, and value-added services (if supported by the negotiated application layer protocol). According to IEC 61851-24, some message pairs are not necessary after a pause or renegotiation, for example, authentication or payment options.
t602	• The EV/PHEV shall send parameters "EVMaximumVoltageLimit" and "EVMaximumCurrentLimit" (amongst other parameters) with the first ChargeParameterDiscoveryReq <3a> message.
t602 ► t603	• The EVSE shall perform a compatibility check. • The EVSE shall check if the absolute value of the present voltage at the DC output between DC+ and DC- is <60 V DC and shall send message ChargeParameterDiscovery <3b> with parameter "EVSEProcessing" = 'Ongoing' if the absolute value of the present voltage at the DC output is ≥60 V DC. • The EVSE shall send parameters "EVSEMaximumVoltageLimit," "EVSEMinimumVoltageLimit," "EVSEMaximumCurrentLimit," and "EVSEMinimumCurrentLimit" (amongst other parameters) in message ChargeParameterDiscoveryRes <3b> considering the compatibility check. • The EVSE shall send parameter "EVSEStatusCode" = 'EVSE_IsolationMonitoringActive' in the "ChargeParameterDiscoveryRes <3b>" messages, unless the EVSE wants to perform a shutdown. The EV/PHEV is recommended to continue the communication session if the EVSE sends ChargeParameterDiscoveryRes <3b> messages with parameter "EVSE_StatusCode" = 'EVSE_Ready' or 'EVSE_NotReady.' NOTE 1: EVSEs based on IEC 61851-23:2014 can send parameter "EVSE_StatusCode" = "EVSE_Ready," "EVSE_NotReady," or "EVSE_IsolationMonitoringActive" in ChargeParameterDiscoveryRes <3b> messages. • If the EVSE replies with parameters "ResponseCode" = 'OK' and "EVSEProcessing" = 'Ongoing' in message ChargeParameterDiscoveryRes <3b>, the EV/PHEV and EVSE may update the parameters sent in the next ChargeParameterDiscoveryReq/Res messages. NOTE 2: The EVSE may use "EVSEProcessing" = 'Ongoing' for other reasons. Example: load management, etc. • If the EV/PHEV sends parameter "EVErrorCode" = 'FAILED_ChargerConnectorLockFault' in a ChargeParameterDiscoveryReq <3a> message, the EVSE should respond with cyclic ChargeParameterDiscoveryRes <3b> messages with parameters "EVSEProcessing" = 'Ongoing' and "ResponseCode" = 'OK' to give the EV/PHEV additional time to solve the fault in the locking mechanism. NOTE 3: The EVSE should inform the user how to improve the locking process. For example, by indicating how to properly mate the vehicle connector in the vehicle inlet.
t602 ► t603	• ISO 15118-2:2014 does not specify the possibility to update the parameters in subsequent ChargeParameterDiscoveryReq/Res messages, however, it is recommended for the EVSE not to perform a shutdown if the EV/PHEV changes the parameters.

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	• To improve interoperability, the EVSE shall tolerate the EV/PHEV changing CP state to C/D during cyclic ChargeParameterDiscoveryReq/Res messages. If the EV/PHEV changes back to CP state B, the EVSE shall trigger an EVSE initiated emergency shutdown. See F.1.11. NOTE 4: Requirement (V2G2-912) in ISO 15118-2:2014 and a similar requirement in outdated versions of SAE J1772 don't specify that the EV/PHEV must receive a ChargeParameterDiscoveryRe <3b> with parameter "EVSEProcessing" = "Finished" before changing the CP state from state B to state C/D, leading to this unwanted behavior.
t603	• If the absolute value of the present voltage at the DC output is <60 V DC, the EVSE shall send the EV/PHEV the result of the compatibility check and trigger for a communication session pause before cable-check phase in message ChargeParameterDiscoveryRes <3b> using parameters "EVSEStatusCode" = 'EVSE_IsolationMonitoringActive', "EVSEProcessing" = 'Finished', and: -"ResponseCode" = 'OK', "EVSENotification" = 'StopCharging,' and "NotificationMaxDelay" = '0' if the compatibility check was completed successfully and the EVSE has no power available, or -"ResponseCode" = 'Failed_WrongChargeParameter' if the compatibility check was completed and failed, triggering an EVSE initiated error shutdown. NOTE 1: A ChargeParameterDiscoveryRes <3b> message with "ResponseCode" = 'Failed_WrongChargeParameter' and parameter "EVSEProcessing" = 'Ongoing,' will trigger an EVSE initiated error shutdown. Refer to error handling specifications for the digital communication standards in IEC 61851-24. NOTE 2: If the absolute value of the present voltage at the DC output is not <60 V DC at the end of the compatibility check (based on the timing requirements of IEC 61851-24), the EVSE cannot send a ChargeParameterDiscoveryRes <3b> message with parameter "EVSEProcessing" = 'Finished.' In this case, the EV/PHEV must trigger an error shutdown NOTE 3: EVSEs based on IEC 61851-23:2014 can send parameter "EVSE_StatusCode" = "EVSE_Ready," "EVSE_NotReady," or "EVSE_IsolationMonitoringActive" in ChargeParameterDiscoveryRes <3b> messages. The EV/PHEV is recommended to continue the communication session if the EVSE sends ChargeParameterDiscoveryRes <3b> messages with parameter "EVSE_StatusCode" = 'EVSE_Ready' or 'EVSE_NotReady.' • It is recommended that the EVSE sends parameter "EVSEStatusCode" = 'EVSE_IsolationMonitoringActive' in the last ChargeParameterDiscoveryRes <3b> message.
t603 ► t604	• The EV/PHEV may lock the vehicle connector in the vehicle inlet. • The EV/PHEV shall not send messages CableCheckReq <4a> and PreChargeReq <5a>. NOTE: The EV/PHEV does not send messages CableCheckReq <4a> and PreChargeReq <5a> because the EVSE has indicated that it has no power available.
t603 ► t607	• The EV/PHEV shall not change to CP state C/D during the communication session pause.
t603 ►	• The EVSE shall trigger an error shutdown if the present voltage at the DC output between DC+ and DC- is <-60 V DC for 400 consecutive ms or more.
t604	• The EV/PHEV shall not send messages CableCheckReq <4a> and PreChargeReq <5a>, but instead the EV/PHEV shall send message PowerDeliveryReq <8a> with "ChargeProgress" = 'Stop.' NOTE: The EV/PHEV does not send messages CableCheckReq <4a> and PreChargeReq <5a>, as the EVSE has indicated that it has no power available. • If the EV/PHEV tried and failed to lock the vehicle connector, the EV/PHEV shall trigger an EV/PHEV initiated error shutdown with parameter "EVErrorCode" = 'FAILED_ChargerConnectorLockFault' in message PowerDeliveryReq <6a>.
t605	• The EVSE shall send message PowerDeliveryRes <8b> with parameters "EVSEStatusCode" = 'EVSE_Shutdown,' "EVSENotification" = 'StopCharging,' and "NotificationMaxDelay" = '0.'
t606	• The EV/PHEV shall send message SessionStopReq <10a> with parameter "ChargingSession" = 'Pause.'
t607	• The EVSE shall send message SessionStopRes <10b> according to IEC 61851-24. • The EVSE shall turn off its CP oscillator according to IEC 61851-24.
t607 ► t608	• Duration of the communication session pause. • If the EV/PHEV or EVSE want to stop the communication session, the EV/PHEV or EVSE, respectively, shall end the pause by performing a restart (see 6.4.8), followed by a normal start up (see t1 ► t2 in Table F1), and then a normal shutdown (see F.1.9). • If the EV/PHEV or EVSE want to resume the communication session, the EV/PHEV or EVSE, respectively, shall end the pause by performing a restart (see 6.35.31) followed by a normal start up (see F.1.8). • If the vehicle connector is un-mated, the EVSE shall terminate the data link according to IEC 61851-24.
t608	• The EVSE shall turn on its CP oscillator according to IEC 61851-24, to indicate to the EV/PHEV that power is now available. • The EVSE shall continue to t1 in the normal start up sequence F.1.8.

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F.1.12.2 Pause After Pre-Charge and Before Energy Transfer Triggered by the EVSE Using ISO 15118-2:2014

In case the EVSE has power available at the beginning of the charging session to do cable-check and pre-charge but not energy transfer, the EVSE can perform a pause after pre-charge and before energy transfer. This case allows the EVSE to verify that the insulation value is valid before the pause. If cable-check fails, the user is notified before the pause that the EVSE is not safe and can proceed to another EVSE. This sequence is only applicable for ISO 15118-2:2014.

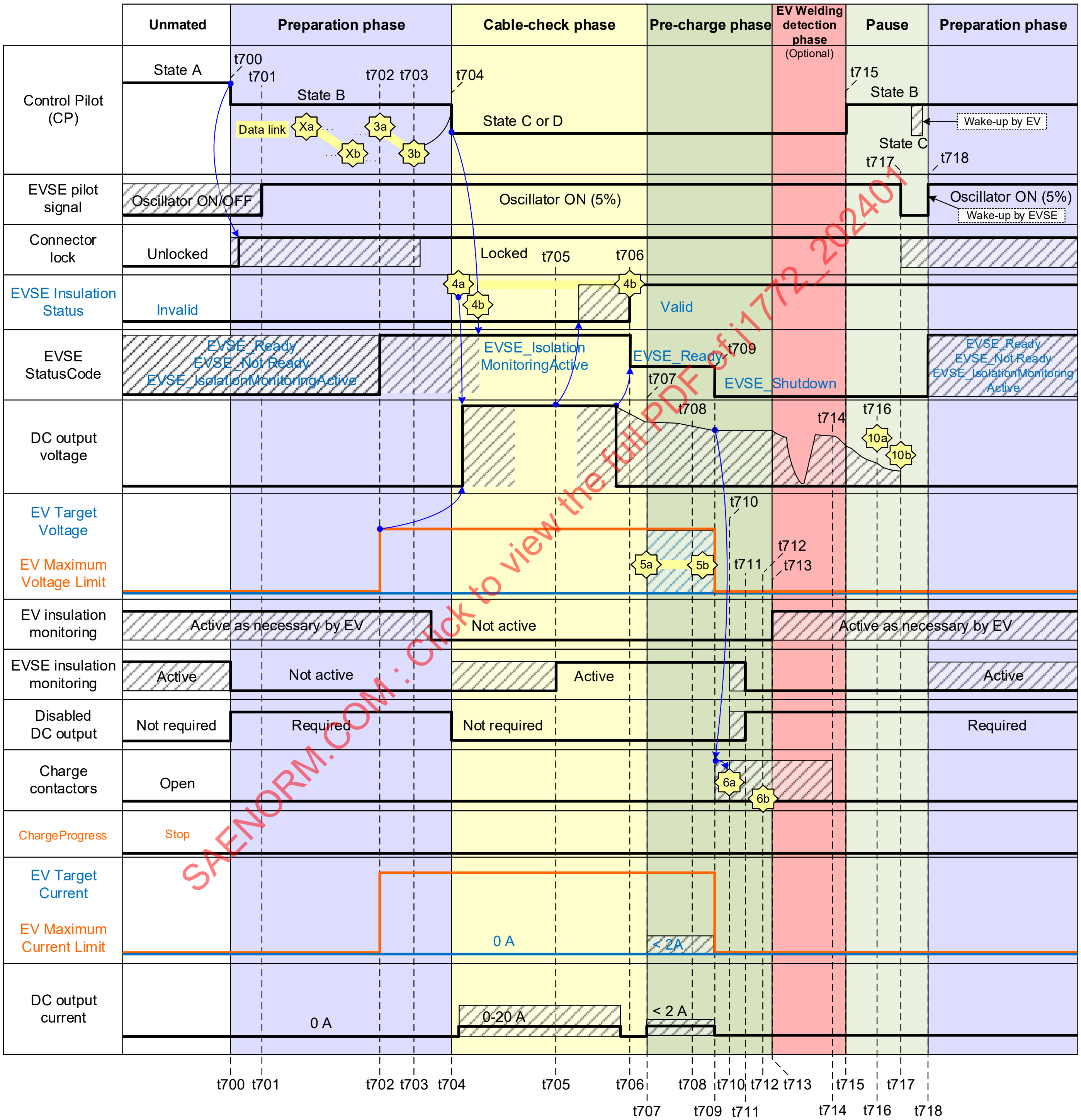

Figure F8 - Pause after pre-charge and before energy transfer triggered by the EVSE

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