SURFACE VEHICLE RECOMMENDED PRACTICE	J3400™	SEP2024
	Issued 2023-12 Revised 2024-09 Superseding J3400 DEC2023	

(R) North American Charging System (NACS) for Electric Vehicles

RATIONALE

There are a number of revisions needed to the document to provide additional communication requirements and the creation of reference devices for the NACS.

FOREWORD

This SAE Recommended Practice is intended as a guide toward standard practice and is subject to change to keep pace with experience and technical advances.

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TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
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Fax: 724-776-0790
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For more information on this standard, visit
https://www.sae.org/standards/content/J3400_202409/

1. SCOPE

This document covers the general physical, electrical, functional, safety, and performance requirements for conductive power transfer to an electric vehicle using a coupler, which can be hand-mated and is capable of transferring either DC or AC single-phase power using two current-carrying contacts.

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 J1772 SAE Electric Vehicle and Plug-in Hybrid Electric Vehicle Conductive Charge Coupler

SAE J2012 Diagnostic Trouble Code Definitions

SAE J2411 Single Wire CAN Network for Vehicle Applications

SAE J2847/2 Communication Between Plug-in Vehicles and Off-Board DC Chargers

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

SAE J2847/5 Communication Between Plug-in Vehicles and Customers

SAE J3068 Electric Vehicle Power Transfer System Using a Three-Phase Capable Coupler

SAE J3068/2 Control of Bidirectional Power for AC Conductive Charging

SAE J3072 Interconnection Requirements for Onboard, Grid Support Inverter Systems

SAE USCAR2 Performance Standard for Automotive Electrical Connector Systems

SAE/USCAR-25 Electrical Connector Assembly Ergonomic Design Criteria

PKI001 SAE EV Charging Public Key Infrastructure - Certificate Policy, V1.1

2.1.2 ANSI Accredited and UL Publications

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

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

ANSI/UL 943 Ground-Fault Circuit-Interrupters

ANSI/UL 1998 Software in Programmable Components

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

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

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

ANSI/UL 2251 Plugs, Receptacles, and Couplers for Electric Vehicles

ANSI/UL 2594 Electric Vehicle Supply Equipment

2.1.3 California Code of Regulations Publications

Copies of these documents are available online at https://oal.ca.gov/.

13 CCR § 1971.1 On-Board Diagnostic System Requirements - 2010 and Subsequent Model-Year Heavy-Duty Engines

2.1.4 Code of Federal Regulations (CFR) Publications

Copies of these documents are available online at https://www.ecfr.gov.

16 CFR § 309.17 Labels

47 CFR Part 15 Radio Frequency Devices

2.1.5 CSA Publications

Available from CSA International, 178 Rexdale Boulevard, Toronto, Ontario, Canada M9W 1R3, Tel: 416-747-4000, www.csa-international.org.

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

CSA C22.2 NO. 280 Electric Vehicle Supply Equipment

CSA C22.2 NO. 281.1 Standard for Safety for Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits: General Requirements

CSA C22.2 NO. 281.2 Standard for Safety for Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits: Particular Requirements for Protection Devices for Use in Charging Systems

CSA C22.2 NO. 282 Plugs, Receptacles, and Couplers for Electric Vehicles

CSA C22.2 NO. 346 DC Charging Equipment for Electric Vehicles

2.1.6 DIN Publications

Copies of these documents are available online at https://www.din.de/en/.

DIN SPEC 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

2.1.7 IEC Publications

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

IEC 60038 IEC standard voltages

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

IEC 61508 Functional safety of electrical/electronic/programmable electronic safety-related systems

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

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 62196-1 Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles - Part 1: General requirements

IEC 62196-2 Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles - Part 2: Dimensional compatibility and interchangeability requirements for AC pin and contact-tube accessories

2.1.8 IEEE Publications

Available from IEEE Operations Center, 445 and 501 Hoes Lane, Piscataway, NJ 08854-4141, Tel: 732-981-0060, www.ieee.org.

IEEE 100 CD Standards Dictionary: Glossary of Terms and Definitions

IEEE 1547 IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces

IEEE 2030.5 IEEE Standard for Smart Energy Profile Application Protocol

2.1.9 ISO Publications

Available from International Organization for Standardization, ISO Central Secretariat, 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, Tel: +41 22 749 01 11, www.iso.org.

ISO 5474-1 Electrically propelled road vehicles - Functional requirements and safety requirements for power transfer - Part 1: General requirements for conductive power transfer

ISO 5474-2 Electrically propelled road vehicles - Functional requirements and safety requirements for power transfer - Part 2: AC power transfer

ISO 5474-3 Electrically propelled road vehicles - Functional requirements and safety requirements for power transfer - Part 3: DC power transfer

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

ISO 10303-21 Industrial automation systems and integration - Product data representation and exchange - Part 21: Implementation methods: Clear text encoding of the exchange structure

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

ISO 15118-4 Road vehicles - Vehicle to grid communication interface - Part 4: Network and application protocol conformance test

ISO 15118-5 Road vehicles - Vehicle to grid communication interface - Part 5: Physical layer and data link layer conformance test

ISO 15118-20 Road vehicles - Vehicle to grid communication interface - Part 20: 2nd generation network layer and application layer requirements

ISO 19642-5 Road vehicles - Automotive cabins - Part 5: Dimensions and requirements for 600 V a.c. or 900 V d.c. and 1000 V a.c. or 1500 d.c. single core copper conductor cables

ISO 26262 Road vehicles - Functional safety

2.1.10 NEMA Publications

Available from National Electrical Manufacturers Association, 1300 North 17th Street, Suite 900, Arlington, VA 22209, Tel: 703-841-3200, www.nema.org.

ANSI C84.1 American National Standard for Electric Power Systems and Equipment - Voltage Ratings (60 Hetz)

2.1.11 NFPA Publications

Available from National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471, Tel: 617-770-3000, www.nfpa.org.

NFPA 70 National Electric Code

2.1.12 Normas Mexicanas

Available from Sistema Integral de Normas y Evaluación de la Conformidad (SINEC), Insurgentes Sur 1735, Col. Guadalupe Inn., Delegación Alvaro Obregón, México, D.F. C.P. 01020, Tel: (01)-(55)-2000-3000, www.gob.mx.

NOM-001-SEDE Instalaciones Electricas (Utilización) Articulo 625

NMX-J-668/1-ANCE Vehículos eléctricos (VE) - Sistemas de protección personal para circuitos de alimentación - Parte 1: Requisitos generales

NMX-J-668/2-ANCE Vehículos eléctricos (VE) - Sistemas de protección personal para circuitos de alimentación - Parte 2: Requisitos particulares para dispositivos de protección para utilizarse en sistemas de carga

NMX-J-677-ANCE Vehículos eléctricos - Equipos de alimentación (AC)

NMX-J-678-ANCE Vehículos eléctricos - Clavijas, receptáculos y acopladores

NMX-J-817-ANCE Vehículos eléctricos - Equipos de alimentación (DC)

2.1.13 UL Publications

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

UL 991 Standard for Tests for Safety-Related Controls Employing Solid-State Devices

UL 1741 Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources

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 J1211 Handbook for Robustness Validation of Automotive Electrical/Electronic Modules

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 J1812 Function Performance Status Classification for EMC Immunity Testing

SAE J2344 Guidelines for Electric Vehicle Safety

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

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

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 J2931/1 Digital Communications for Plug-in Electric Vehicles

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

SAE J2931/6 Signaling Communication for Wirelessly Charged Electric Vehicles

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

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 J2953/4 Plug-In Electrical Vehicle Charge Rate Reporting and Test Procedures

SAE J2954 Wireless Power Transfer for Light-Duty Plug-in/Electric Vehicles and Alignment Methodology

2.2.2 ANSI Accredited and UL Publications

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

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

ANSI/UL 50 Enclosures for Electrical Equipment, Non-Environmental Considerations

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

ANSI/UL 231 Standard for Power Outlets

ANSI/UL 2263 Electric Vehicle Cable

2.2.3 Code of Federal Regulations (CFR) Publications

Copies of these documents are available online at https://www.ecfr.gov.

40 CFR Part 600 Fuel Economy and Greenhouse Gas Exhaust Emissions of Motor Vehicles

47 CFR Part 15, Subpart A Radio Frequency Devices, General

47 CFR Part 15, Subpart B Radio Frequency Devices, Unintentional Radiators

47 CFR Part 18, Subpart C Industrial, Scientific, and Medical Equipment, Technical Standards

2.2.4 CSA Publications

Available from CSA International, 178 Rexdale Boulevard, Toronto, Ontario, Canada M9W 1R3, Tel: 416-747-4000, www.csa-international.org.

CSA C22.2 NO. 0 General requirements - Canadian Electrical Code, Part II

2.2.5 DIN Publications

Copies of these documents are available online at https://www.din.de/en/.

DIN SPEC 70122 Electromobility - Conformance tests for digital communication between a d.c. EV charging station and an electric vehicle for control of d.c. charging in the Combined Charging System

2.2.6 IEC Publications

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

CISPR 12 Vehicles, boats and internal combustion engines - Radio disturbance characteristics - Limits and methods of measurement for the protection of off-board receivers

CISPR 16-1-2 Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-2: Radio disturbance and immunity measuring apparatus - Coupling devices for conducted disturbance measurements

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

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 61851-24 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 62196-3 Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles - Part 3: Dimensional compatibility and interchangeability requirements for DC and AC/DC pin and contact-tube vehicle couplers

IEC TS 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

2.2.7 ISO Publications

Available from International Organization for Standardization, ISO Central Secretariat, 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, Tel: +41 22 749 01 11, www.iso.org.

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

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

ISO 17987-1 Road vehicles - Local Interconnect Network (LIN) - Part 1: General information and use case definition

ISO 17987-2 Road vehicles - Local Interconnect Network (LIN) - Part 2: Transport protocol and network layer services

ISO 17987-3 Road vehicles - Local Interconnect Network (LIN) - Part 3: Protocol specification

ISO 17987-4 Road vehicles - Local Interconnect Network (LIN) - Part 4: Electrical physical layer (EPL) specification 12 V/24 V

ISO/TR 17987-5 Road vehicles - Local Interconnect Network (LIN) - Part 5: Application programmers interface (API)

ISO 17987-6 Road vehicles - Local Interconnect Network (LIN) - Part 6: Protocol conformance test specification

ISO 17987-7 Road vehicles - Local Interconnect Network (LIN) - Part 7: Electrical Physical Layer (EPL) conformance test specification

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

2.2.8 NEMA Publications

Available from National Electrical Manufacturers Association, 1300 North 17th Street, Suite 900, Arlington, VA 22209, Tel: 703-841-3200, www.nema.org.

NEMA WD 6 Wiring Devices

2.2.9 UL Publications

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

UL 2252 Outline of Investigation for Adapters for use with Electric Vehicle Couplers

3. DEFINITIONS

Some terminology and acronyms used in this document are not defined terms. See the list of abbreviations used in this document in Appendix C.

3.1 ACCESSORY, INLET

A device that mates with a vehicle *inlet* which creates *contact* mating points other than those described under *case B* or *case C*. Examples include an AC *V2L accessory* with a NEMA receptacle or an adapter that allows mating a SAE J3400 *EV* to an SAE J1772 Level 2 DC *EVSE connector*.

3.2 AREA ELECTRIC POWER SYSTEM (AREA EPS)

An *EPS* that serves a *local EPS*.

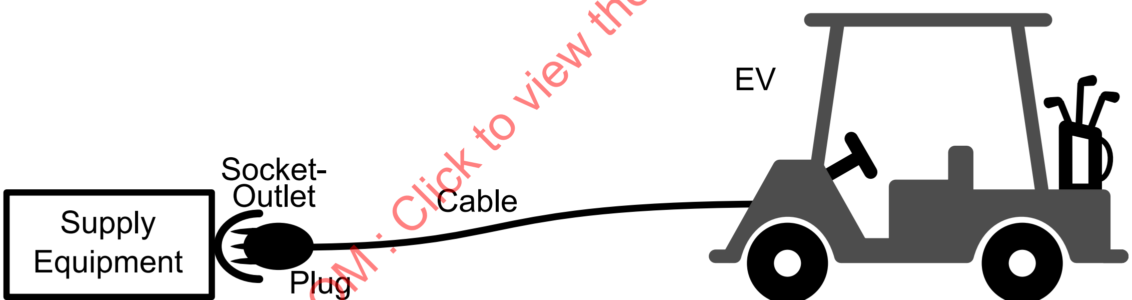
NOTE: Typically, an *area EPS* has primary access to public rights-of-way, priority crossing of property boundaries, etc., and is subject to regulatory oversight.

3.3 CABLE ASSEMBLY, EV

A portable *cable assembly* consisting of a length of *EV* cable, a vehicle *connector* on one end, and a *universal AC plug* (only as defined in 3.34) on the other.

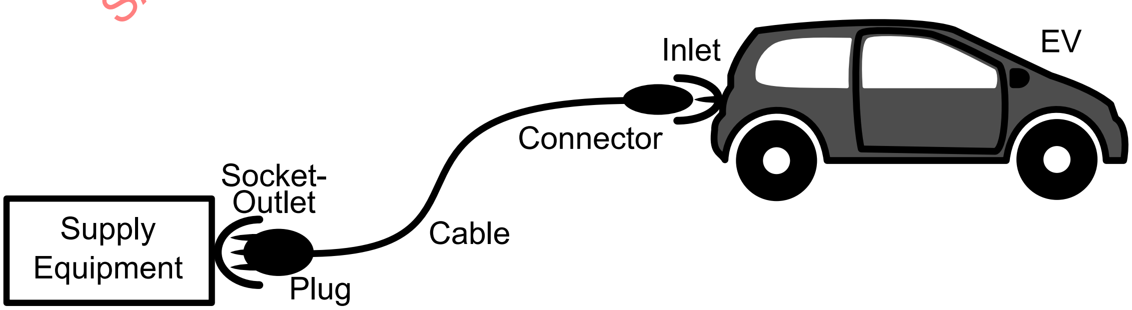
3.4 CASE A

EV connects to an AC *EVSE* via a *plug* and cable permanently attached to the *EV*.



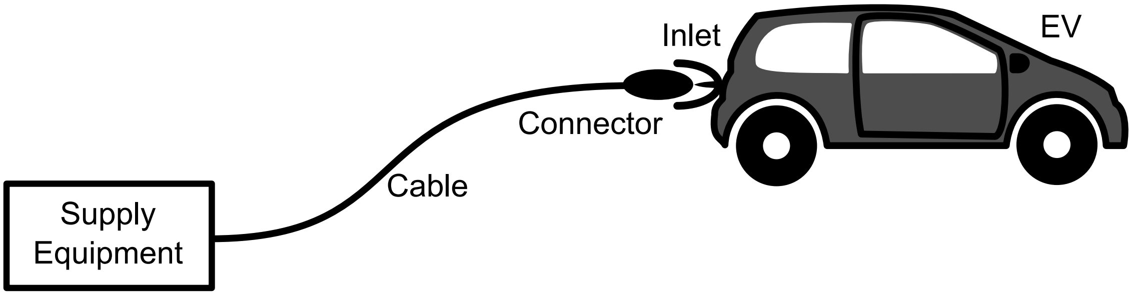
3.5 CASE B

EV inlet directly connects to an AC *EVSE* via an *EV cable assembly* (only as defined in 3.3) that is detachable by the driver at both ends.



3.6 CASE C

EV inlet directly connects to an AC or DC *EVSE* via a *connector* permanently attached to the *EVSE*.



3.7 CHARGING CIRCUIT INTERRUPTION DEVICE

Charging circuit interruption device (CCID), as defined in the *Tri-National EVSE Safety Standards*. A *CCID* interrupts the charging circuit if differential current exceeds a threshold, usually 20 mA for permanently wired installations. AC and DC thresholds are specified, and automatic reclosure is allowed under certain conditions. Contrast to ANSI/UL 943 for ground fault circuit interrupters, which provide similar protections at different levels.

3.8 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. See 3.32 and 3.33.

3.9 CHASSIS GROUND

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

3.10 COMBINED CHARGING SYSTEM (CCS)

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.

3.11 CONDUCTIVE

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

3.12 CONDUCTOR

A body, usually in the form of a wire, cable, or bus bar, suitable for carrying an electric current. Refer to IEEE 100 CD.

3.13 CONNECTION SESSION

A *connection session* starts when the *connector* is inserted into the *inlet* and ends when the *connector* is removed from the *inlet*. A normal *connection session* may contain one or more periods of charging.

3.14 CONNECTOR, EV

A handheld *conductive* device at the end of a flexible cable from the *EVSE*, which is inserted into the *EV inlet* to charge the battery.

3.15 CONTACT, COUPLER

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

3.16 CONTROL PILOT (CP)

An electrical signal that is sourced by the *EVSE*, controlled by the *EV* and the *EVSE*, and used for the following functions: (a) verifies that the *EV* and *EVSE* are present and connected, (b) controls energization/de-energization of the power transfer interface, (c) transmits operating parameters and constraints between *EVSE* and *EV*, and (d) monitors the presence of the *equipment ground*.

3.17 CONTROL SEQUENCE

A sequence of automated tasks performed by the *EV* and the *EVSE* during a *connection session* for the purpose of power transfer for the *EV*. A new *control sequence* occurs after a restart or wakeup.

3.18 COUPLER

A physical and electrical mating system connecting the *EVSE* to the *EV*. The *coupler* includes the *connector* at the end of the flexible cable from the *EVSE* side and the *inlet* on the *EV*.

3.19 ELECTRIC POWER SYSTEM (EPS)

Facilities that deliver electric power to a load.

3.20 ELECTRIC VEHICLE (EV)

A vehicle designed to receive energy from an *EVSE*. This term is used to cover *electric vehicles* and plug-in hybrid *electric vehicles*. This includes on-road *electric vehicles*, off-road *electric vehicles*, airport ground support equipment, etc.

3.21 ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE)

A device responsible for safely providing power to the *EV* through the use of certain control functions which are defined in this document and is listed according to the *Tri-National AC EVSE Standard* or *Tri-National DC EVSE Standard*. It may be permanently wired or connected via a cord to the premises wiring. To supply the *EV*, it may have a permanently attached *connector* or an AC *EVSE socket-outlet* (see 3.39) which accepts a *universal EV plug* (see 3.34).

3.22 EQUIPMENT GROUND

A *conductor* used to connect the non-current carrying metal parts of the *EVSE* to the system *grounding conductor*, the *grounding* electrode *conductor*, or both, at the *EVSE*. See 3.22 for general *ground* nomenclature.

3.23 FOLDBACK

A current-quenching function to mitigate arcing and/or damage to *contacts*. *Foldback* is a temporal state, triggered by the detection of a condition, where the current of the *charger* (either *on-board* or *off-board*) is rapidly reduced. If the conditions resolve, and a system-level shutdown is not otherwise required, then the power transfer may continue.

3.24 FORM, LOCAL EPS

The act of providing a voltage reference and a frequency standard to the *local EPS* when separate from the *area EPS*. Typically, this includes providing power to the *local EPS*. Refer to IEEE 100 CD.

3.25 GROUND CONDUCTOR (GROUNDING CONDUCTOR or GROUND)

A *conductor* which does not carry current under normal operating conditions but is capable of carrying sufficient fault current to trip a circuit protection device such as a fuse or circuit breaker. Also known as “Protective Earth” outside of North America. See 3.9 for *EV ground* nomenclature and 3.22 for *EVSE ground* nomenclature.

3.26 INLET, EV

The device on the *EV* into which the *connector* mates. This is part of the *coupler*.

3.27 LIN-CP

The control method using Local Interconnect Network (LIN) signals and *CP* levels, as described in this document. Refer to SAE J3068.

3.28 LATCH (LATCHED, LATCHING)

A mechanical interlock provided to hold a *plug* in the *socket-outlet* or to hold the *connector* in the *inlet* and to prevent its intentional or unintentional withdrawal.

3.29 LOCAL ELECTRIC POWER SYSTEM (LOCAL EPS)

An *EPS* contained entirely within a single premises or group of premises.

3.30 LOCAL ELECTRICAL CODES

Refers to the regulations governing electrical installations in their corresponding jurisdictions: NFPA 70, CSA C22.1, or NOM-001-SEDE, and/or any applicable local regulations.

3.31 NEUTRAL CONDUCTOR (NEUTRAL)

The *conductor* connected to the *neutral* point of a system that is intended to carry current under normal conditions. Refer to NFPA 70 (National Electrical Code), Article 100.

3.32 OFF-BOARD CHARGER

A *charger* located off of the *electric vehicle*. See 3.8.

3.33 ON-BOARD CHARGER

A *charger* located on the *electric vehicle*. See 3.8.

3.34 PLUG, UNIVERSAL AC

A handheld *conductive* component at one end of an *EV cable assembly* which mates into the *socket-outlet*; see *case B* (see 3.5) and *case A* (see 3.4). Not present in *case C* (see 3.6). See Appendix B for the specific implementation requirements.

3.35 PROXIMITY DETECTION (PROXIMITY or PROX)

A method whereby the *EV* can ascertain whether a *connector* is plugged into the *inlet*, without requiring active elements in the *connector* or cable. *Proximity detection* may also provide additional functionality. See 6.2.1.

3.36 PWM/PLC-CP

The control and communications method that adds PLC to *PWM-CP*.

3.37 PWM-CP

The control method using *PWM* signals and DC voltage levels on the *CP*.

3.38 S2

A means for the *EV* to change the *CP* voltage levels to switch between states (e.g., to indicate *EV* is not ready to accept energy or *EV* is ready to accept energy).

3.39 SOCKET-OUTLET, UNIVERSAL AC

The component on the *EVSE* into which the *plug* of an *EV cable assembly* is inserted. The *EVSE socket-outlet* only exists in *case B* (see 3.5) and *case A* (see 3.4) applications. The *EVSE* may instead have a permanently attached cable; see *case C* (see 3.6). These components are not general-purpose (e.g., NEMA) receptacles, but are instead specifically for *EVs*. These components are not used to provide a connection between the premises wiring and the *supply equipment*, but instead connect the *EV cable assembly* to the *supply equipment*. In this document, SAE J3068 Appendix B defines the specific *EVSE* requirements for the *universal AC socket-outlet*.

3.40 SW-CAN-CP

A proprietary control method using SAE J2411 single-wire CAN over the *CP* used in some SAE J3400 *coupler* applications.

3.41 TRI-NATIONAL COUPLER STANDARD

Refers to the standards documents covering *plugs*, *socket-outlets*, *cable assemblies*, *connectors*, and *inlets* in their corresponding jurisdictions: ANSI/UL 2251, CSA C22.2 No. 282, or NMX-J-678-ANCE.

3.42 TRI-NATIONAL EVSE SAFETY STANDARD

Refers to the *EVSE* safety standards in their corresponding jurisdictions: ANSI/UL 2231-1 and ANSI/UL 2231-2, CSA C22.2 No. 281.1 and CSA C22.2 No. 281.2, or NMX-J-668/1-ANCE and NMX-J-668/2-ANCE.

3.43 TRI-NATIONAL AC EVSE STANDARD

Refers to the *EVSE* product standard in their corresponding jurisdictions: ANSI/UL 2594, CSA C22.2 No. 280, or NMX-J-677-ANCE.

3.44 TRI-NATIONAL DC EVSE STANDARD

Refers to the *EVSE* product standard in their corresponding jurisdictions: ANSI/UL 2202, CSA C22.2 No. 346, or NMX-J-817-ANCE.

3.45 VEHICLE-TO-GRID (V2G)

Allows power transfer from the *EVSE/EV* to the *area EPS*. Consistent with SAE usage and not ISO 15118 definitions.

3.46 VEHICLE-TO-HOME (V2H)

Allows power transfer from the *EVSE/EV* to the *local EPS*, which is isolated from the *area EPS*.

3.47 VEHICLE-TO-LOAD (V2L)

Allows powering *off-board* loads via the *inlet*, typically connected with a portable *accessory*. V2V is a special case of V2L where the load is another vehicle.

3.48 VEHICLE-TO-X (V2X)

Any combination of *vehicle-to-grid*, *vehicle-to-home*, or *vehicle-to-load*.

4. DOCUMENT OVERVIEW

Section 5 defines the *coupler* interface.

Section 6 provides general requirements.

Section 7 provides requirements for AC power transfer.

Section 8 provides requirements for DC power transfer.

Section 9 provides requirements for bidirectional power transfer.

Section 10 provides the *coupler* mechanical drawings for the SAE J3400 *coupler*.

Section 11.3 provides notes about future revisions.

Appendix A provides the *coupler* mechanical drawings for the legacy *coupler (*500 VDC max rated).

Appendix B describes an optional system of carry-along *EV cable assemblies* for AC power transfer.

Appendix C lists the abbreviations used in the document.

Appendix D summarizes the requirements (with links to explanatory text in context) to assist verification planning.

4.1 Document Formatting Features

All requirements are given level-four section numbers and appear in the text starting from Section 5. See 5.1.1.1 as an example of one of the first requirements.

All defined terms are shown in *italic* font.

For figures in this document, lines that are intersected are connected, and lines that cross and are not connected would be shown as jumping over (with a small semicircle).

4.1.1 Optional Functions

Sections marked as optional are not required for baseline implementation of SAE J3400. Each optional section describes a discrete feature/function, and if implemented, all requirements within that subsection must be met.

4.2 Applicability/Limitations on Incorporation

Requirements created by incorporation of IEC, ISO, or DIN documents are inherently subject to the following interpretation:

- Requirements that apply to "type 2," "configuration FF," and "system c" (as referenced in the IEC/ISO documents) are taken as applicable to SAE J3400 *coupler* systems, unless it conflicts with or is superseded by requirements/functions/ratings contained or normatively referenced in this document.

- Requirements that would prevent *EVSE* compliance with the *Tri-National DC EVSE Standard*, the *Tri-National AC EVSE Standard*, IEEE Standards, other relevant ANSI/NMX/CSA standards, adopted *local electrical codes,* or government regulation are not applicable for those jurisdictions. Also, where the product standards provide a competing/alternate method to implement a required function, the North American product standard shall be considered sufficient for compliance under this document.

- Requirements that would prevent vehicle compliance with FMVSS, CMVSS, or other government regulations are not applicable in those jurisdictions. Also, where the vehicle standards provide a competing/alternate method to implement a required function, the North American vehicle standard shall be considered sufficient for compliance under this document.

EXAMPLE 1: For *EVSE*, *CCID*20 is one authorized method for protection from electric shock under the *Tri-National EVSE Safety Standard*, but the IEC 61851 series requires a type of RCD protection which is not equivalent, and the corresponding national notes are very incomplete. Therefore, *CCID*20 is sufficient and aligned with existing North American practices and shall supersede the IEC requirements.

EXAMPLE 2: SAE J3072 describes a method for AC bidirectional power flow which is designed to conform to IEEE 1547, which is incorporated into U.S. law by the Energy Policy Act of 2005. SAE J3072 is included in an upcoming UL 1741 supplement to meet requirements for state government regulations for interconnection of DER. Without the limitations of 4.2, the requirements created by the incorporation of the IEC 61851 series or the ISO 15118 series could be understood as disallowing or at least not providing a path for the optional approach given in 9.4.1.1.

EXAMPLE 3: Fundamental to the basic vehicle interface defined in IEC 62196-2 is general interoperability between three-phase supplies and single-phase vehicles. IEC 62196-2 states compatibility with a three-phase rating of 480 VAC, but this is in conjunction with a stated single-phase voltage rating of 250 VAC within IEC 62196-2 and IEC 61851-1. As this rating is mathematically incongruent (480 divided by the square root of 3 is 277, but 250 multiplied by the square root of 3 is approximately 433), the implied higher rating is taken for North American application thus allowing single-phase charging at 277 VAC nominal (as specified in 7.2.2.1) as derived from a 480Y/277 VAC three-phase wye-connected four-wire supply.

NOTE: Ideally, a systematic effort to cover all differences between IEC/ISO documents that are relevant to SAE J3400 with additional (and more complete) country-specific notes in IEC/ISO documents, add coverage of the SAE J3400 *coupler* within IEC/ISO documents, and harmonization of *EV* functions allowed under this document would remove the need for this limitation section. Alternatively, future editions of this document could reduce the scope of the limitations under this section. A similar issue affects SAE J1772.

5. INTERFACE

The SAE J3400 *coupler* provides either DC or single-phase AC power to and/or from an *EV* using two current-carrying *contacts*. The *coupler* also provides *contacts* for *control pilot*, *proximity detection*, and *ground*. All *contacts* provide multiple functions depending on operating mode and state.

The design capabilities of SAE J3400 *couplers:*

- With *connector*, thermal transport up to 900 A
- With *connector* and *inlet*, thermal transport up to 1000 A
- AC *EVSE* using *case C*, up to 80 A under *PWM-CP* (see 7.2)
- AC *EVSE* using *case B*, up to 70 A (see Appendix B)

5.1 Coupler Mechanical Requirements

Mechanical drawings and models for SAE J3400 *couplers* are listed in Table 1. These models are provided digitally with this document. The models define features (i.e., spline and other complex shapes) which are not described in the drawings; therefore, the models and the drawings must be used together for design and verification of SAE J3400 *couplers*. For a high-level understanding of *coupler* mechanical interface, see Figure 2.

Table 1 - Inlet and connector reference model and drawings

Coupler Component	Drawing(4)	Section	Version	Model(1) (3)
SAE J3400 reference *inlet*	10.1	5.1.2	3	SAE_J3400_INLET_v3.step
SAE J3400 reference *connector*	10.2	5.1.3	3	SAE_J3400_CONNECTOR_v3.step
SAE J3400 mated *coupler*(2)	10.3	5.1.1	3	SAE_J3400_COUPLER_MATED_v3.step
SAE J3400 *connector* keep-in zone – Ordinary	--	10.4.1	1	SAE_J3400_CONNECTOR_KEEP_IN_ZONE_V1.step
SAE J3400 *inlet* access zone – Ordinary	--	10.4.2	5	SAE_J3400_INLET_KEEP_OUT_ZONE_V5.step
SAE J3400 keep-out zone – ACD-S	--	10.4.3	--	Model under development
NACS legacy reference *inlet*	A.1	--	1	NACS_LEGACY_500V_INLET_v1.step
NACS legacy reference *connector*	A.2	--	1	NACS_LEGACY_500V_CONNECTOR_v1.step
NACS legacy mated *coupler*(5)	--	--	1	NACS_LEGACY_500V_COUPLER_MATED_v1.step

(1) STEP file format as defined by ISO 10303-21:2002.
(2) Model shows the typical *latch* element shape in two positions - *latched* and *unlatched*.
(3) Unless otherwise stated in the drawings, the default profile surface and position tolerances for the models are ±0.3 mm.
(4) All drawing dimensions are normative requirements unless indicated as typical or notional.
(5) Model helps with compliance with 5.1.2.3 and 5.1.3.3.

5.1.1 General Coupler Requirements

Consistent with the defined term *coupler*, these requirements apply to both *connectors* and *inlets*. Existing applications may appropriately utilize the 500 VDC maximum rated legacy *connector* or *inlet* within its ratings, but it is not recommended for new designs. See 5.1.2.3 and 5.1.3.3.

5.1.1.1 The SAE J3400 *coupler* interface shall be rated up to a maximum of 1000 V.

5.1.1.2 The SAE J3400 *coupler contacts* (e.g., SAE J3400 *EV inlet*, SAE J3400 *EVSE*'s *connector*, etc.…) and wiring terminals materials shall operate at 100 °C (212 °F) to be safely interoperable with existing use.

NOTE: The *Tri-National Coupler Standard* requires that *contacts* and wiring terminals do not exceed the maximum temperature as specified in ANSI/UL 2251, Edition 4; Amendment for a limit of 100 °C (212 °F) irrespective of ambient rating, and requires some nearby materials be rated for 105 °C (221 °F).

EXAMPLE: *EVSE* thermal control should limit the maximum *coupler contact* temperature to 100 °C irrespective of ambient operating rating, meaning if the *EVSE* was operated at 60 °C ambient, only a 40 °C *coupler contact* temperature rise would be allowed.

5.1.1.3 The insertion force required to mate SAE J3400 *couplers* shall be ≤100 N (22-1/2 lbf).

5.1.1.4 SAE J3400 *couplers* shall not be designed to make and break under load under normal operation. The system mechanical interlocks and electrical monitoring should function to prevent it.

5.1.1.5 SAE J3400 *couplers* shall meet the applicable requirements (see 4.2) of IEC 62196-1.

NOTE: IEC 62196-1 includes many *coupler* requirements, including electrical and mechanical endurance cycling tests.

5.1.1.6 SAE J3400 *couplers* shall specify their peak and constant current ratings if different. The *coupler* manufacturer identifies a performance curve showing current versus time. This shall depict the maximum charging current load the component is endorsed to support at any moment after the start of a charging session. The manufacturer shall minimally provide this curve for a constant ambient temperature of 30 °C.

5.1.1.7 SAE J3400 *couplers* shall be designed to withstand continuous ambient temperatures in the range of -40 to +80 °C (-40 to 176 °F) during shipping or storage when the component's parts are assembled, supplied with the *EVSE*, or installed in the *EV*.

5.1.1.8 SAE J3400 *couplers* shall operate under ambient temperatures ranging from -30 to 50 °C (-22 to 122 °F).

5.1.1.9 SAE J3400 *couplers* shall be unaffected by lubricants, solvents, and fuels as specified in SAE USCAR2.

5.1.2 Inlet Mechanical Requirements

5.1.2.1 SAE J3400 *inlets* shall have a mechanical design according to 10.1 and latch function according to 10.3.

5.1.2.2 SAE J3400 *inlets* shall couple with the SAE J3400 reference connector in Table 1 over the entire range of allowed tolerances and environmental conditions.

5.1.2.3 SAE J3400 *inlets* shall couple with the NACS legacy reference connector in Table 1 over the entire range of allowed tolerances and environmental conditions.

5.1.2.4 SAE J3400 *inlets* shall provide a latching mechanism with position monitoring to ensure proper engagement whenever the *coupler* is energized.

NOTE: The proper engagement of the *latching* device is typically checked by the detection of the end position of the actuator of the *latching* device.

5.1.2.5 SAE J3400 *inlets* shall be latched before closing S_2 and shall not *unlatch* while S_2 is closed. This is required for AC and DC power transfer.

SAE J3400 *inlets* may include means to ensure the function of the *latch* in adverse environmental conditions (e.g., a heater to prevent the formation of ice).

5.1.2.6 SAE J3400 *inlets* may deviate from a typical *latch* profile as shown in 10.3 and provide an alternative *latching* element shape if all the following requirements are met:

- The alternative *latch* element shall maintain the 4 mm nominal dimension as shown in the *latch* profile detail to limit *connector* movement while mated (see 5.1.2.7).

- Alternative *latches* shall be designed in a way that their effective positional height while in the engaged and disengaged state shall conform with 10.3.

5.1.2.7 SAE J3400 *latches* shall be constructed to comply with IEC 62196-1 tests which verify the *latching* device with an axial withdraw force of 750 N (167 lbf) (1000 N [225 lbf] is recommended) for all ratings AC and DC.

NOTE: During this test, the *latch* should not allow a reference *connector* to axially travel more than 2 mm in either direction when force is applied.

5.1.2.8 SAE J3400 *inlets* shall comply with requirements 26.7 (insulating end cap pull test) from IEC 62196-1:2022 with the following additional requirements:

- The insulated end caps shall be aged at 85 °C/85% relative humidity for 500 hours.

- After aging, at ambient temperature, a force of 450 N (101 lbf) shall be applied axially to the end caps for 1 minute.

- The test passes if the end cap remains in place with no cracking or visible damage observed.

EXCEPTION: These requirements can be substituted for a manufacturer-defined alternative end cap pull test that exceeds the baseline insulating end cap pull test requirement in IEC 62196-1:2022 until the ANSI ratification of an enhanced test which then takes precedence.

5.1.2.9 SAE J3400 *inlets* shall have temperature sensing for each DC power *contact*. Functional compliance is verified by a vehicle manufacturer-defined test which provides interoperable thermal sensing functions for use with compliant *connector* assemblies under 10.5.3 and Figure 17.

5.1.2.10 SAE J3400 *inlets* shall provide for the egress of fluids.

SAE J3400 *inlets* may omit the notional *inlet* flange shown in 10.1. See 6.5.2 for required flange areas.

5.1.3 Connector Mechanical Requirements

The electrical circuity for the request-to-stop function is different between AC and DC power transfer and means the same *connector* assembly cannot be used for both. See 6.3.1.3.

5.1.3.1 SAE J3400 *connectors* shall have a mechanical design according to 10.2 and *latch* function according to 10.3.

5.1.3.2 SAE J3400 *connectors* shall couple with the SAE J3400 reference *inlet* in Table 1 over the entire range of allowed tolerances and environmental conditions.

5.1.3.3 SAE J3400 *connectors* shall couple with the NACS legacy reference *inlet* in Table 1 over the entire range of allowed tolerances and environmental conditions.

5.1.3.4 SAE J3400 *connectors* shall meet the requirements of the *Tri-National Coupler Standard* unless an alternative path is provided by the end-product standard referred to in 7.1.1.1 and 8.1.1.1.

5.1.3.5 SAE J3400 *connectors* shall comply with requirements 26.3 (drop test) from IEC 62196-1:2022 with the following additional requirements:

- The number of drops shall be 100, with the *connectors* rotated 90 degrees each drop.
- Upon completion of the impact test (100 drops), the *connector* shall show no functional damage, withstand the water ingress test to which it is rated, and maintain the creepage and clearance distances to which it was designed.

5.1.3.6 SAE J3400 *connector cable* assemblies for DC power transfer shall conform to testing requirements in 10.5 and have required thermal sensing covering each DC power *contact*.

NOTE: Requirements and specifications for alternative reference devices and tables that cover ≥600 ADC are under consideration. Boost mode (dynamic current rating) test definitions and test methods.

5.1.3.7 SAE J3400 *connectors* shall be designed to meet point-of-contact equations (shown in 10.2) over the entire range of allowed tolerances (including analysis for a worst-case compliant *inlet*) and environmental conditions.

NOTE: These equations ensure correct mating sequencing and help mitigate arc risk in the event of a failure on the *latching* mechanism. These equations require that the *coupler*, during unmating, breaks *control pilot* and *prox* at least 5 mm before (axial withdrawal distance including worst-case tolerancing) the live *contacts* break. This requirement means a setback of DC+ and DC- *connector* requires a corresponding setback in the *control pilot* and *prox contacts* to meet 5.1.3.7.

IPXXB compliance can be met by using end-caps on *conductive* center pins on the *connector*-side terminals, or it can be met using fully-insulated center pins. The drop test in 5.1.3.5 can be used to assess the strength of the solution.

5.2 Technical Derivation of Point-of-Contact Equations

On the *inlet*, the pins are rounded; therefore, the point-of-contact is where the full pin diameter is achieved (as shown below). Accordingly, measurement from datum C to the start of contact is:

Power is 15.0 mm (directly specified) = D_{pin_power}
Signal is 21.8 mm (21 + R 0.79) = D_{pin_signal}
Ground is 9.3 mm (7.5 + R 1.79) = D_{pin_ground}

On the *connector*, different *contact* technologies (split finger, lamella, coil spring) will result in different contact points relative to datum C (shown with as $D_{subscript}$). For example, the point-of-contact for split finger socket is the minimum diameter position inside the socket because it is the intended area to conductively interface to the *inlet* pin.

$D_{socket\_power} - D_{pin\_power} \geq 5\text{ mm} + D_{socket\_signal} - D_{pin\_signal}$ (point-of-contact requirement)
$D_{pin\_signal} - D_{pin\_power} = 21.8 - 15 = 6.8\text{ mm}$ (inlet constraint)
solving
$D_{socket\_power} - D_{socket\_signal} + 6.8\text{ mm} \geq 5\text{ mm}$
$D_{socket\_signal}(\max) - D_{socket\_power}(\min) < 1.8\text{ mm}$ (point-of-contact equation in 10.2)

Using a similar approach for ground gives
$D_{socket\_power}(\min) - D_{socket\_ground}(\max) < 0.7\text{ mm}$ (point-of-contact equation in 10.2)

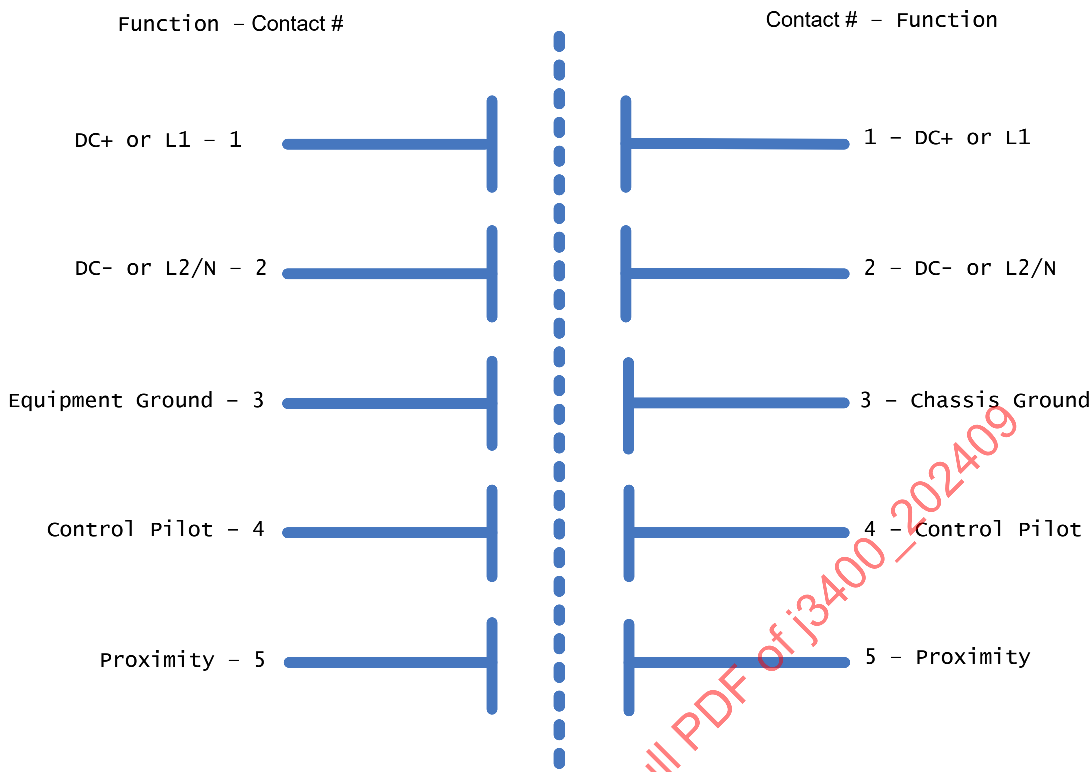


Figure 1 - SAE J3400 coupler conceptual interface: connector (left); inlet (right)

NOTE: Figure 1 does not show or indicate a mating sequence.

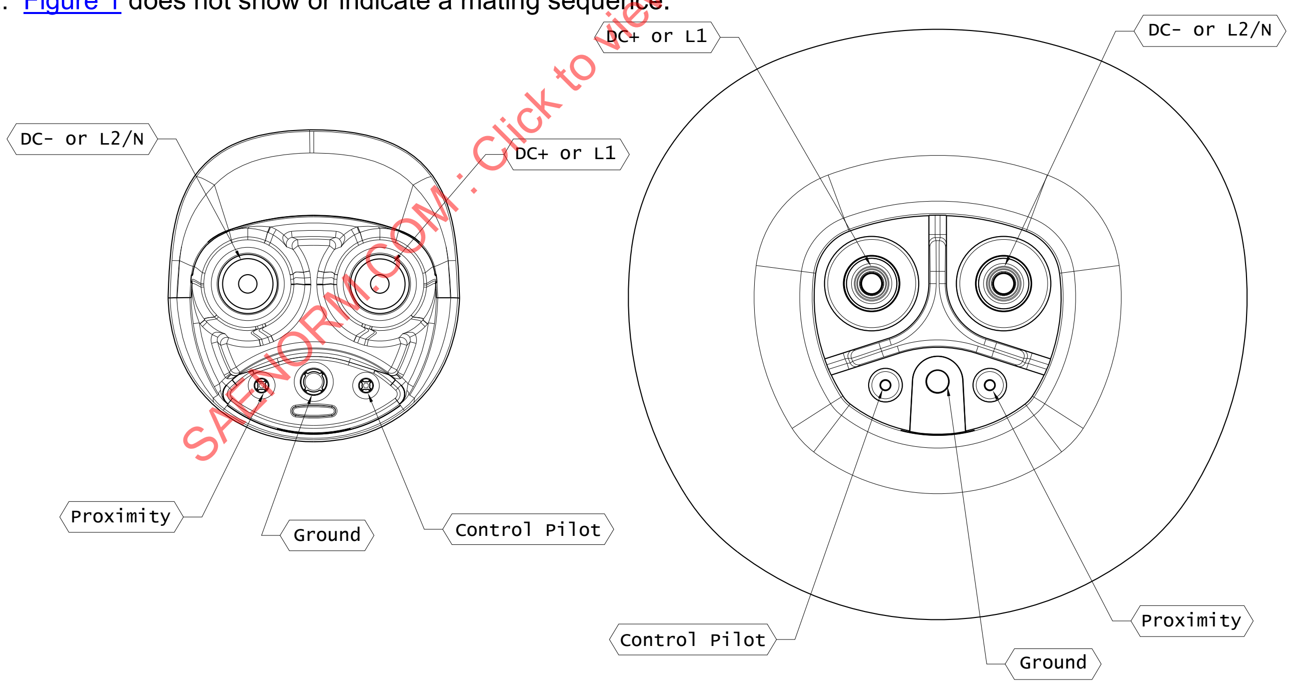


Figure 2 - SAE J3400 coupler mechanical interface: connector (left); inlet (right)

6. GENERAL REQUIREMENTS

6.1 Conductive Power Transfer - Labeling

EVSE may be required by regulation to have certain labeling. Examples include United States Code of Federal Regulations - Title 16 § 309.17 and end-product standards referred to in 7.1.1.1 and 8.1.1.1.

6.2 Conductive Power Transfer - General Requirements

6.2.1 Conductive Power Transfer - Coupler Proximity Detection

SAE J3400 *couplers* do not contain a hand-actuated electromechanical lever-style *latch* (that additionally affects the *proximity* circuit) as found on SAE J1772 *connectors*. However, some configurations can present an impedance (using a momentary switch) on the *coupler proximity* circuit equivalent to the *unlatched* state in SAE J1772, as described in 7.1.3.

6.2.1.1 Upon insertion of the *connector* into the *EV inlet*, the *coupler* system shall provide a means to detect the presence and status of the *connector* in the *inlet*, as described in Tables 2 and 3 and shown in Figures 3, 4, 6, and 7.

After termination or shutdown of any power transfer, if not otherwise retained for any reason (access-control, security, *case B*, etc.), the *inlet* is typically *unlatched* for *connector* removal.

Table 2 - Inlet and connector (coupler) proximity circuit component parameters

Parameter	Symbol	Units	Nominal value	Tolerance(1)	Range
SAE J3400 Inlet Proximity Circuit Parameters					
Proximity supply	+5 VDC	VDC	5.0	±5%	4.75-5.25
Equivalent load resistance	R_4	Ω	330	±3%(2)(3)	320.1-339.9
Equivalent load resistance	R_5	Ω	2700	±3%(2)(3)	2619-2781
SAE J3400 Connector Proximity Circuit Parameters					
Equivalent load resistance	R_6	Ω	150	±3%(2)(3)	145.5-154.5
Equivalent load resistance	R_7(4)	Ω	330	±3%(2)(3)	320.1-339.9

(1) Per tolerances to be maintained over the environmental conditions and useful life as specified by the manufacturer.
(2) These components have a 10% tolerance in SAE J1772. See Table 3 for associated mated voltage ranges.
(3) IEC 61851-23 v2 recommends a tolerance of ±1% for DC applications; and this also aligns with existing NACS DC *EVSE*; therefore, ±1% is recommended under this document for DC *EVSE* and *EV* which support DC power transfer.
(4) R_7 is only used in SAE J3400 *connectors* for AC power transfer (see Figure 4).

Table 3 - Inlet proximity detection circuit voltage parameters

Status	Units	Nominal value	SAE J1772 Coupler[1]	SAE J3400 Coupler[1]	Cross-coupler Interop Detection Range[2]
Inlet proximity unmated					
Disconnected	VDC	4.46	4.13-4.78	4.20-4.71	--
Inlet proximity mated					
Reserved	VDC	4.09	--	--	--
"SAE J1772 *Unlatched*"[4]	VDC	2.76[5]	2.38-3.16	2.55-2.98	2.46-3.09
Connector Inserted	VDC	1.51[5]	1.23-1.82	1.37-1.65	1.30-1.74[6][7]
DC Thermal Warning	VDC	1.16	--	1.04-1.28	0.99-1.35[6][7]
DC Thermal Shutdown	VDC	0.63	--	0.58-0.73[3]	0.55-0.78[3]

[1] Voltage ranges based on a 3% tolerance for SAE J3400-only system and 10% tolerance for SAE 1772-only system.
[2] Assuming widest combination (worst-case tolerancing) of [R_6/R_7 at 3% for *EVSE* mated to R_4/R_5 at 10% for *EV*] or [R_6/R_7 at 10% for *EVSE* mated to R_4/R_5 at 3% for *EV*]. Assuming 3% for R_{AIT1} and R_{AIT2}. See notes (6) and (7).
[3] *EVSE*-sensed *proximity* voltage during a DC Thermal Shutdown; the *EV*-sensed *proximity* voltage in this state is "SAE J1772 *Unlatched*," which per 8.2.1.1, also triggers a shutdown.
[4] Typically, this state indicates SAE J3400 S_{3B} is open (AC) or SAE J1772 S_3 is open (*unlatched*), but also see note (3).
[5] SAE J1772 lists these nominals as 2.77 and 1.53 due to a rounding inconsistency.
[6] In the possible overlap zone (1.30-1.35 V) between "DC Thermal Warning" and "*Connector* Inserted" states, the following methods can be used to discriminate/choose between states:
- Cancelling the tolerance by looking for per-unit *proximity* voltage changes to detect transitions (i.e., percentage drop)
- *EVs* can use +5 VDC *prox* as a measurement reference to remove supply-contributed variance
- Or another manufacturer-defined method since the function is a proactive prevention that can be triggered independently by either side; therefore, is it not necessary that both sides agree on state; and, ultimately if not triggered under certain edge cases, it is backstopped by DC Thermal Shutdown.
[7] The overlap can be avoided by component selection under any the following configurations (assuming 3% R_{AIT1}):
- SAE J1772 *EVSE* with 5% R_6/R_7 when mated to baseline SAE J3400 *EV* (3% R_4/R_5) yielding 1.03-1.29 and 1.35-1.67
- SAE J1772 *EV* with 5% R_4/R_5 when mated to a baseline SAE J3400 *EVSE* (3% R_6/R_7) yielding 1.03-1.30 and 1.35-1.68
- SAE J3400 *EV* with 1% R_4/R_5 when mated to a baseline SAE J1772 *EVSE* (10% R_6/R_7) yielding 1.02-1.30 and 1.32-1.70

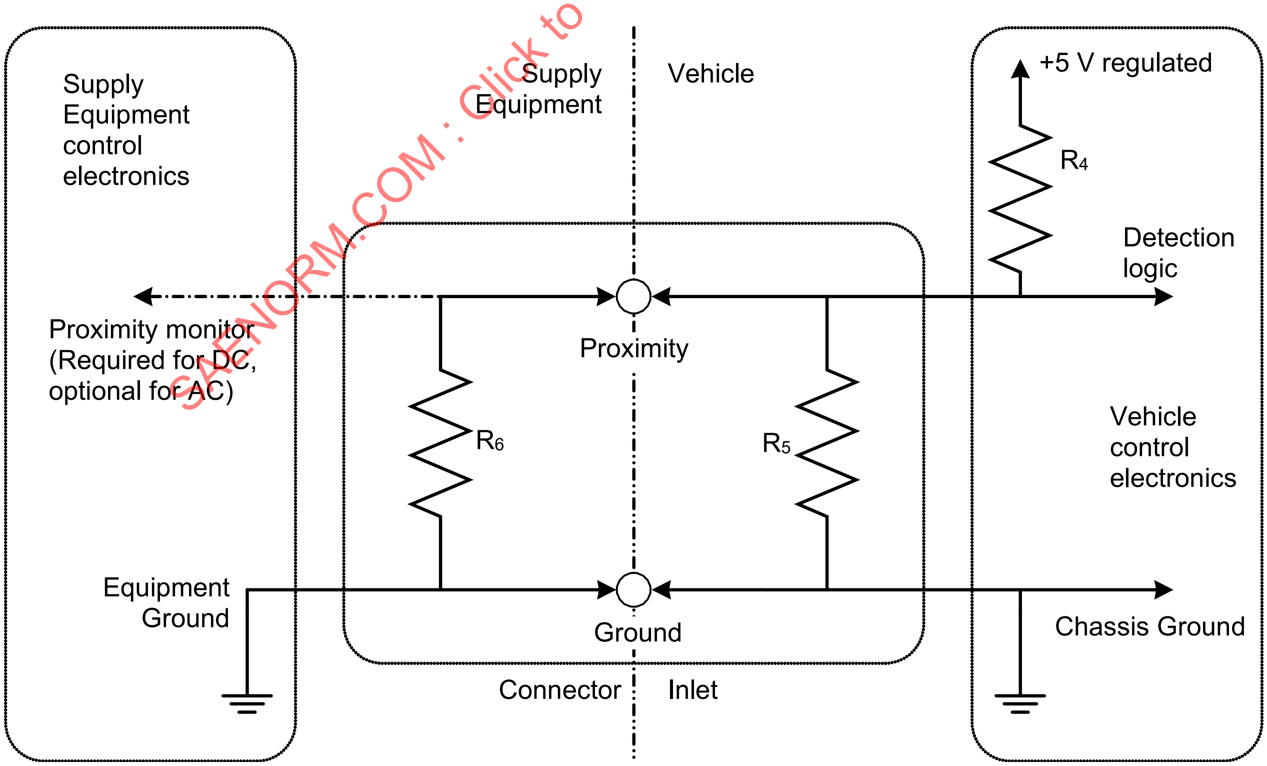


Figure 3 - Simplified case C proximity diagram for SAE J3400 coupler in the Connector Inserted state

PHEV may be required to place R_5 in the *inlet* assembly, as shown in Figure 3, in order to enable diagnostics in some jurisdictions; otherwise, the placement and the method of archiving equivalent required impedance is up to the OEM.

NOTE: If an *inlet* is disconnected from the internal *EV* controller, it becomes impossible to detect a mated *connector* in the *inlet*; and therefore, immobilization cannot be guaranteed. At a minimum in such a case, an *EV* should notify the driver that it cannot detect the connected state of the *inlet* and should be acknowledged before moving. Plug-in hybrids are required under title 13, CCR section 1971.1 "comprehensive component monitoring" to diagnose such a condition and report it to a generic scan tool (refer to SAE J2012 codes P0D56 through P0D5A).

6.2.1.2 An *EVSE proximity* monitoring circuit for a *case C* connection (required for DC power transfer and optional for AC power transfer) shall not interfere with the *EV proximity detection* function whether the *EVSE* is powered or unpowered, specifically:

- Limiting the monitoring effect on *proximity* voltages at the *coupler* interface by less than ±0.1% whenever mated.
- Limiting *EVSE* + cable capacitance to 1.8 nF and limiting the series inductance (between *coupler contact* and SECC) to 1 mH on *proximity*.
- Shall measure 0.0 VDC ± 0.1 VDC measured from *EVSE proximity*-to-*ground* whenever unmated.

6.2.1.3 A severed *cable assembly* with intact *connector* (but without shorts between conductors) shall provide a *proximity* impedance detectable by the *EV* as one of the valid mated *proximity* states defined in Table 3.

EXAMPLE: *EVSE* may distribute R_6 equivalent impedance along the *EVSE* control electronics and the *connector* assembly. For example, if R_6 was split into two resistors, R_{6A} and R_{6B}, and R_{6A} was a 470 Ω resistor-to-*ground* in the *connector* and R_{6B} was a 220 Ω resistor-to-*ground* inside the *EVSE* control electronics; a *connector* assembly with a severed cable going to the *EVSE* with a 470 Ω R_{6A} in the intact *connector* would still meet 6.2.1.2, because the *EV* could detect the damaged mated assembly as being in the "SAE J1772 *Unlatched"* state. This could also be used to dynamically detect the *connector* configuration.

6.2.1.4 Thermal cut-outs or interlocks present in *connectors* and/or *inlet accessories* shall not function to create the *proximity* "Disconnected" state as sensed by the *EV* because this would interfere with the immobilization function.

6.3 EVSE Conductive Power Transfer - General Requirements

6.3.1 EVSE Conductive Power Transfer - Personnel Protection Requirements

6.3.1.1 *EVSE* shall incorporate a system of personnel protection as specified in the *Tri-National EVSE Safety Standards* (see 3.42) as specified by the product standards listed in 7.1.1.1 and 8.1.1.1.

NOTE: The *Tri-National EVSE Safety Standards (*in the USA named ANSI/UL 2231), provides requirements and tests for required protective functions such as: *contact* welding detection, self-test, *CCID*, and withstand requirements for the *EVSE* contactor.

6.3.1.2 The *EVSE* shall construct and design the circuits and software generating, or provide a supervisory function, *PWM-CP*, for correct duty cycle and detection of loss of ground, according to ANSI/UL 1998, UL 991, and/or IEC 61508 which provides a similar methodology.

NOTE: The *EVSE* manufacturer should consider that applying a *PWM* duty cycle that does not match the *EVSE's* capabilities (AC charging versus DC charging) can lead to increased risks of electric shock or thermal events. Some aspects of the *CP* circuit are already evaluated for functional safety under the T*ri-National EVSE Safety Standards,* like the detection of State A indicating loss of *ground* to the *EV* (which requires the *EVSE* contactor to open), but 6.3.1.2 extends this to the correct generation of the duty cycle.

6.3.1.3 The SAE J3400 *connector* request-to-stop function (as described in Figures 4 and 6) is required.

EXCEPTION: Although not recommended, if the *case C EVSE* provides non-emergency HMI means to stop the charging session, *connectors* without the request-to-stop means are allowed.

6.3.2 EVSE Conductive Power Transfer - EMC Requirements

6.3.2.1 In the United States, the *EVSE* shall meet FCC rules (Title 47 CFR Part 15) for radiated and conducted limits for unintentional and intentional radiators. In Canada, the *EVSE* shall meet the Industry Canada license-exempt RSS standard(s).

NOTE: The *Tri-National EVSE Safety Standard* provides additional EMC requirements, and SAE J1772 provides some additional notes and test setups useful for EMC compliance.

6.3.2.2 *EVSE* shall meet all applicable requirements (see 4.2) specified in IEC 61851-21-2.

EXCEPTION: AC *EVSE* without *PLC-CP* are not required to comply with 6.3.2.2 if manufactured before December 31, 2027, but they still must meet all EMC requirements required by national standards and *local electrical codes*.

6.3.3 EVSE Conductive Power Transfer - Installation Requirements

6.3.3.1 The installation of the *EVSE* shall be done in accordance with the adopted *local electrical codes* (see 3.30).

6.4 EV Conductive Power Transfer - General Requirements

6.4.1 EV Conductive Power Transfer - HMI Requirements

The *EV* is recommended to indicate to the operator:

- The power transfer status visible from the position of the operator while inserting the *connector* into the *inlet*.
- If power transfer is limited due to atypical condition (e.g., thermal limit).

6.4.1.1 The *EV* shall provide means to stop power transfer to allow the operator to disconnect.

NOTE: The exact implementation is determined by the OEM to meet 6.4.1.1. For example, buttons near the *inlet* on the *EV* could meet these requirements, but other means are allowed, such as HMI inside the *EV*.

6.4.2 EV Conductive Power Transfer - Requirements from ISO

6.4.2.1 *EV* shall meet the applicable requirements (see 4.2) specified in ISO 5474-1, ISO 5474-2, and ISO 5474-3.

NOTE: The ISO 5474 series gives requirements for *EV* electrical safety while *conductively* connected to an *EVSE*, including requirements on *latching*, AC/DC *contact* sharing, insulation coordination, and fault protection.

For gauging the *grounded conductor*, the design of the *coupler* system does not need to consider the occurrence of a double fault on the DC circuit.

6.4.2.2 *EV* shall meet all applicable requirements (see 4.2) specified in ISO 6469-3.

NOTE: ISO 6469-3 provides requirements for *EV* electrical safety when not *conductively* connected to an *EVSE*, including requirements for protection of persons against electric shock including: basic protection, fault protection, protective provisions, de-energization, limitation on stored energy and voltage, and touch safety of unmated *inlets*.

6.4.3 EV Conductive Power Transfer - EMC Requirements

6.4.3.1 *EV* shall meet all applicable requirements (see 4.2) specified in IEC 61851-21-1.

6.4.4 EV Conductive Power Transfer - Requirements from AC and DC Contact Overlay

6.4.4.1 *EV* shall be able to distinguish between AC and DC power transfer based on the inputs from the *EVSE*. See 7.4.1 and 8.2.1.1.

NOTE 1: The *EV* manufacturer should consider that the device generating a *PWM/PLC-CP* signal in the *EVSE* may not be developed according to the provisions of ISO 26262, and that IEC 61851-1 does not mandate the application of IEC 61508 for AC stations; but it does so for DC stations in IEC 61851-1:2017, 6.3.2.4. IEC 61851-23:2024 does not mention IEC 61508 except in the bibliography.

NOTE 2: Refer to ISO 5474-1:2024 clause 6.5 "AC or DC electric power at the same contacts" required by 6.4.2.1.

6.4.4.2 *EV* shall have a robust safety strategy to ensure the *inlet* is only energized with DC power from traction battery if the requirements for safe DC power transfer have been met.

6.4.4.3 The *EV* shall consider, at least, the following AC and DC *contact* overlay fault scenarios in its design:

- One DC charging contactor within the *EV* is closed unintentionally during AC charging, thus directly connecting the AC voltage to the HV DC circuit of the *EV*.
- Both DC charging contactors within the *EV* are closed unintentionally during AC charging, thus connecting the HV battery of the *EV* directly to the AC electrical grid.
- One DC charging contactor within the *EV* was welded, and the defect was not detected. When the next AC charging session is started, the AC voltage is directly connected to the HV DC circuit of the *EV*.
- Both DC charging contactors within the *EV* were welded and the defect was not detected. When the next AC charging session is started, it connects the AC *EVSE* to HV DC circuit of the *EV*.
- Single point DC contactor unintentional close during AC charging.
- Double point DC contactor unintentional close during AC charging.
- Single point DC contactor fails to close during AC charging.
- Double point DC contactor fails to close during AC charging.
- Unintentional HV DC voltage applied to *on-board charger* during DC charging.
- Unintentional *EV* AC reverse power generation during DC charging.

EXAMPLE: The following are mitigations that may be used to address the above scenarios:

- The DC charging contactors being inhibited from closing if not connected to a DC *EVSE*.
- The DC charging contactors being inhibited from closing if there is AC voltage greater than 30 VAC detected on the *inlet* power *contacts*.
- The DC contactors being inhibited from closing if the *EV* detects an AC *EVSE* is connected.
- With no *connector* detected, the *inlet* engaging the *latch* (preemptively preventing *connector* mating), if DC voltage greater than 60 VDC is detected on the *inlet*.
- With a *connector* possibly mated, and if conditions for being energized with DC on the power *contacts* are not met, the *EV* isolates the battery from the *inlet* within 1 second if DC voltage greater than 60 VDC is detected on the *inlet*.
- If DC charge contactors are detected as closed, the system disallows requesting voltage from an AC *EVSE*.

6.5 Conductive Power Transfer - Interoperability

Some existing deployed NACS AC and DC *EVSE* support a method of communication via single-wire controller area network over the *control pilot* (*SW-CAN-CP*). SAE J2411 transceivers are connected to the *control pilot*, and the *PWM* is turned off. This method of charging is not described in this edition of the document; however, to avoid certain interoperability issues, certain aspects are described.

6.5.1 EV Interoperability with SW-CAN-CP

6.5.1.1 *EVs* which do not support *SW-CAN-CP* and have not yet started establishing a PLC data link (e.g., ISO 15118-3) shall not close S_2 in response to a *PWM-CP* signal with a 5% duty cycle at 1 kHz.

NOTE: This requirement would not conflict with one type of ISO 15118-3 startup sequence using 5% duty cycle at 1 kHz where in response, the *EV* sends and receives SLAC messages to start to set up the PLC data link before S_2 closure. This can be differentiated from closing S_2 before sending and receiving SLAC responses during a 5% duty cycle, which is how the *EV* selects *SW-CAN-CP*.

6.5.1.2 *EVs* which initially detect a *PWM-CP* signal with a 5% duty cycle at 1 kHz at the beginning of the *connection session*, which are subsequently unable to establish a PLC data link (e.g., ISO 15118-3), shall be able to start AC power transfer when duty cycle becomes valid for AC power transfer under *PWM-CP* (e.g., *EVSE* generated 10 to 96% duty cycle at 1 kHz).

NOTE: *EVSE* which support *SW-CAN-CP* use 5% duty cycle at 1 kHz as a startup sequence, and if the *EV* follows 6.5.1.1, the *EVSE* falls back to a nominal (10 to 96%) duty cycle after several seconds and then the *EV* should be able to start basic charging. The requirement does not preclude closing S_2 while sending and receiving SLAC messages during matching, nor does it preclude closing S_2 at 100% duty cycle to wake up the *EVSE*.

6.5.2 Interoperability with Inlet Accessories

6.5.2.1 SAE J3400 *EVs* which support *inlet accessories* shall:

- Provide at minimum a 10 x 10 mm *inlet accessory* interlock flange area as shown in 10.1.

NOTE: Additional requirements are under consideration. Future SAE J3400 series documents may supplement these requirements with additional ones, including required keep-out zones for *inlet accessories*.

6.5.3 Application of Cybersecurity and Public Key Infrastructure (PKI)

If the use of a public key infrastructure (PKI) by the EVCC and SECC to enable secure *EV-EVSE* communication is required by the protocol to implement Plug and Charge (PnC), value-added services, or other functionality, the PKI should comply with the SAE International EV Charging PKI – Certificate Policy version 1.1 published December 5, 2023 (refer to PKI001). This document is available from SAE: https://www.sae-itc.com/programs/evpki.

7. AC POWER TRANSFER

7.1 AC Conductive Power Transfer - General Requirements

7.1.1 AC EVSE Requirements

7.1.1.1 *EVSE* providing AC power shall meet and be listed to general product requirements specified in the *Tri-National AC EVSE Standard* (see 3.43).

7.1.1.2 *EV* shall be compatible with power transfer from an *EVSE* providing *CCID*5 or *CCID*20 as defined by the *Tri-National EVSE Safety Standard*.

*CCID*5 compatibility may be limited in certain operational environments because the fault current limit is low, and the risk of nuisance trips is high. OEMs may specify operational limitations on *CCID*5 interoperability. *CCID*5 interoperability allows power transfer from a GFCI Class A protected circuit (e.g., NEMA outlet).

7.1.2 AC Conductive Power Transfer - Initiation and Termination

Vehicles upon detecting the "SAE J1772 *Unlatched*" state referred to as “S3 open” in Appendix E of SAE J1772 are expected to reduce the OBC current (see 7.1.2.3).

For SAE J3400 *connectors* to terminate an active AC power transfer, the operator would typically press S_{3B} to create this condition, although “SAE J1772 *Unlatched*” state could also indicate a mated *accessory* is *unlatched* or some other condition requiring termination.

The *EV* detection of the “SAE J1772 *Unlatched*” is a normal way to terminate an AC power transfer.

If the “SAE J1772 *Unlatched*” state persists (typically 1 second), the *control sequences* would end and if not otherwise retained for any reason (access-control, security, *case B*, etc.), the *connector* is typically *unlatched* to allow for removal.

The vehicle may re-*latch* the *connector* and continue the power transfer after some reasonable time (typically >30 seconds) if the operator never removes the *connector* from the *inlet*.

7.1.2.1 SAE J3400 *EV* shall only close S_2 to initiate AC power transfer if the *inlet* is verified *latched* and the *coupler proximity* (*inlet*-side) is “*Connector* Inserted.”

7.1.2.2 In normal operation, the *EV* shall reduce the current to ≤1.0 A before opening S_2.

During atypical operation (emergency or other faults), the *EV* may open S_2 anytime.

7.1.2.3 SAE J3400 *EV* during AC power transfer shall *foldback* within 100 ms ≤ 1.0 A upon the leaving the "Connector Inserted" *coupler proximity* (*inlet*-side) or if there is a loss of *control pilot* (open-circuit).

NOTE 1: It is recommended for *EV* to *foldback* faster than required. The *foldback* recommendation considers the geometry of the *coupler* (see 11.3) to mitigate undetected *latch* failures and to allow better interoperability with a SAE J1772 AC *coupler* which may not be effectively *latched*, or simply a SAE J1772 *coupler* with a non-locked *latch* where S_3 is pressed and subsequently withdrawn at a moderate speed. For all of these cases, 100 ms is insufficient for mitigating micro-arcs with significant enough energy to cause *contact* damage. In summary, it is compliant but sub-optimal and not recommended on new vehicle platforms/architectures.

NOTE 2: The *foldback* timing requirement itself does not necessitate opening S_2 during this period, which means that power transfer can quickly recover if the event that triggered the *foldback* is resolved or determined to be spurious. AC *Foldback* is an *EV*-side OBC current-reduction that does not require any mechanical switching. This increases the reliability and lifetime of the *coupler* system while also avoiding a spuriously triggered *EV*-signaled *EVSE*-sensed S_2 shutdown.

NOTE 3: OBC may incorporate series arc detection to trigger a temporal *foldback* and it can offer additional protection to cover other fault cases. For instance, this feature would mitigate an arc forming from excessive side loads (e.g., operator trips over a cable) where the *contacts' control pilot* and *prox* never lose continuity, but L1 and/or L2/N do.

NOTE 4: OBC may monitor the *control pilot* and *prox* directly to remove intervehicle communication latency to lower the *foldback* response time. The *EV* limits total circuit inductance and capacitance as specified in 7.2.1.1.

NOTE 5: The optimal timing for a *CP*-triggered (open-circuit detected) or *prox*-triggered (leaving the "Connector Inserted" state) *foldback* process is within 6.25 ms ≤ 5.0 A (see 11.5) and within 100 ms ≤ 1.0 A, and this is meet by existing (pre-standardization) NACS vehicles. With only 7.1.2.3 as a requirement, compliant response timings for system-level analog-signal-triggered termination remains harmonized to SAE J1772 per 7.2.1.2.

7.1.3 EV-Sensed AC-Only Request-to-Stop Connector Function on Proximity

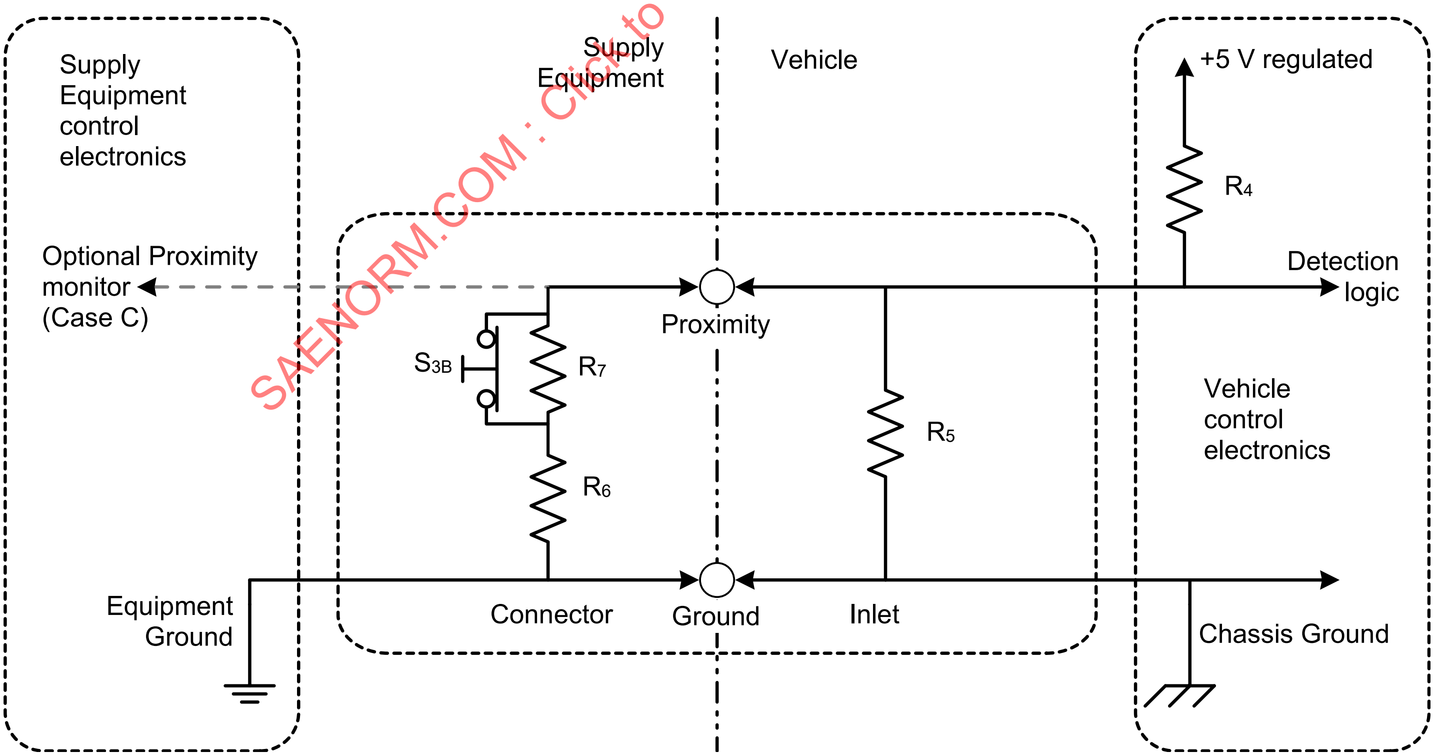


Figure 4 - EV-sensed request-to-stop on SAE J3400 connectors for AC power transfer

7.1.3.1 An SAE J3400 *connector* used for AC power transfer equipped with a stop request, under this section, shall provide a function electrically equivalent to a normally closed momentary switch (S_{3B}), that when pressed, adds R_7 into the *proximity* circuit (as shown in Figure 4).

The method shown in Figure 4 is detected equivalently to the "SAE J1772 *Unlatched*" state in Table 3, which the *EV* is required to detect by 7.2.1.2. The method shown in Figure 4 is used on the SAE J3400 *connector* under *case C* or *case B*.

AC *connectors* may contain means to create "SAE J1772 *Unlatched*" on the *proximity* circuit to trigger a thermal shutdown by putting a normally closed thermal cut-out or other similar device in series with S_{3B}.

Also shown in Figure 4 is the optional *EVSE proximity* monitor (under *case C*), which is an unrelated function that can be used independently of the *EV*-sensed request-to-stop *connector* function. AC *EVSE,* which monitor the *proximity,* may add redundancy to the detection of the "SAE J1772 *Unlatched*" state and terminate the session but must meet 6.2.1.2.

7.2 AC Conductive Power Transfer - PWM-CP Basic Signaling

EV charging using pulse-width modulation on a *control pilot* is commonly used for AC charging. While it is also defined in IEC, this document relies on the SAE J1772 definition as there are some differences with IEC 61851-1 Annex A. *PWM-CP* describes a system of baseband signaling on the *control pilot*. Another type of baseband signaling is defined in 7.3.

7.2.1 AC Conductive Power Transfer - Requirements from SAE J1772

7.2.1.1 *EVSE* and *EVs* shall meet the *control pilot* requirements given in 4.2.1 of SAE J1772 for AC power transfer under *PWM-CP*.

7.2.1.2 *EVSE* and *EVs* shall meet the timing and sequence requirements given in Appendix E of SAE J1772 for AC power transfer under *PWM-CP* unless otherwise specified in Section 7.

EXAMPLE: See 7.1.2.2, which is aligned to IEC 61851-1:2017 Annex A Sequence 7 abbreviations, which has no equivalent requirement in SAE J1772.

7.2.2 AC Conductive Power Transfer - AC Ratings Using PWM-CP

Existing deployed AC *EVSE* in North America using the SAE J3400 *coupler* utilize nominal single-phase supply voltages from 120 up to 277 VAC, and up to 80 A at 60 Hz when operating under *PWM-CP*. AC power transfer beyond these parameters are required to use an optional digital protocols which do a AC voltage ratings compatibility pre-check.

EVSE can be designed and listed for a single nominal voltage (e.g., 120 VAC, 240 VAC, etc.) or be designed and listed for multi-voltage input (e.g., 120/240 VAC, 208-240 VAC, 200-277 VAC, etc.). AC *EVSE* with three-phase and power transfer using more than two power wires both giving single-phase SAE J3400 interoperability is described in Appendix B.

NOTE 1: SAE J1772 defines AC Level 2 as power transfer for *EVSE* nominal voltages from 208 to 240 VAC; however, since the 199610 edition of SAE J1772, the *coupler* rating has been 300 VAC (described as a minimum in the latest editions). Also, 240 VAC high-leg delta is a valid supply voltage for SAE J1772 AC Level 2, exceeding 150 VAC (high-leg) line-to-*neutral*/*ground* consequently requiring 300 VAC coordination per IEC 60664-1 (see below). However, SAE J1772 *EVs* which are not designed or verified to be fully interoperable with SAE J3400 may not operate with supply voltages outside of what is defined for SAE J1772 AC Level 2 even if they are properly coordinated.

NOTE 2: 277 VAC is a common single-phase derived from 480Y/277 three-phase four-wire supply, provided from between a line conductor and grounded conductor (earthed neutral system), which is commonly found at commercial and urban locations throughout North America and is the most common AC supply for DC *EVSE*. *On-board chargers* supporting 277 VAC reduce installation costs, transformer losses, and I^2R losses.

7.2.2.1 In a North American application, *EV* which are designed for AC power transfer using *PWM-CP* under SAE J3400 shall operate within ANSI C84.1 utilization voltage range B for 120–277 VAC single-phase nominal system voltages.

NOTE 1: An *EV* meeting 7.2.2.1 functions with a minimum utilization voltage of 104 VAC and a maximum utilization voltage of 293 VAC as given by Table 1 of ANSI C84.1-2020 Voltage Range B. Requirement 7.2.2.1 should not be interpreted to disallow the OBC from operating outside the ranges defined in ANSI C84.1.

NOTE 2: *EVs* which do not use SAE J3400 *inlets* (for example, those that use SAE J1772 *inlets*), but which are designed or verified to be fully interoperable with SAE J3400 equipment, either through adapter or other connection means, would meet 7.2.2.1. At minimum, if provided with means to mate with SAE J3400 *connectors*, the instruction manual needs to explicitly state *EV* model compatibility and any limitations.

Within the ANSI C84.1 Voltage Range A (-10% +5%), it is recommended that OBC operate normally at the power level and state-of-charge (SoC) range as specified by the vehicle manufacturer, which can vary for each supported nominal system voltage.

Voltage Range B covers voltage perturbations, which per ANSI C84.1 are limited in extent, frequency, and duration. Corrective actions are required to be taken from the electricity supplier to bring the voltage back within Voltage Range A. ANSI C84.1 requires “acceptable performance in the extremes of the range of utilization voltages (Range B), although not necessarily as good performance as in Range A.” An OBC may have reduced power range and/or reduced SoC range, minor reductions in power quality, minor EMC deviation, when operating outside Voltage Range A (i.e., >277 VAC +5%), and the OBC is not required to operate outside of Voltage Range B (i.e., >277 VAC +6%).

SAE J3400 *EVSE* and *EV* equipment can be designed for normal operating supply/utilization ranges per ANSI C84.1 (-10% +5%/+6%), instead of the generic ±10% recommendation specified in IEC 60038, and then correspondingly these ANSI operating supply/utilization ranges are used to understand IEC 60664-1, when considering North American specific supplies (e.g., 277 VAC).

For IEC 60664-1, Tables B.1, B.2, and F.1, *EVSE* and *EV* OBC should consider the line ≤300 VAC nominal line-to-*neutral/ground* in those tables, which as specified in those documents are equivalently coordinated overvoltage categories (same table row) with AC supplies such as 400Y/230 and 480Y/277 because they both exceed 150 VAC line-to-*neutral/ground*.

It is common for electrical equipment designed for worldwide use (which include both North America and Japan in this case), such as ordinary AC to DC power supplies for mixed industrial/commercial/residential use, to have a marked rating of 100-240 VAC 50/60 Hz and include 277 VAC for North American use only. See Figure 5 for a typical example where 277 VAC is not supported in the European regulatory context (which would be ±10% supply range), and instead allows use of -10% +5/6% as specified in ANSI C84.1 for the North American context while being properly labeled and compliant for multiple markets.

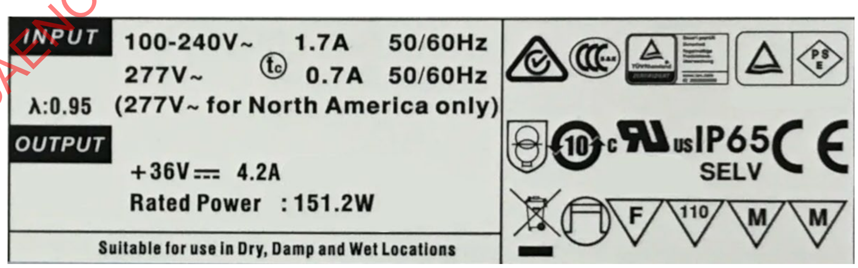


Figure 5 - Example photo of a mixed voltage range rating compliance label (for EU, US/CA, JP, etc.) (informative-use only)

NOTE: This is an example from a lighting power supply and not meant to imply any labeling or other requirements (see 6.1 for those), but instead illustrates one form of mixed voltage range rating compliance labeling that can be used for cross-continental homologation. A similar strategy is currently used for some three-phase *EVSE* (AC or DC) where the 480Y/277 VAC supply is only supported for use in North America.

7.3 AC Conductive Power Transfer - Digital Signaling with LIN-CP (Optional; see 4.1.1)

Under this section, a *LIN-CP* transceiver is coupled to the *control pilot* circuit as baseband digital replacement for the duty cycle in *PWM-CP*. PLC communication can be used simultaneously with *LIN-CP* (in the same way that PLC is used simultaneously with *PWM-CP*).

AC power transfer using *LIN-CP* is described in SAE J3068 (also IEC 61851-1 Annex D). It maintains the analog schemes for detecting the loss of *ground* and it makes use of S_2. When within the AC ratings for *PWM-CP* (see 7.2.2), a *LIN-CP EVSE* switches to *PWM-CP* roughly 1 second after *coupler* mating to a *PWM-CP*-only *EV* which gives backwards compatibility.

For more information about using *LIN-CP* with single-phase AC *coupler* systems such as SAE J3400 and SAE J1772, refer to SAE J3068 Appendix C. *LIN-CP* is also defined in IEC 61851-1 Annex D (the draft 4th edition of Annex D is harmonized to protocol version 2 as defined SAE J3068).

7.3.1 AC Conductive Power Transfer - Digital Signaling with LIN-CP: General Requirements

7.3.1.1 *EV* with SAE J3400 *inlets* or *EVSE* with SAE J3400 *connectors* or SAE *universal socket-outlets* that support *LIN-CP* shall follow the applicable requirements in the SAE J3068 series for single-phase and three-phase power transfer.

7.4 AC Conductive Power Transfer - Digital Communication with PWM/PLC-CP (Optional; see 4.1.1)

Under this section, a PLC transceiver is coupled to the *control pilot* circuit to achieve additional functionality.

7.4.1 AC Conductive Power Transfer - Digital Communication with PWM/PLC-CP: General Requirements

7.4.1.1 *EVSE* prior to AC power transfer (energizing the circuit to the *EV* in response to S_2 closing) using *PWM/PLC-CP* shall ensure the duty cycle is valid. See 8.2.1.2 for DC power transfer.

NOTE: See 6.3.1.2 and 6.4.4.1 for important considerations for this requirement.

7.4.2 AC Conductive Power Transfer - Additional Requirements When Using ISO 15118

This section defines optional use of the ISO 15118 series for AC power transfer. These requirements apply to *EVs* with SAE J3400 *inlets* or *EVSE* with SAE J3400 *connectors*. See 6.5.3 for PKI recommendations which are especially applicable for AC PnC.

If the *EVSE* chose to start with a 5% duty cycle and if the *EV* did not start the “Data Link Setup” process within 4 seconds of plug-in, the SECC may change to a *PWM* duty cycle of 10 to 96% if power transfer is pre-authorized. This case, it may skip the legacy wake-up (State E/F for 4 seconds) sequence that is described under ISO 15118-3:2015.

NOTE 1: The “Data Link Setup” process is considered started if EVCC sent an initial CM_SLAC_PARM.REQ message and SECC received it. Under this condition, the 5% duty cycle can continue for more than 4 seconds because the *EV* support of PLC is confirmed.

NOTE 2: This is done to maximize backwards compatibility and improve the user experience for *EVs* that do not support AC power transfer under ISO 15118. Otherwise, these *EV* will experience longer startup times with stations which support ISO 15118 but do not require it for power transfer.

NOTE 3: This relates to requirements in 6.5.1 because it describes a startup sequence where the *EVSE* started with a 5% duty cycle and then changed to a nominal duty cycle.

If PLC communications fail during *connection sessions* with a nominal pilot duty cycle and charging is otherwise still authorized without ongoing communication, the *EVSE* should continue charging the *EV*.

7.4.2.1 For AC charging using ISO 15118-2, the *EVSE* shall send at minimum “AC_single_phase_core” in the SupportedEnergyTransferMode parameter of the ServiceDiscoveryRes message.

EXAMPLE: If the *EVSE can* also provide three-phase power (permitted under Appendix B), it would send both “AC_single_phase_core” and “AC_three_phase_core.”

7.4.2.2 For AC charging using ISO 15118-2, the *EV* shall send “AC_single_phase_core” in the RequestedEnergyTransferMode parameter of the ChargeParameterDiscoveryREQ message.

NOTE: The *EV* selects AC power transfer by sending “AC_single_phase_core” in the RequestedEnergyTransfer parameter of the ChargeParameterDiscoveryREQ message. Then, the SECC acknowledges (“ResponseCode = OK”) the selection of AC power transfer in the ChargeParameterDiscoveryRES.

7.4.2.3 After 7.4.2.2, the *EVSE* uses a valid pilot duty cycle indicating availability of energy, or 100% duty cycle indicating non-availability of energy for the remainder of the *connection session*, including pauses.

8. DC POWER TRANSFER

8.1 General DC Power Transfer Requirements

8.1.1 DC EVSE Requirements

General class DC *EVSE* under this document should have preferred ratings of 1000 VDC and operate over a voltage range including, but not limited to, 200 to 920 VDC.

Under this document, "U" class DC *EVSE* operate over a voltage range including, but not limited to, 50 to 200 VDC.

NOTE: "U" class is designed to cover motorcycles, off-road vehicles/craft, other light-duty conveyance, and certain industrial *EVs*. It is recommended for "U" class DC *EVSE* to target 50 to 920 VDC for full interoperability.

8.1.1.1 *EVSE* providing DC power shall meet and be listed to general product requirements specified in the *Tri-National DC EVSE Standard* (see 3.44).

8.1.1.2 *EVSE* providing DC power shall meet the applicable requirements (see 4.2) in the latest version of IEC 61851-23.

8.1.2 DC Proximity Requirements

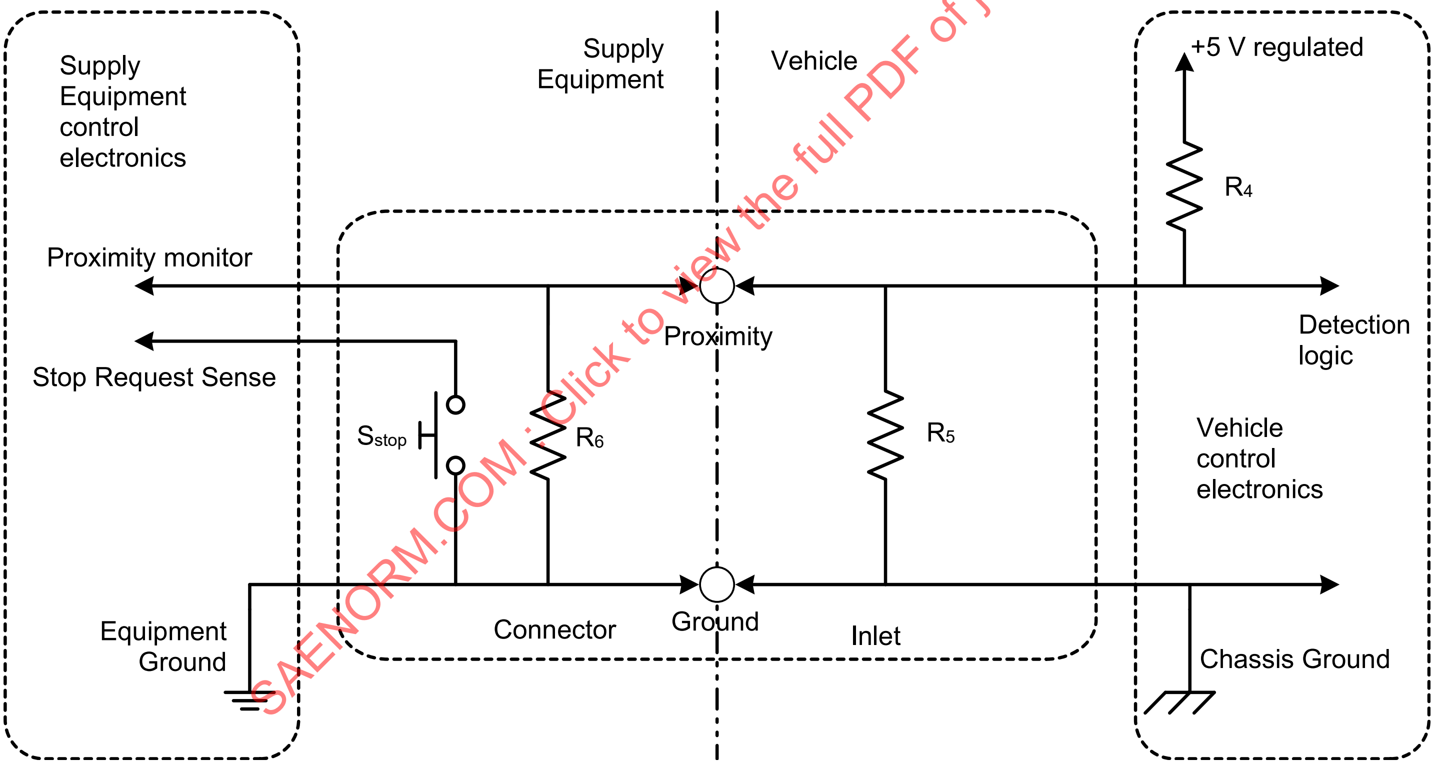


Figure 6 - DC proximity circuit with EVSE-sensed request-to-stop function

8.1.2.1 The DC *EVSE* request-to-stop switch on the *connector* shall have no effect on the *proximity* circuit as shown in Figure 6, nor shall it affect the *CP* circuit.

NOTE 1: The exact method shown in Figure 6 is entirely up the manufacturer since the *EV* cannot sense this circuit. Typically, the circuit with S_{stop} would include some impedances in the circuit for safety or EMC reasons. It may use *ground* for current return, or it may use an isolated circuit.

NOTE 2: The purpose of including Figure 6 is to contrast this with the method described in Figure 4, which can only be used for AC power transfer.

8.1.2.2 During DC transfer, the "Disconnected" and "SAE J1772 *Unlatched*" state shall trigger an *EV*-initiated emergency shutdown.

8.1.2.3 DC *EVSE* shall monitor the voltage on the *proximity* and terminate when it is not valid for DC power transfer (typically only "Connector Inserted" and "DC Thermal Warning" are valid).

8.1.2.4 DC *EVSE* shall trigger an emergency shutdown in the "Disconnected," "SAE J1772 *Unlatched*," and "DC Thermal Shutdown" *proximity* states.

System-level DC emergency shutdown requirements continue to be aligned with System C of IEC 61851-23 and SAE J1772. The *EVSE* response timing requirements for a *control pilot* or *prox* fault related to emergency shutdown (I_{DC} < 5 A within 30 ms of system shutdown, *EVSE* triggers shutdown within 10 ms of *control pilot* transition to State A/B, etc.) are pulled in from 8.1.1.2.

It is strongly recommended that DC *EVSE foldback* to I < 20 A within 6.25 ms of the occurrence of an event (as mentioned above) which may trigger a system-level emergency shutdown (e.g., 8.1.2.4).

NOTE 1: DC *EVSE* fast *foldback* is implemented in existing pre-standardization NACS DC stations. The recommendation considers the geometry of the *coupler* to mitigate *latch* failures and allow better interoperability with SAE J1772 *couplers* (which may not be effectively *latched*). *Foldback* functionally is also used as part of DC arc fault mitigation and other fast thermal protections (see 11.3).

NOTE 2: During this *foldback* period, the *EVSE* would decide whether to signal an emergency shutdown (by turning off the *PWM-CP* oscillator, etc., and continuing the emergency shutdown procedure within the overall required timings as described in and 8.1.1.2) or recover if the event triggering the *foldback* is resolved or determined to be spurious.

NOTE 3: DC *foldback also* reduces the likelihood of a load dump on the vehicle in the event of a concurrent *EV*-initiated emergency shutdown, since a DC *EVSE* meeting the fast *foldback* recommendation will have already reduced the current.

NOTE 4: This recommendation may be phased in by future editions of this document as a requirement.

8.1.2.5 SAE J3400 *couplers* used for DC power transfer shall not have means to create the "SAE J1772 *Unlatched*" condition for a normal shutdown.

NOTE: A request-to-stop button function for SAE J3400 *connectors* is shown in Figure 6 that has no effect on the *proximity* function and therefore complies with 8.1.2.5.

8.1.2.6 A DC *control sequence* can only be started in the "*Connector* Inserted" *proximity* state, not ("DC Thermal Shutdown," "SAE J1772 *Unlatched*," or "Disconnected"). See 8.1.3.2 for "DC Thermal Warning."

8.1.3 DC Proximity Requirements Related to Inlet Accessories

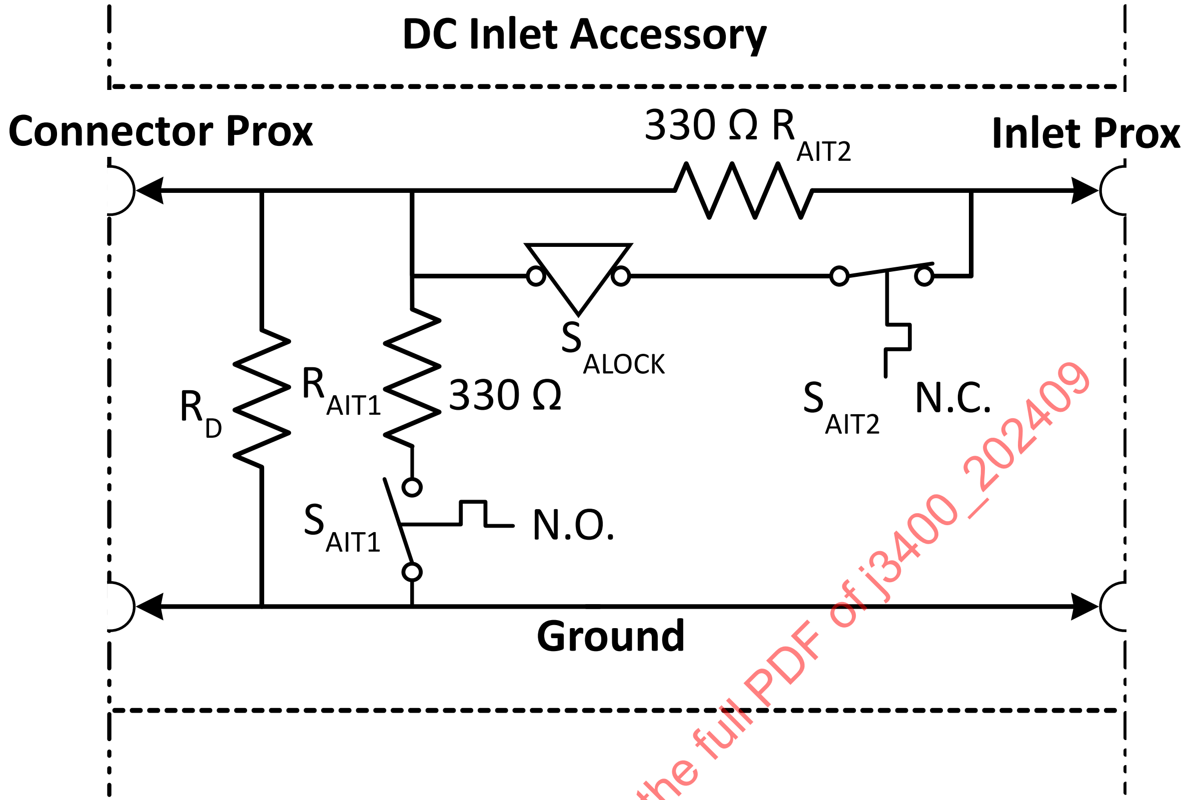


Figure 7 - Inlet accessory with proximity on both mating interfaces typical for DC power transfer from CCS

Inlet accessories may contain more than one normally-open S_{AIT1} in parallel (S_{AIT1a} S_{AIT1b} S_{AIT1c} …), any of which can close, adding R_{AIT1} into the *proximity* circuit as required below.

Inlet accessories may contain more than one normally-closed S_{AIT2} in series (S_{AIT2a} S_{AIT2b} S_{AIT2c} …), any of which can open, adding R_{AIT2} into the *proximity* circuit as required below.

Inlet accessories may contain more than one normally-closed S_{ALOCK} in series ($S_{ALOCK\_CONNECTOR}$ S_{ALOCK_INLET}) any of which can open, adding R_{AIT2} into the *proximity* circuit as required below.

R_D is not populated for *inlet accessories* designed to mate from or to SAE J1772 *connector* (*CCS1*).

NOTE: R_D is used for accessories mating with SAE J3068 DC_8 *connectors* (*CCS2*). This allows for SAE J3068 *inlet* vehicles to be interoperable with SAE J3400 and SAE J1772 stations which are required to monitor for specific *inlet proximity* voltages. Refer to SAE J3068 for details of interoperability requirements between these *coupler* types.

8.1.3.1 *Inlet accessories* designed for DC power transfer shall:

- Contain means to create the "DC Thermal Warning" state when reaching a temperature near the thermal limit, *accessory* intervention temperature 1 (AIT1), of the device which can be detected by the *EVSE* and *EV*.

- Contain means to shut down the DC session by creating the ["DC Thermal Shutdown" as detected by the *EVSE* and the "SAE J1772 *Unlatched*" state as detected by the *EV*] if the rated thermal limit is reached, *accessory* intervention temperature 2 (AIT2), on any of the live *contacts* on either mating side of the *accessory*.

- Contain means to interlock the mated *connector* side of the *accessory*, mechanically preventing a live disconnect and electrically inhibiting the power transfer when not interlocked:

    - The mechanical interlock shall be fully engaged before $S_{ALOCK\_CONNECTOR}$ closes, and $S_{ALOCK\_CONNECTOR}$ shall open before the mechanical interlock is disengaged
    OR
    alternatively, *inlet accessories* shall instead use $S_{ALOCK\_CONNECTOR}$ to interrupt/open *CP* whenever it is possible to separate the *connector* from the *accessory* (i.e., whenever not mechanically interlocked).

    - Additionally, *inlet accessories* that accept SAE J1772 *CCS*1 *connectors* shall be mechanically interlocked when the combined assembly is mated with the SAE J3400 *inlet* such that it prevents the *latch* from actuating (which prevents the SAE J1772 *connector* S_3 from being depressed by the operator).

- *Inlet accessories* that mate with SAE J1772 *CCS*1 *inlets* shall have an *inlet*-lockable mechanical *latching* mechanism as would be required under SAE J1772 for *connectors*. The SAE J1772 S_3 equivalent interlock in the *accessory* would be referred to as S_{ALOCK_INLET}.

- *Inlet accessories* are recommended to use ±1% resistors for DC application but shall be within ±3%.

- Also, S_{AIT1} shall be designed to close before S_{AIT2} opens when heating up; S_{AIT1} shall be designed to continue stay closed when S_{AIT2} is opened; and, S_{AIT2} shall be designed to re-close before S_{AIT1} re-opens when cooling down.

- Contain temperature delta between AIT1 and AIT2 so that a complaint system-level response to thermal warning a prevents a thermal shutdown. See 11.6 for tests under consideration.

- Meet the requirements of 6.2.1.4.

Future SAE J3400 documents may supplement these requirements with additional ones.

8.1.3.2 During DC transfer, a transition to the "DC Thermal Warning" *proximity* state indicates that a mated *accessory* is near the rated thermal limit. The power transfer continues at a reduced current; specifically:

- When transitioning from *"Connector* Inserted*"* to "DC Thermal Warning" each side determines the [largest value of EVSEPresentCurrent] during [the entire *control sequence* or at minimum the preceding 5 minutes]. This shall be referred to as $I_{MAX\_PRE\_WARN}$:

    - Or alternatively, if the control sequence starts in "DC Thermal *Warning*," $I_{MAX\_PRE\_WARN}$ shall be asserted no greater than 200 A, (which limits current to 100 A [½ * $I_{MAX\_PRE\_WARN}$] in "DC Thermal *Warning*" or [⅘ * $I_{MAX\_PRE\_WARN}$] 160 A after thermal recovery as stated below);

    - And, if the [largest value of EVSEPresentCurrent] exceeded 500 A, $I_{MAX\_PRE\_WARN}$ shall be set no greater than 500 A, (which will limit current to 250 A [½ * $I_{MAX\_PRE\_WARN}$] in "DC Thermal *Warning*" or [⅘ * $I_{MAX\_PRE\_WARN}$] 400 A after thermal recovery as stated below).

- DC *EVSE* shall set the EVSEMaximumCurrentLimit to no greater than [½ * $I_{MAX\_PRE\_WARN}$] while in "DC Thermal Warning" *proximity* state.

- *EV* shall set the EVMaximumCurrentLimit to no greater than [½ * $I_{MAX\_PRE\_WARN}$] while in "DC Thermal Warning" *proximity* state.

- The EVTargetCurrent shall respect both limits set in EVSEMaximumCurrentLimit and EVMaximumCurrentLimit.

- The [½ * $I_{MAX\_PRE\_WARN}$] reduction shall be applied by each side within 5 seconds from the transition into the "DC Thermal Warning" *proximity* state.

- If *the proximity* state returns to *"Connector* Inserted" (thermal recovery), EVSEMaximumCurrentLimit and EVMaximumCurrentLimit shall be set to no greater than [⅘ * $I_{MAX\_PRE\_WARN}$].

NOTE: This method is required to be present in DC *inlet accessories* and is meant to be used in addition to the required *EVSE's connector* and *EV inlet contact* temperature monitoring which function independently from the *inlet accessory* warning and shutdown scheme.

8.2 DC Using PWM/PLC-CP

8.2.1 Digital Communication with PWM/PLC-CP - General Requirements for DC EVSE and EVs

8.2.1.1 The *EV* shall only close S_2 as part of a DC power transfer if the duty cycle detected is ≤7% and ≥3%. This does not preclude closing S_2 at 100% duty cycle to trigger wake up from the *EVSE* power-saving function.

NOTE: See 6.3.1.2 and 6.4.4.1 for important considerations for this requirement.

8.2.1.2 The *EVSE* for DC power transfer shall ensure the duty cycle being generated for *PWM/PLC-CP* is 5% or 100% depending on the state as required by 8.1.1.2.

8.2.2 Digital Communication with PWM/PLC-CP and DIN 70121 for DC EVSE and EVs

8.2.2.1 The EVCC and SECC shall support the DIN 70121 high-level communication protocol for control of *electric vehicle* DC charging. This implies that interoperability Class P1 is the baseline requirement. See 8.2.5.

8.2.2.2 An EVCC supporting only the DIN 70121 protocol shall send an SECC Discovery Protocol (SDP) Request message with Transport Protocol equal to "TCP" and Security level equal to "No transport layer security" (according to applicable values in DIN SPEC 70121, Table 23).

8.2.2.3 An SECC supporting only the DIN 70121 protocol shall send an SDP Response message with Transport Protocol equal to "TCP" and Security level equal to "No transport layer security" (according to applicable values in DIN SPEC 70121, Table 23).

8.2.2.4 For DC charging using DIN 70121, the *EV* shall send "DC_extended" in the EVRequestedEnergyTransferType parameter of the ChargeParameterDiscoveryREQ message.

8.2.3 Digital Communication with PWM/PLC-CP with DIN 70121 and ISO 15118 for EVSE and EVs

8.2.3.1 An EVCC supporting ISO 15118-2 shall only use EIM Identification mode if it sends an SDP Request message with Transport Protocol equal to "TCP" and security equal to "no TLS."

8.2.3.2 An EVCC supporting ISO 15118-2 using PnC Identification mode shall send an SDP Request message with Transport Protocol equal to "TCP" and security equal to "secured with TLS."

8.2.3.3 An SECC supporting "TCP + TLS" shall always send an SDP Response message with the same Security level (TCP or TLS) being requested by the EVCC.

8.2.3.4 An SECC supporting DIN 70121 and ISO 15118-2 with no support for TLS (TCP and no TLS) shall always send an SDP Response message with the security set to "No TLS."

NOTE: It is the responsibility of the EVCC to either accept the SDP response from the *EVSE* or end the charging session.

8.2.3.5 For DC charging using ISO 15118-2, the EVCC shall support selecting "DC_extended" in the RequestedEnergyTransferMode parameter of the ChargeParameterDiscoveryREQ message.

8.2.3.6 If the *EVSE* maximum current limit changes, the SECC shall communicate a change to EVSEMaximumCurrentLimit in the CurrentDemandRes message, and if the *EV* maximum current limit changes, the EVCC shall communicate a change to EVMaximumCurrentLimit in the CurrentDemandReq message.

NOTE: This requirement to transmit EVSEMaximumCurrentLimit and EVMaximumCurrentLimit upon change is consistent with ISO 15118-2 edition 2 draft requirements. SAE J3400 DC *EVSE* and *EVs* are required to detect and respond to "DC Thermal Warning" on *proximity* per 8.1.3.2, which will result in a change to maximum current limits.

8.2.4 Digital Communication with PWM/PLC-CP with DIN 70121, ISO 15118-2, and ISO 15118-20 for EVSE and EVs

ISO 15118-20:2022 is the second-generation *vehicle-to-grid* communication protocol for electric road vehicles and electric industrial trucks. In addition to DC and AC charging services, ISO 15118-20 adds new services that include AC/DC bidirectional power transfer (BPT) and wireless power transfer (WPT). It contains requirements for *electric vehicles* to act as distributed energy resources capable of providing power back to the grid and the optimization of energy production systems.

ISO 15118-20 is not inherently compatible with the first edition of ISO 15118-2 due to enhanced cybersecurity measures (TLS v1.3 mandatory), new messages, new message header payload types, changes to the state machine (message sequence), and introduction of a new absolute pricing model. Interoperability is possible only if *EV* and *EVSE* communication controllers support both first- and second-generation protocols.

8.2.4.1 The SECC Discovery Protocol (SDP) message exchange and processing shall remain unchanged if an EVCC and SECC supports both ISO 15118-2 and ISO 15118-20 high-level communication (HLC) protocols.

8.2.4.2 The EVCC and SECC shall support both TLS v1.2 and TLS v1.3 if both ISO 15118-2 and ISO 15118-20 are implemented and PnC and certificate management features are implemented.

8.2.4.3 The mechanism(s) for determining TLS support level shall be initiated by the EVCC using the "supported_versions" extension and "legacy_version" fields in the "Client Hello" message as described in 7.7.3.3 of ISO 15118-20.

8.2.4.4 An EVCC supporting TLS v1.2 shall include version 0x0303 in the "supported_versions" extension, allowing the SECC to establish a TLS v1.2 session.

8.2.4.5 An EVCC supporting TLS v1.3 shall include version 0x0304 in the "supported_versions" extension, allowing the SECC to establish a TLS v1.3 session.

8.2.4.6 The supported level of TLS shall determine what communication protocols can be used by the EVCC and SECC according to Table 5 in ISO 15118-20.

8.2.4.7 If an application requires use of TLS to implement optional functionality, an EVCC and SECC supporting both ISO 15118-2 and 15118-20 protocols shall follow compatibility requirements as specified in 7.7.3.10 of ISO 15118-20.

8.2.5 ISO 15118 Interoperability

Two SAE J3400 system classifications will apply for EVCC and SECC controllers based on their support protocols for DC power transfer. Implementing a class does not restrict use of newer or alternative protocols; for example, Interoperability Class P2 vehicle may support ISO 15118-20 and/or SAE J2847/2.

SAE J3400 communications interoperability class definitions:

- **Interoperability Class P1**

  Required: Digital communication with *PWM/PLC-CP* using DIN 70121 for *EVSE* and *EVs*

  Class P1 systems are primarily applicable to use cases such as fleet operation or home systems and a specific vehicle or vehicle family. Use of TLS and a public key infrastructure (PKI) by Class P1 systems is not required unless PnC and certificate management features are implemented.

  Class P1 systems are normally interoperable with Class P2 systems for DC charging with a reduced function set.

- **Interoperability Class P2**

  Required: Digital communication with *PWM/PLC-CP* using DIN 70121 and ISO 15118-2 for *EVSE* and *EVs*

  Class P2 systems are intended to deliver full performance in both public and private charging use cases. For these systems, use of public key infrastructure (PKI; see 6.5.3) to enable secure *EV-EVSE* communication is required and must follow cybersecurity requirements per the protocol standard.

  Class P2 systems are therefore able to support PnC using PKI.

9. V2X

V2X requires Bidirectional Power Transfer (BPT) functionality which allows for energy to flow into and out of the battery during the same session. This includes the ability of an *electric vehicle* to transfer power to the home (*V2H*), a multi-facility "microgrid," or the *area EPS* (public power grids - *V2G*). Applications include providing back-up power in the event of a service outage and participation in revenue-generating energy services such as demand-response, frequency regulation, distribution services offered by the utility, ISO/RTO, or energy service provider. Another form of BPT is *Vehicle-to-Load* (*V2L*), which is a feature that allows the *EV* equipped with an *on-board* inverter to provide AC power to external devices like power tools or other consumer devices.

9.1 General Requirements for Reverse Power Flow

See Section 7 for general requirements for *EVs* and *EVSE* which support AC power transfer.

See Section 8 for general requirements for *EVs* and *EVSE* which support DC power transfer.

ISO 5474 series has requirements for reverse power flow. See 6.4.2.1.

See 9.2.2.1 for any requirement for any *V2L*-capable *EV* which is *proximity*-triggered.

See note under 9.4.2.1 regarding AC BPT under ISO 15118-20:2022.

9.1.1 General Requirements for Reverse Power Flow

9.1.1.1 *EV* BPT-capable OBC shall limit the available fault current to 5000 A (symmetrical RMS).

Many existing AC *inlet accessories* between NACS and SAE J1772 swap L1 and L2/N; therefore, polarization cannot be guaranteed.

9.1.1.2 *EVs* shall not bond the *inlet neutral* (N/L2) *contact* to the *grounding conductor*.

BPT *EV,* if disconnected from the *EPS* shall ensure the L1 and L2/N *conductors* in the *inlet* are insulated from the chassis *ground* by at least 500 Ω/V (i.e., when the *EVSE's contactor* is open, no unsafe leakage/residual current can flow).

9.1.2 General Requirements for Reverse Power Flow into an Area EPS – V2G

Interconnection to *area EPS* requires distributed energy systems to follow rules that specify criteria, procedures and technical requirements which vary from one utility service area, or state, to another. In the U.S., many jurisdictions use the IEEE Standard 1547-2018 (or different version) as a basis for interconnection and interoperability of distributed energy resources.

9.1.2.1 Systems interconnecting with *Area EPS* shall meet applicable regional utility grid interconnection regulations and standards including IEEE 1547 (or equivalent in non-U.S. jurisdictions).

9.1.2.2 *EVs* equipped with an OBC providing BPT to the *area EPS* (*V2G*) shall comply with SAE J3072.

9.2 Analog Signaling for Local EPS Forming

The devices described in this section are not intended to be used in-conjunction with additional *inlet accessories* and should be labeled to guide users for proper use. The *area EPS* is isolated from the *local EPS*.

9.2.1 Local EPS Forming Using PWM-CP Frequency Variation (Optional; see 4.1.1)

Under this mode, the *EV forms* the *local EPS* by maintaining a nominal AC voltage and frequency via the *inlet* using *PWM-CP* frequency variation signaled by the *EVSE*.

9.2.1.1 *EVs* and *EVSE* providing *local EPS* forming using *PWM-CP* frequency variation shall follow the requirements in SAE J2847/5.

NOTE: Please refer directly to SAE J2847/5 for details on implementation, as the following is only a summary of the AC *PWM-CP* frequency variations from the *EVSE* and what output voltages are expected from the *EV* bidirectional OBC limited by the duty cycle.

- *EVSE* sets 125 Hz *CP* frequency, *EV* outputs 120 VAC with current set by *PWM* duty cycle.
- *EVSE* sets 166 Hz *CP* frequency, *EV* outputs 240 VAC with current set by *PWM* duty cycle.

9.2.2 EV Local EPS Forming (V2L) by the Using Prox Voltage Variation (Optional; see 4.1.1)

Under this mode, the *EV forms* the *local EPS* (*V2L*) by maintaining a nominal AC voltage and frequency via the *inlet*.

There are existing AC *V2L* systems using the SAE J1772 that use special *proximity* voltages that overlap with existing DC thermal warning and DC thermal shutdown implementations. Some are proprietary and others are based on recommended practices like SAE J2847/5.

Specific implementation recommendations for AC *V2L* via *prox* for *EV* with SAE J3400 *inlets* are under consideration; however, the following requirement must be met for any implementation (including proprietary ones):

9.2.2.1 *EV V2L* which is *proximity*-triggered shall be inhibited unless the *control pilot* continuously meets one of these conditions:

- *Control pilot* is grounded for the entire *connection session*, or
- *Control pilot* is an open circuit (*EV* detects equivalent to unplugged *CP*) for the entire *connection session*, or
- *Control pilot* is measured within the range -1.2 to 1.2 VDC or VRMS for the entire *connection session*; and, the inhibitive response time, for termination of AC *V2L*, shall be within 100 ms.

9.3 V2X with LIN-CP

9.3.1 V2X with LIN-CP - AC Power Transfer (Optional; see 4.1.1)

9.3.1.1 *EVs* and *EVSE* that support *V2H* or *V2L using LIN-CP* shall follow the applicable requirements in SAE J3068/2.

9.3.1.2 *EVs* and *EVSE* that support *V2G* using *LIN-CP* shall follow the applicable requirements in SAE J3068/2 and SAE J3072 (System Type D3 or D* for *socket-outlets*).

9.4 V2X with PWM/PLC-CP

9.4.1 V2X with PWM/PLC-CP - AC Power Transfer: Using IEEE 2030.5 (Optional; see 4.1.1)

9.4.1.1 *EVs* and *EVSE* that support SAE J2847/3 for *V2X* and SAE J3072 (System Type C3 or C* for *socket-outlets*) for *V2G* using IEEE 2030.5 for AC shall follow the applicable requirements in those documents.

9.4.2 V2G with PWM/PLC-CP - AC Power Transfer: Using ISO 15118-20 (Optional; see 4.1.1)

9.4.2.1 *EVs* and *EVSE* that support SAE J3072 (System Type E3 or E* for *socket-outlets*) using ISO 15118-20 for AC *V2G*/*V2X* shall follow the applicable requirements in both of those documents.

NOTE: ISO 15118-20:2022 is being amended to meet applicable regional utility grid interconnection regulations which require the transfer of settings and controls. SAE J3072 has a placeholder (System Type E*) for ISO 15118 series systems once amended.

9.4.3 V2X with PWM/PLC-CP - DC Power Transfer: Using SAE J2847/2 (Optional; see 4.1.1)

9.4.3.1 *EVs* and *EVSE* that support SAE J2847/2 for DC *V2G*/*V2X* shall follow the applicable requirements in that document.

9.4.4 V2X with PWM/PLC-CP - DC Power Transfer: Using ISO 15118-20 (Optional; see 4.1.1)

9.4.4.1 *EVs* and *EVSE* that support ISO 15118-20 for DC *V2G*/*V2X* shall follow the applicable requirements in that document.

10. COUPLER MECHANICAL DRAWINGS

10.1 Inlet

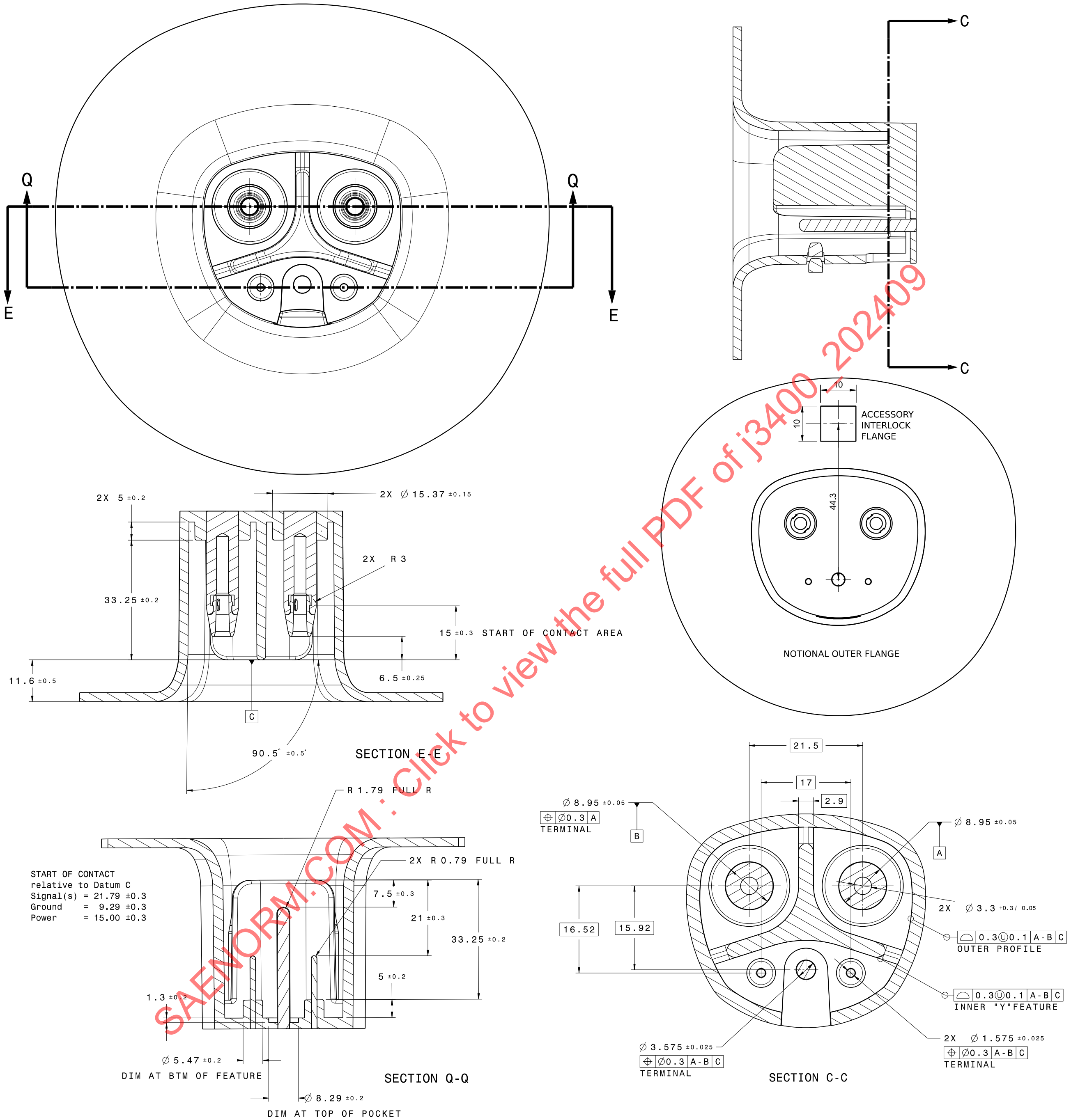


Figure 8 - SAE J3400 inlet mechanical drawing

NOTE: For information about the *accessory* interlock flange, see 6.5.2.

10.2 Connector

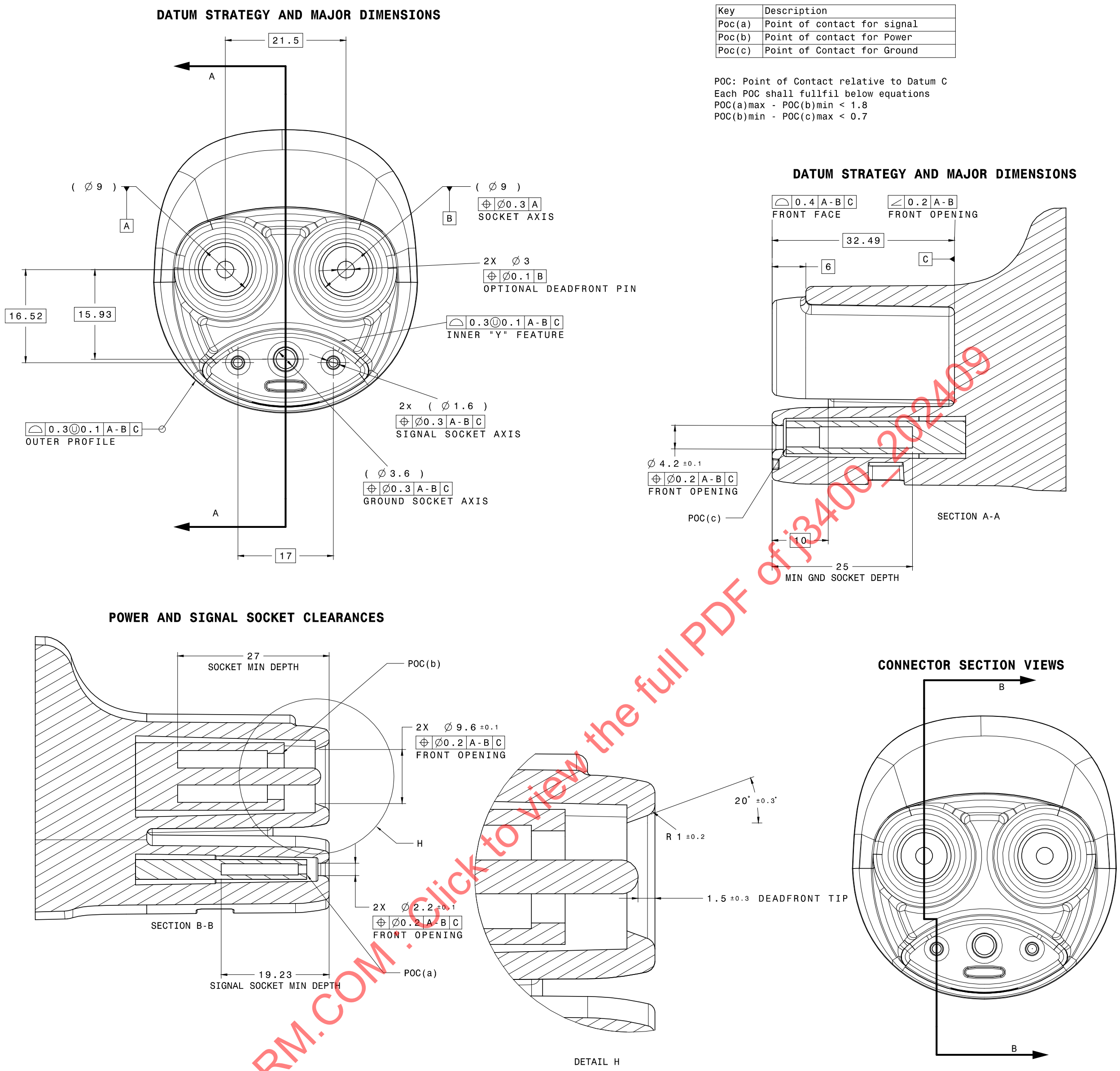


Figure 9 - SAE J3400 connector mechanical drawing

10.3 Latch

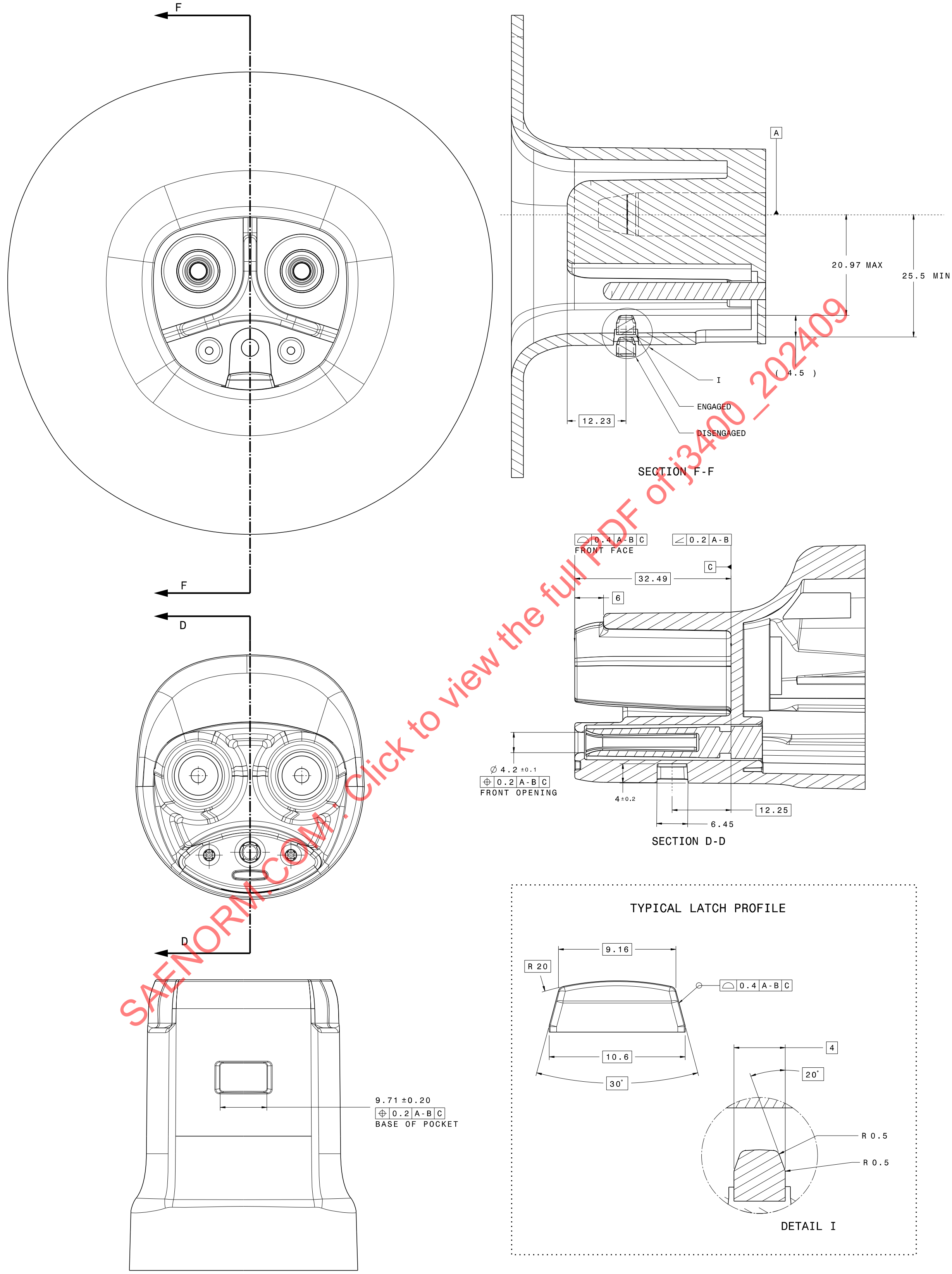


Figure 10 - SAE J3400 latch mechanical drawing

10.4 EV Inlet Zones

A zone is an empty area which the *EV* makes available for certain use cases as defined below.

There are two basic zones:

- Ordinary *connectors* keep-in zone: An area which entirely contains ordinary *connector* assemblies.
- Ordinary *inlet* access zone: An area for ergonomic *inlet* access space including access to *connector* controls and gripping space.

The *connectors* keep-in zone is entirely within the *inlet* access zone. The space between the two areas creates hand-access space.

All models contain polygonal shapes attached to the mating part of a nominal SAE J3400 *connector* (for alignment to the *inlet*), which together form the entire shape of the zone.

The SAE J3400 connector on the model provides an alignment reference for the inlet (and vehicle body) and should be positioned entirely overlapping with the connector as shown in the SAE J3400 mated coupler model listed in Table 1.

10.4.1 Requirements for Connector Assemblies

10.4.1.1 SAE J3400 *connectors* shall remain within the ordinary *connectors* keep-in zone envelope.

Following the guidance from SAE/USCAR-25 will ensure that the grasping area of the connector and the vehicle body geometry provide adequate ergonomic and safety considerations for the user's hand.

10.4.1.2 SAE J3400 *connectors* shall be designed to accommodate a 95th percentile gloved hand for the intended grasping area, as described by SAE/USCAR-25 and actuator-access areas within the ordinary *inlet* access zone described by the model listed in Table 1.

NOTE: The 95th percentile gloved hand necessitates a 32 mm hand-clearance according to SAE/USCAR-25.

10.4.2 Requirements for EV Inlet Assemblies

For *EVs*, the ordinary *inlet* access zone described by the model listed in Table 1 forms a guideline for a common understanding of the bounds of access space needed to maximize ergonomics for hand-coupled *connectors* but not a requirement. Instead, the ordinary *connectors* keep-in zone ensures *coupler* mating success for the ordinary use case.

10.4.2.1 When ready to mate (*inlet* flaps, doors, and covers open), an SAE J3400 *EV* shall provide an area free of vehicle body geometry, described by the ordinary *connectors* keep-in zone model listed in Table 1.

NOTE: These zones are intended for four- or more wheeled *EVs*; any tailoring for motorcycles and other two- and three-wheel vehicles, and/or off-road vehicles or watercraft is under consideration.

10.4.3 Automated Connection Devices (ACD-S) Zone

The ACD-S zone is for SAE J3400 vehicles designed to be serviced for automated connection devices to an *EV inlet* on the sides (or front/back) of the vehicle. This is in contrast with an underbody connection (ACD-U) and a pantograph connection (ACD-P).

10.4.3.1 SAE J3400 *EV* which support ACD shall provide an *inlet* access zone free of vehicle body geometry, described by the ACD-S keep-out model listed in Table 1.

10.5 DC Reference Device

With the introduction of the so-called "high power charging," the risk of a thermal incident increases. The DC *contacts* are the most vulnerable point, as the *contact* resistance can increase over lifetime due to mating cycles or environmental influences. The DC *contact* temperature must therefore be monitored. Experience with *cable assemblies* in accordance with historical versions of IEC 62196-1 have shown that detailed requirements and tests are necessary to detect the temperature at the DC *contacts*.

To mitigate the risks, the *cable assembly* is tested to show that it does not violate temperature limits at rated current. Additionally, temperature monitoring is required during energy transfer.

10.5.1 Reference Device Characteristics

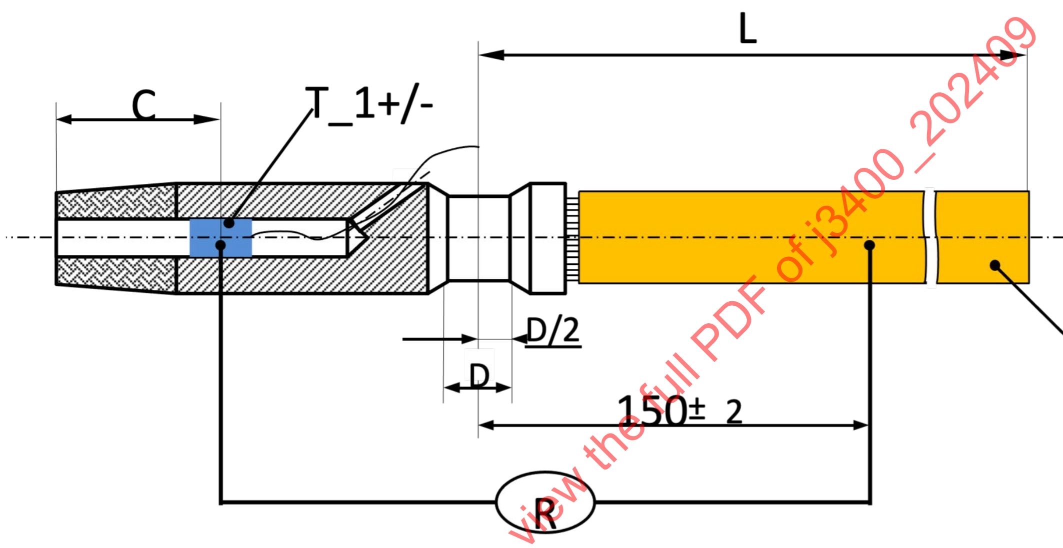
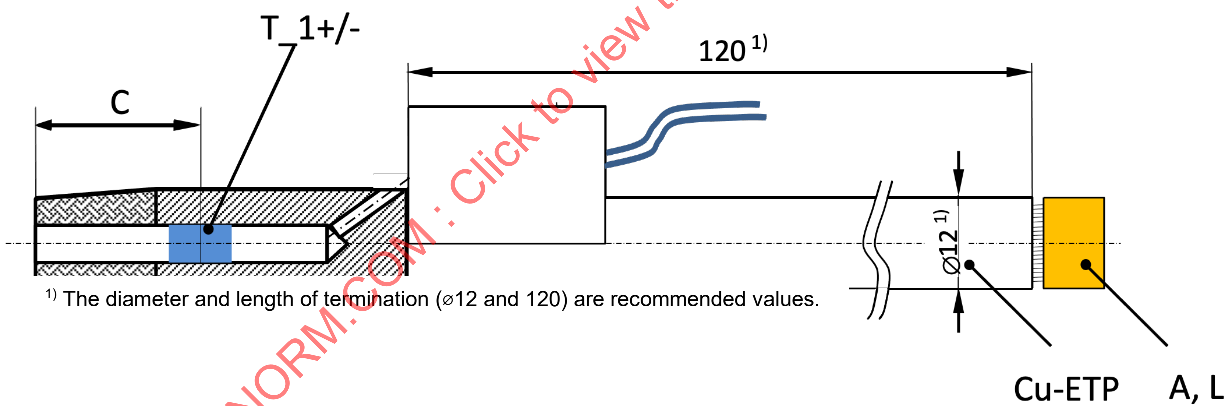


Figure 11 - Reference device contact dimensions

Table 4 - Contact resistances and dimensions of reference device

Rated current continuous [e] A	**A** mm² [d]	***L*** m	***C*** mm	D mm	**R** [a] [b] [c] µΩ
200	50	min 1	18	TBD by manufacturer	123 to 128
300	70				91 to 96
400	95				65 to 70
500	120				57 to 62
600	Bus Bar A	Under development			
700	Bus Bar B				
800+	Bus Bar C				

[a] Resistance values at 90 °C ± 2 °C.
[b] Recommended cables acc. ISO 19642-5 (thin-wall).
[c] The resistance R simulates a worst-case vehicle *inlet*.
[d] For ratings between values in this table, the next smaller conductor cross section or bus bar shall be used.
[e] Boost mode test definitions and test methods are under development.



[1] The diameter and length of termination (⌀12 and 120) are recommended values.

Figure 12 - Reference device with contact dimensions, with heater

Table 5 - Contact dimensions of reference device, with heater

Rated current continuous (b) (d) A	**A** mm² (c)	***L*** m	***C*** mm
200	50 (a)	min 1	18
300	70 (a)		
400	95 (a)		
500	120		
600	Bus Bar A	Under development	
700	Bus Bar B		
800+	Bus Bar C		

(a) Recommended cables acc. ISO 19642-5 (thin-wall).
(b) Resistance values are identical to those of Table 4.
(c) For ratings between values in this table, the next smaller conductor cross section or bus bar shall be used.
(d) Boost mode test definitions and test methods are under development.

10.5.2 Temperature Rise Test for Cable Assembly

The purpose of this test is to demonstrate a *cable assembly* is constructed such that the temperature rise during normal use is not excessive.

10.5.2.1 The procedures and conditions for the test shall be as follows:

- If the *cable assembly* is equipped with thermal transport, then the thermal exchange parameters are used as specified by the manufacturer in the installation manual for an ambient temperature of 40 °C.

- The test current is the rated current according to the DUT manufacturer's data sheet.

- For a *cable assembly* with thermal sensing only, the test is performed at an ambient temperature of 20 to 40 °C and the obtained results are corrected to an ambient temperature of 40 °C.

- For a *cable assembly* with thermal transport, the test is performed at an ambient temperature of 40 °C ± 5 °C. The results are corrected to an ambient temperature of 40 °C.

- The tests are conducted in a draft-free environment without forced convection. The cable must be placed on a mesh/grated surface or raised 200 mm off the table/floor such that natural convection can occur.

- The *cable assembly* is mated to the reference device.

- The rated current is applied to the *cable assembly* at the DC+ and DC− *contacts*. When thermal stabilization is reached, the applied current shall be reduced to 0 A after 10 minutes. The temperatures at the DC *contacts* measured by the temperature sensors (T_1+ and T_1−) and the provided values from the thermal sensing devices of the *cable assembly* (T_S+ and T_S−) are recorded with one or more sample per second throughout the test. The values provided by the thermal sensing devices of the *cable assembly* are converted into temperature values according to the manufacturer's data sheet.

- Examples of test results are shown in Figures 16 and 17.

10.5.2.2 The following criteria shall be met for the test to pass:

- The temperature value measured by the temperature sensors (T_1+ and T_1−) has not exceeded 100 °C; and

- The surface temperature of the *cable assembly* does not exceed the limits according to *Tri-National Coupler Standard*; and

- The measured values of the thermal sensing devices (T_S+ and T_S−) have not exceeded the intervention value provided by the manufacturer.

10.5.3 Test for Thermal Sensing Device of Cable Assembly

Cable assemblies are constructed so that the thermal sensing device in normal use is reliable. This section describes the test for compliance.

NOTE: These requirements do not specific how thermal sensing devices are designed nor where they are located. These thermal sensing devices are not designed to directly modulate the charging current.

10.5.3.1 The procedures and conditions for the test shall be as follows:

- The reference device is compliant with 10.5.1.

- The test setup is compliant with 10.5.4. An example of the test setup is shown in 10.5.6.

- The DUT is a *cable assembly* with the cable attached to the vehicle *connector* having the shortest length as specified by the manufacturer.

- If the *cable assembly* is equipped with thermal transport, then the thermal exchange parameters are used as specified by the manufacturer in the installation manual for an ambient temperature of 40 °C.

- The test current is the rated current according to the DUT manufacturer's data sheet.

- The test is performed at an ambient temperature of 40 °C ± 5 °C. The results are corrected to an ambient temperature of 40 °C.

- The test is conducted in a draft-free environment without forced convection. The cable must be placed on a mesh/grated surface or raised 200 mm off the table/floor such that natural convection can occur.

- The temperatures at the DC *contacts* as measured by the temperature sensors (T_1+ and T_1−) and the provided values from the thermal sensing devices of the *cable assembly* (T_S+ and T_S−) are recorded with one or more sample per second throughout the test. The values provided by the thermal sensing devices of the *cable assembly* are converted into temperature values according to the manufacturer's data sheet.

- Once thermal stabilization has been reached, the over-temperature of the vehicle *connector* is stimulated by applying heat power ensuring a constant temperature rise of 2.5 K/min ± 0.5 K/min measured by the temperature sensors T_1+ and T_1−.

- The heating and current supplies are discontinued once one of the temperature sensors T_1+ or T_1− reaches 105 °C (or 5 K above the manufacturer specified maximum contact temperature). The gradient is calculated by taking the times when the heating starts (t1) and stops (t2). For example, the gradient of T_S+ = (T_S+(t2) − T_S+(t1)) / (t2 − t1).

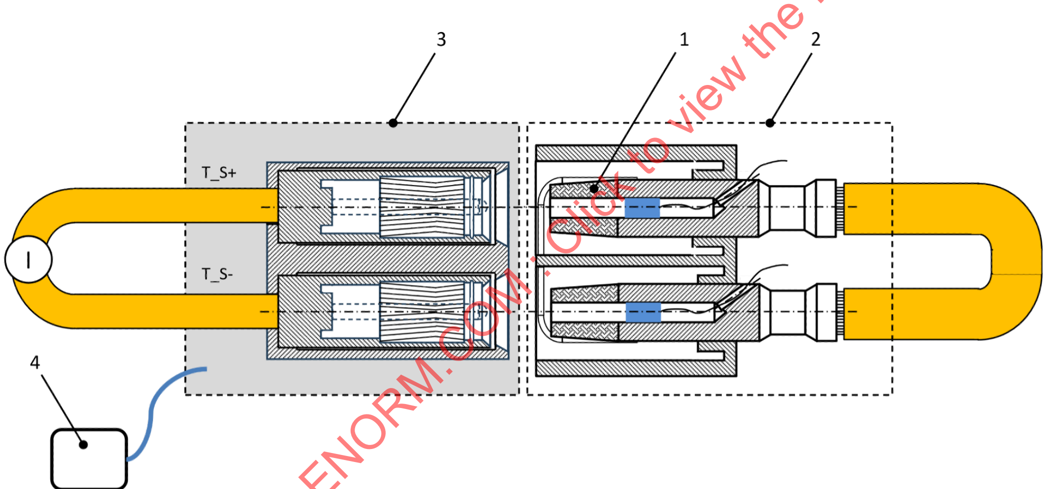
10.5.3.2 The temperature sensing devices shall fulfill the pass criteria if:

- The temperature gradient measured by the thermal sensing devices T_S+ and T_S− deviates by less than 1.5 K/min of the temperature gradient measured by the corresponding temperature sensors T_1+ or T_1-; and

- The mathematical absolute value of the equation:
  | (gradient of T_S+ / gradient of T_1+) – (gradient of T_S− / gradient of T_1−) | ≤0.2; and

- The temperature value of temperature sensors T_1+ and T_1− is equal to or less than 100 °C (or a lower manufacturer specified maximum *contact* temperature) at the time when either thermal sensing device T_S+ or T_S− reaches the intervention value provided by the manufacturer.

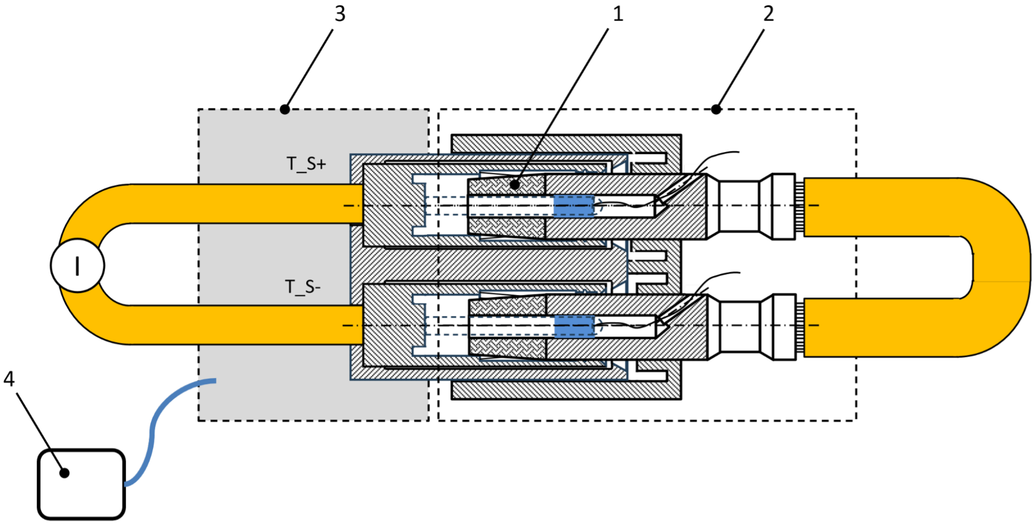
10.5.4 Thermal Sensing Device Test Setup



Key

T_S+ Thermal sensing device inside vehicle connector at DC+
T_S− Thermal sensing device inside vehicle connector at DC−
1 Reference device
2 Housing and support for reference device
3 Device under test (w/o central pin)
4 Thermal exchange device – if any

Figure 13 - Unmated test setup

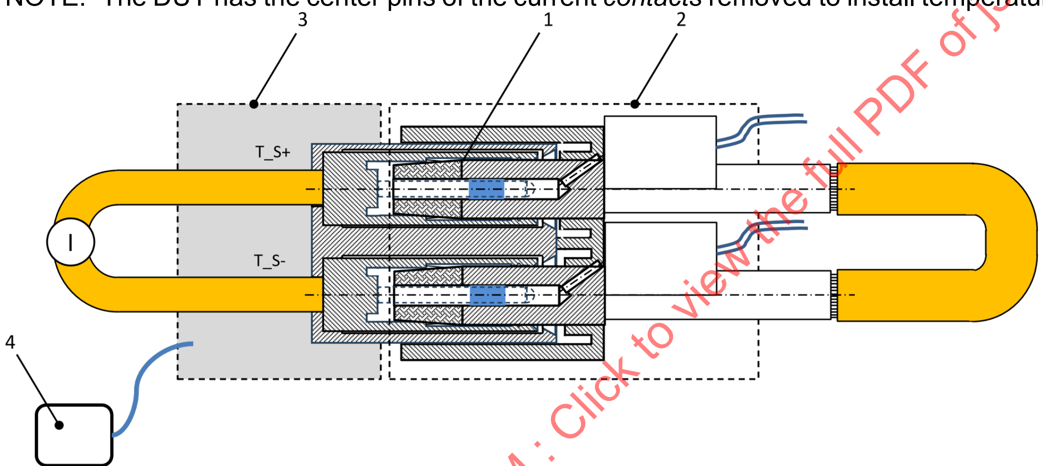


Key

T_S+	Thermal sensing device inside vehicle connector at DC+
T_S−	Thermal sensing device inside vehicle connector at DC−
1	Reference device
2	Housing and support for reference device
3	Device under test (w/o central pin)
4	Thermal exchange device – if any

Figure 14 - Mated test setup

NOTE: The DUT has the center pins of the current *contacts* removed to install temperature sensors in the reference device.



Key

T_S+	Thermal sensing device inside vehicle connector at DC+
T_S−	Thermal sensing device inside vehicle connector at DC−
1	Reference device
2	Housing and support for reference device
3	Device under test (w/o central pin)
4	Thermal exchange device – if any

Figure 15 - Test setup with heater

10.5.5 Example of Test Results

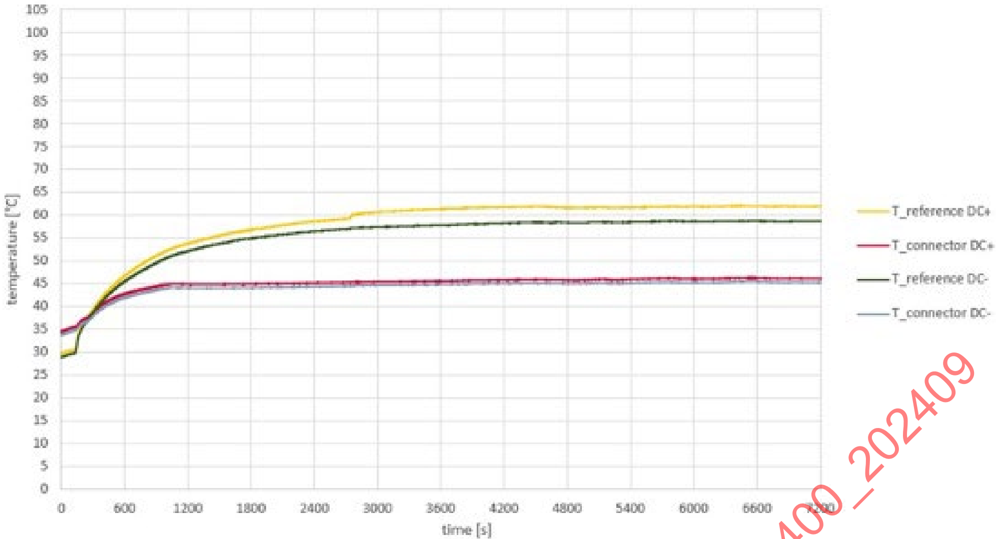


Figure 16 - Example result for temperature rise test. Test is passed.

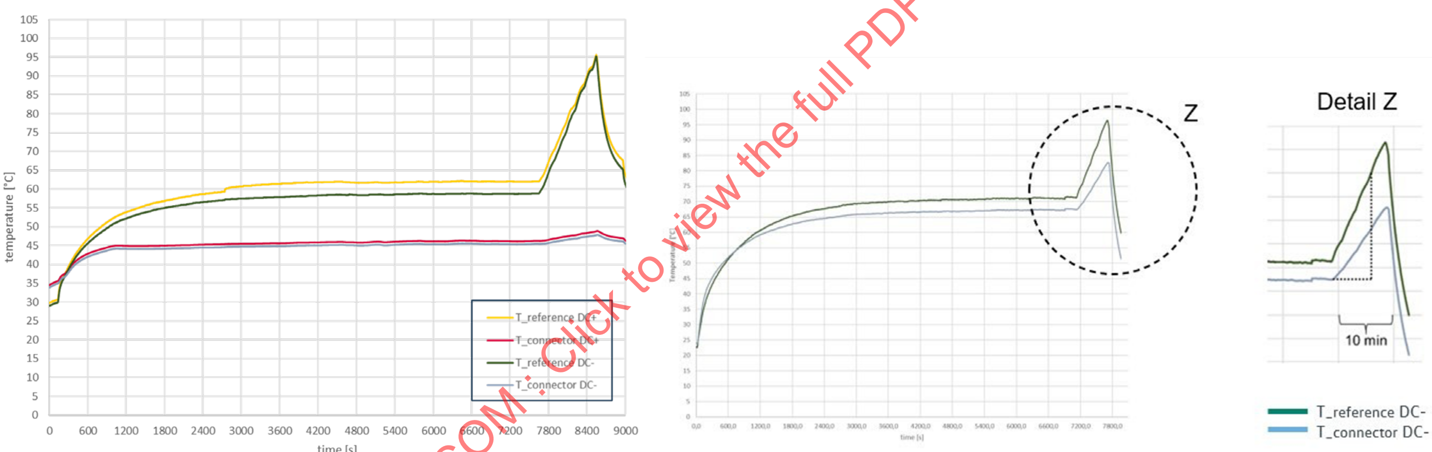


Figure 17 - Two example results for temperature sensor test. Left is pass. Right is fail.