



SURFACE VEHICLE STANDARD

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

RATIONALE

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

FOREWORD

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

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

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https://www.sae.org/standards/content/J1772_202401

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1. SCOPE

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

2. REFERENCES

2.1 Applicable Documents

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

2.1.1 SAE Publications

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

- SAE J1113-21 Electromagnetic Compatibility Measurement Procedure for Vehicle Components - Part 21: Immunity to Electromagnetic Fields, 30 MHz to 18 GHz, Absorber-Lined Chamber
- SAE J1211 Handbook for Robustness Validation of Automotive Electrical/Electronic Modules
- SAE J1812 Function Performance Status Classification for EMC Immunity Testing
- SAE J2344 Guidelines for Electric Vehicle Safety
- SAE J2847/1 Communication for Smart Charging of Plug-in Electric Vehicles Using Smart Energy Profile 2.0
- SAE J2847/2 Communications Between Plug-In Vehicles and Off-Board DC Chargers
- SAE J2931/1 Digital Communications for Plug-in Electric Vehicles
- SAE J2931/4 Broadband PLC Communication for Plug-in Electric Vehicles
- SAE J2953/1 Plug-In Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE)
- SAE J2953/2 Test Procedures for the Plug-In Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE)
- SAE USCAR 2 Performance Specification for Automotive Electrical Connector Systems
- SAE USCAR 25 Ergonomics Specification for Electrical Connections

2.1.2 Canadian Standards Association (CSA Group) Publications

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

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

2.1.3 Code of Federal Regulations (CFR) Publications

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

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

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

2.1.4 IEC Publications

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

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

CISPR 16-1-2	Ancillary equipment - Conducted disturbances
IEC 60479-1	Effects of current on human beings and livestock - Part 1: General aspects
IEC 60479-2	Effects of current on human beings and livestock - Part 2: Special aspects
IEC 60529	Degrees of protection provided by enclosures (IP Code)
IEC 60664-1	Insulation coordination for equipment within low-voltage systems - Part 1: Principles, requirements and tests
IEC 61000-4-3	Electromagnetic compatibility (EMC) - Part 4-3: Testing and measurement techniques - Radiated, radio-frequency, electromagnetic field immunity test
IEC 61000-4-6	Electromagnetic compatibility (EMC) - Part 4-6: Testing and measurement techniques - Immunity to conducted disturbances, induced by radiofrequency fields
IEC 61032	Protection of persons and equipment by enclosures - Probes for verification
IEC 61140	Protection against electric shock - Common aspects for installation and equipment
IEC 61300-2-6	Fibre optic interconnecting devices and passive components - Basic test and measurement procedures - Part 2-6: Tests - Tensile strength of coupling mechanism
IEC 61300-2-7	Fibre optic interconnecting devices and passive components - Basic test and measurement procedures - Part 2-7: Tests - Bending moment
IEC 61558-2-6	Safety of transformers, reactors, power supply units and combinations thereof - Part 2-6: Particular requirements and tests for safety isolating transformers and power supply units incorporating safety isolating transformers for general applications
IEC 61851-21-1	Electric vehicle conductive charging system - Part 21-1 Electric vehicle on-board charger EMC requirements for conductive connection to AC/DC supply
IEC 61851-21-2	Electric vehicle conductive charging system - Part 21-2: Electric vehicle requirements for conductive connection to an AC/DC supply - EMC requirements for off board electric vehicle charging systems
IEC 61851-23	Electric vehicle conductive charging system Part 23: DC electric vehicle supply equipment
IEC 62196-2	Plugs, socket-outlets, vehicles connectors and vehicle inlets - Part 2: Dimensional compatibility and interchangeability requirements for a.c. pin and contact-tube accessories

- IEC 62196-3-1 Plugs, socket-outlets, vehicles connectors and vehicle inlets - Part 3: Dimensional compatibility and interchangeability requirements for d.c. and a.c./d.c. pin and contact-tube vehicle couplers
- IEC 62196-3-1 Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles - Part 3-1: Vehicle connector, vehicle inlet and cable assembly for DC charging intended to be used with a thermal management system
- IEC 62477-1 Safety requirements for power electronic converter systems and equipment - Part 1: General

2.1.5 ISO Publications

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

- ISO 6469-3 Electrically propelled road vehicles - Safety specifications - Part 3: Electrical safety
- ISO 17409 Electrically propelled road vehicles - Conductive power transfer - Safety requirements
- ISO 20653 Road vehicles - Degrees of protection (IP code) - Protection of electrical equipment against foreign objects, water and access
- ISO 15118-1 Road vehicles - Vehicle-to-Grid Communication Interface - Part 1: General information and use-case definition
- ISO 15118-2 Road vehicles - Vehicle-to-Grid Communication Interface - Part 2: Network and application protocol requirements
- ISO 15118-3 Road vehicles - Vehicle-to-Grid Communication Interface - Part 3: Physical and data link layer requirements

2.1.6 National Fire Protection Agency Publications

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

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| National Electric Code (NEC), NFPA 70 Article 625 (2023 edition) | Electric Vehicle Power Transfer System |
| National Electric Code (NEC), NFPA 70 Article 750 (2023 edition) | Energy Management Systems |

2.1.7 UL Publications

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

- UL 50 Standard for Enclosures for Electrical Equipment
- UL 1439 Determination of Sharpness of Edges on Equipment
- UL 2202 Standard for Electric Vehicle (EV) Charging System Equipment
- UL 2231-1 Personnel Protection Systems for Electric Vehicle Supply Circuits: General Requirements
- UL 2231-2 Personnel Protection Systems for Electric Vehicle Supply Circuits: Particular Requirements for Protection Devices for Use in Charging Systems
- UL 2251 Plugs, Receptacles, and Couplers for Electric Vehicles
- UL 2594 Electric Vehicle Supply Equipment

2.1.8 United Nations Economic Commission for Europe (UNECE)

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

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

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

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

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

2.1.10 National Electrical Manufacturers Association (NEMA)

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

ANSI/NEMA WD 6-2021 Wiring Devices

2.2 Related Publications

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

2.2.1 SAE Publications

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

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

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

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

SAE J1773 SAE Electric Vehicle Inductively Coupled Charging

SAE J1812 Function Performance Status Classification for EMC Immunity Testing

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

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

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

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

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

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

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

SAE J2836/4	Use Cases for Diagnostic Communication for Plug-in Electric Vehicles
SAE J2836/5	Use Cases for Customer Communication for Plug-in Electric Vehicles
SAE J2836/6	Use Cases for Wireless Charging Communication for Plug-in Electric Vehicles
SAE J2847/3	Communication for Plug-in Vehicles as a Distributed Energy Resource
SAE J2847/6	Communication for Wireless Power Transfer Between Light-Duty Plug-in Electric Vehicles and Wireless EV Charging Stations
SAE J2894/1	Power Quality Requirements for Plug-In Electric Vehicle Chargers
SAE J2894/2	Power Quality Test Procedures for Plug-In Electric Vehicle Chargers
SAE J2931/6	Signaling Communication for Wirelessly Charged Electric Vehicles
SAE J2931/7	Security for Plug-in Electric Vehicle Communications
SAE J3072	Interconnection Requirements for Onboard, Grid Support Inverter Systems

2.2.2 IEC Publications

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

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

IEC 61851-1	Electric vehicle conductive charging system Part 1: General requirements
IEC 61851-24	Electric vehicle conductive charging system Part 24: Digital communication between a d.c. EV charging station and an electric vehicle for control of d.c. charging
IEC 62196-1	Plugs, socket-outlets, vehicles connectors and vehicle inlets - conductive charging of electric vehicles

2.2.3 UL Publications

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

UL 94	Tests for Flammability of Plastic Materials for Parts in Devices and Appliances
UL 231	Power Outlets
UL 746A	Standard for Polymeric Materials - Short Term Property Evaluations
UL 840	Insulation Coordination Including Clearance and Creepage Distances for Electrical Equipment

3. DEFINITIONS

3.1 AC LEVEL 1 CHARGING

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

3.2 AC LEVEL 2 CHARGING

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

3.3 CHARGER

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

3.4 CHASSIS GROUND

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

3.5 COMBINED CHARGING SYSTEM

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

3.6 CONDUCTIVE

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

3.7 CONNECTOR (CHARGE)

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

3.8 CONTACT (CHARGE)

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

3.9 CONTROL PILOT

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

- a. Verifies that the vehicle is present and connected
- b. Permits energization/de-energization of the supply

- c. Transmits supply equipment current rating to the vehicle
- d. Monitors the presence of the equipment ground
- e. Establishes vehicle ventilation requirements

3.10 COUPLER (CHARGE)

A mating vehicle inlet and connector set.

3.11 DC LEVEL 1 CHARGING

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

3.12 DC LEVEL 2 CHARGING

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

3.13 ELECTRIC VEHICLE (EV)

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

- a. Any four-wheeled vehicle propelled by a combustion engine using on-board fuel or by an electric motor drawing current from a rechargeable storage battery or other portable energy devices (rechargeable using energy from a source off the vehicle such as residential electric service).
- b. Which is manufactured primarily for use on public streets, roads, and highways.
- c. Which is rated not more than 3855.6 kg (8500 pounds), which has a curb weight of not more than 2721.6 kg (6000 pounds), and which has a basic frontal area of not more than 4.18 m² (45 ft²).

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

3.14 ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE)

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

3.15 EQUIPMENT GROUND (GROUNDING CONDUCTOR)

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

3.16 EV/PHEV CHARGING SYSTEM

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

3.17 INSULATOR

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

3.18 INVALID CONTROL PILOT

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

3.19 OFF-BOARD CHARGER

A charger located off of the vehicle.

3.20 ON-BOARD CHARGER

A charger located on the vehicle.

3.21 PLUG IN HYBRID ELECTRIC VEHICLE (PHEV)

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

3.22 PRE-CHARGE

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

3.23 VEHICLE INLET (CHARGE)

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

4. GENERAL CONDUCTIVE CHARGING

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

This document is organized into three major sections:

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

4.1 Electrical Ratings

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

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

4.2 Charging Control and Information

4.2.1 Control Pilot

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

4.2.1.1 Control Pilot Circuit

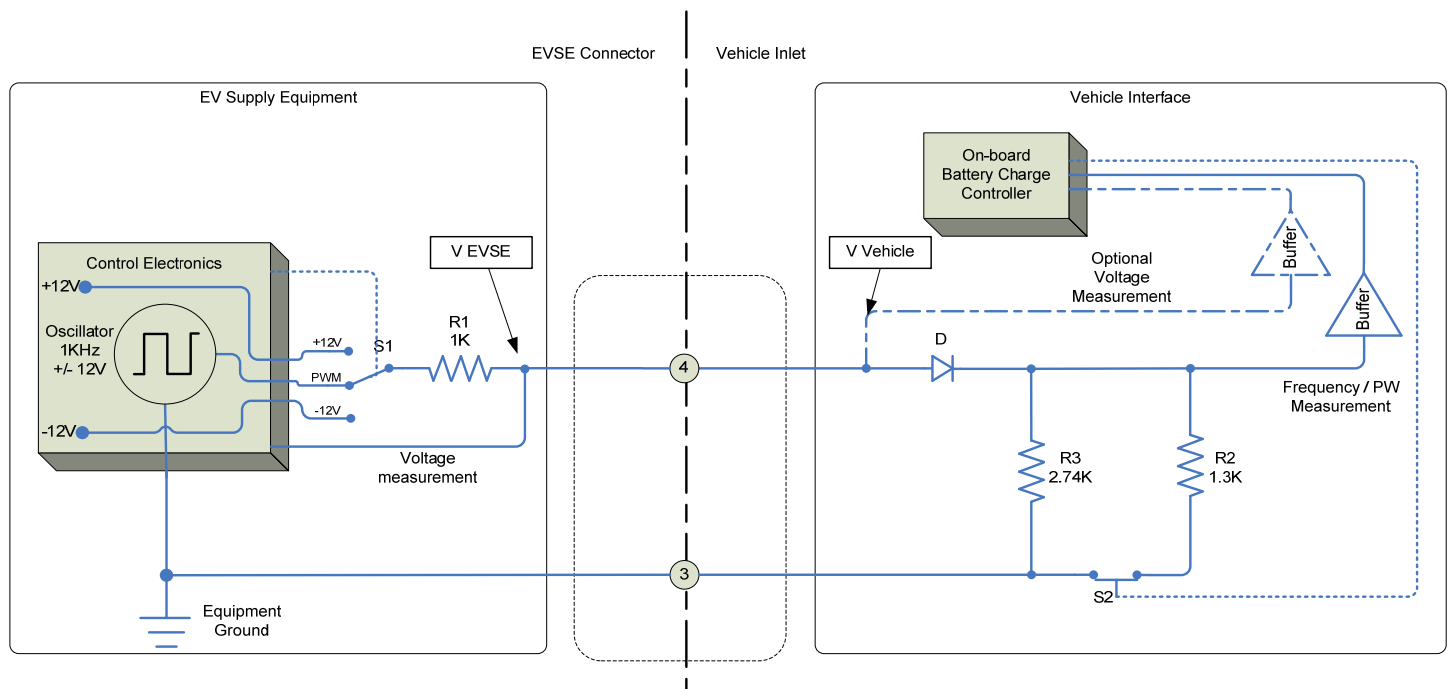


Figure 1 - Control pilot circuit

4.2.1.2 Control Pilot Circuit Parameters and Vehicle States

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

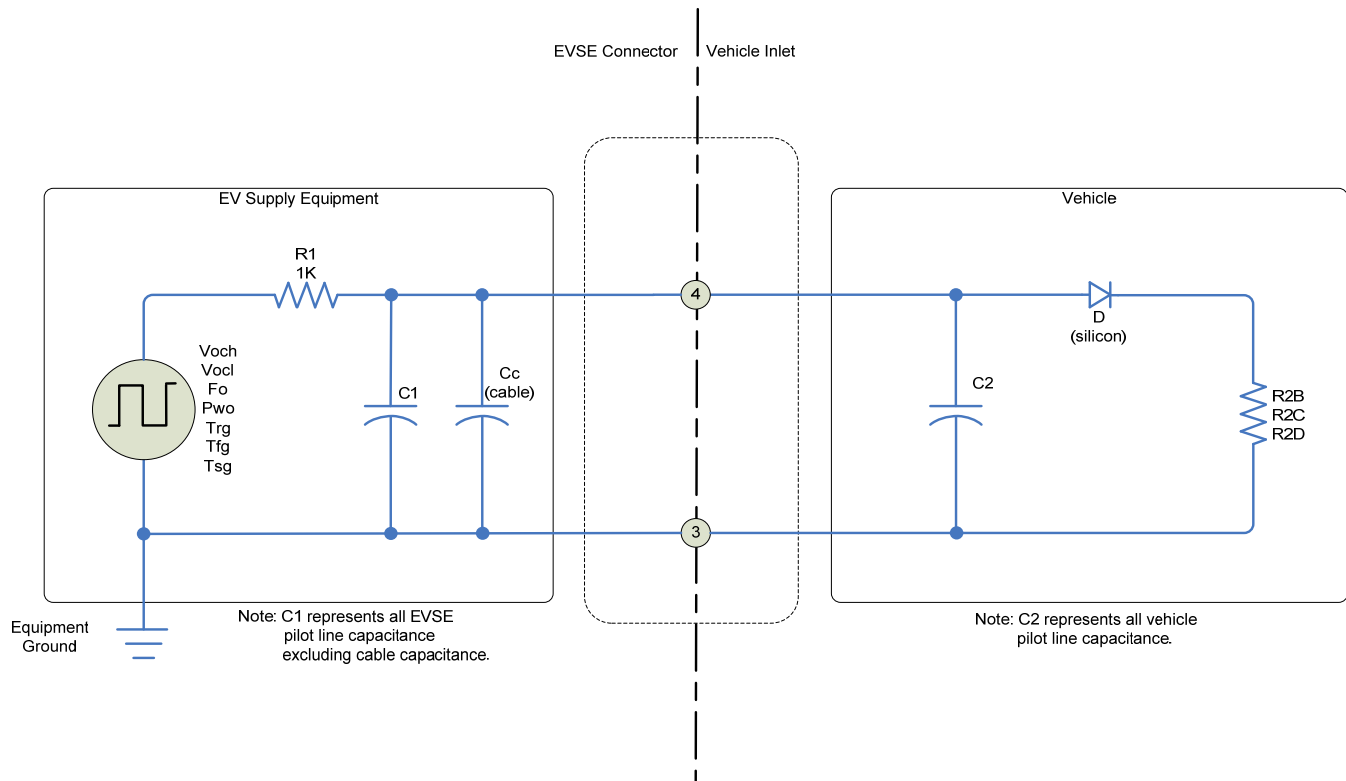


Figure 2 - Control pilot equivalent circuit

Table 1 - Definition of vehicle/EVSE states

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

⁽¹⁾ Static voltage.

⁽²⁾ Positive portion of 1 kHz square wave, measured after transition has fully settled.

⁽³⁾ The transition from State B1 to State B2 begins as a static DC voltage which transitions to PWM upon the EVSE detection of vehicle connected / not ready to accept energy and EVSE capable to provide energy.

⁽⁴⁾ EVSE is not required to actively generate State E.

⁽⁵⁾ Voltage measured by EVSE / Vehicle as shown in Figure 1.

⁽⁶⁾ Optional state. The EVSE may enter State F upon detecting a self-diagnosed fault that prevents the EVSE from delivering power. Once the EVSE is in STATE F, self-restoring (automatic restart) is not required. This option would require user intervention to reset the EVSE to restore normal operation. If the EVSE decides to self-restore while connected to an EV/PHEV, a maximum of 20 retries shall be allowed with a 15-minute minimum time interval between retries. If the EVSE does not recover within a maximum of 20 retries, user intervention is required to reset the EVSE to restore normal operation. EVSE equipment should make every effort to recover from state F when possible.

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

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

Notes:

Table Calculation Parameters

1. The maximum, nominal, and minimum positive regulator voltages from Table 4 (State A).

2. The maximum, nominal, and minimum resistance values allowed for each state from Table 5.

3. The maximum and minimum diode voltage extremes allowed in Table 5.

4. For nominal voltages, the midpoint of the diode voltage extremes in Table 5 (0.70V) was used.

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

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

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

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

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

⁽¹⁾ Tolerances to be maintained over the environmental conditions and useful life as specified by the manufacturer.

⁽²⁾ Measured at 50% points of complete negative-to-positive or positive-to-negative transitions.

⁽³⁾ 10 to 90% of complete negative-to-positive transition or 90 to 10% of complete positive-to-negative transition measured between the pulse generator output and R1. Note that the term Generator is referring to the EVSE circuitry prior to and driving the 1 KΩ source resistor with a ±12 V square wave. This circuitry shall have rise/fall times faster than 2 μs. Rise/fall times slower than this will begin to add noticeably to the output rise/fall times dictated by the 1 KΩ resistor and all capacitance on the Pilot line.

⁽⁴⁾ To 95% of steady-state value, measured from start of transition.

⁽⁵⁾ Maximum and minimum resistor values are ±3% about nominal.

⁽⁶⁾ Guarantees rise time slow enough to remove transmission line effects from cable.

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

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

⁽¹⁾ Tolerances to be maintained over the environmental conditions and useful life as specified by the manufacturer.

⁽²⁾ Maximum and minimum resistor values are $\pm 3\%$ about nominal.

⁽³⁾ Vehicles not requiring ventilation for indoor charging areas.

⁽⁴⁾ Vehicles requiring ventilation for indoor charging areas.

⁽⁵⁾ Silicon small signal diode, -40 to 85 °C, forward current 3.00 to 10.0 ma.

4.2.1.3 Control Pilot Functions

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

4.2.1.3.1 Verification of Vehicle Connection

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

4.2.1.3.2 EVSE Not Ready to Supply Energy

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

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

4.2.1.3.3 EVSE Ready to Supply Energy

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

4.2.1.3.4 EV/PHEV Ready to Accept Energy

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

4.2.1.3.5 Determination of Indoor Ventilation

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

4.2.1.3.6 EV/PHEV Current Control Tolerance

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

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

4.2.1.3.7 EVSE Current Capacity

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

Table 6 - Control pilot duty cycle definition

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

Notes:

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

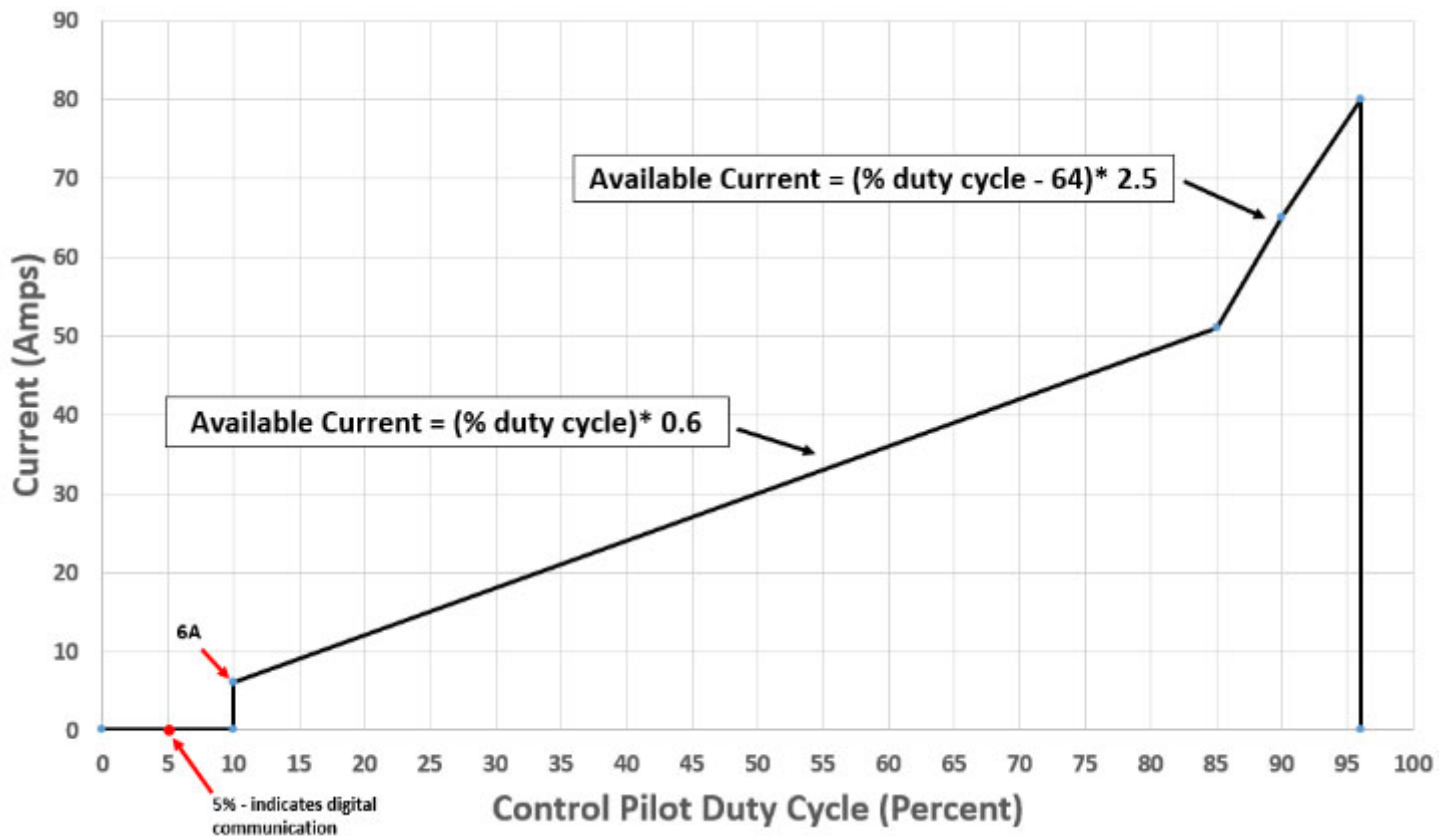


Figure 3 - Supply current rating versus pilot circuit duty cycle

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

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

4.2.1.3.8 Verification of Equipment Grounding Continuity

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

4.2.1.4 Control Pilot Tolerance

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

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

- 4.2.1.4.1 If the EV/PHEV reads a duty cycle of 3 to 7%, the EV/PHEV shall interpret this as a valid digital communications command. See 4.3.
- 4.2.1.4.2 If the EV/PHEV reads a duty cycle between 8% and less than 10%, the EV/PHEV shall interpret this as a valid 10% duty cycle.
- 4.2.1.4.3 If the EV/PHEV reads a duty cycle less than or equal to 85%, the EV/PHEV shall base the current on the $\text{Amps} = (\% \text{ duty cycle}) * 0.6$ formula.

- 4.2.1.4.4 If the EVPHEV reads a duty cycle greater than 85%, the EV/PHEV shall base the current on the Amps = (% duty cycle – 64) * 2.5 formula.
- 4.2.1.4.5 If the EV/PHEV reads a duty cycle of 97%, it is recommended the EV/PHEV consider this as a valid 96% duty cycle.

4.2.2 Proximity Detection

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

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

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

4.2.2.1 Proximity Detection Circuit

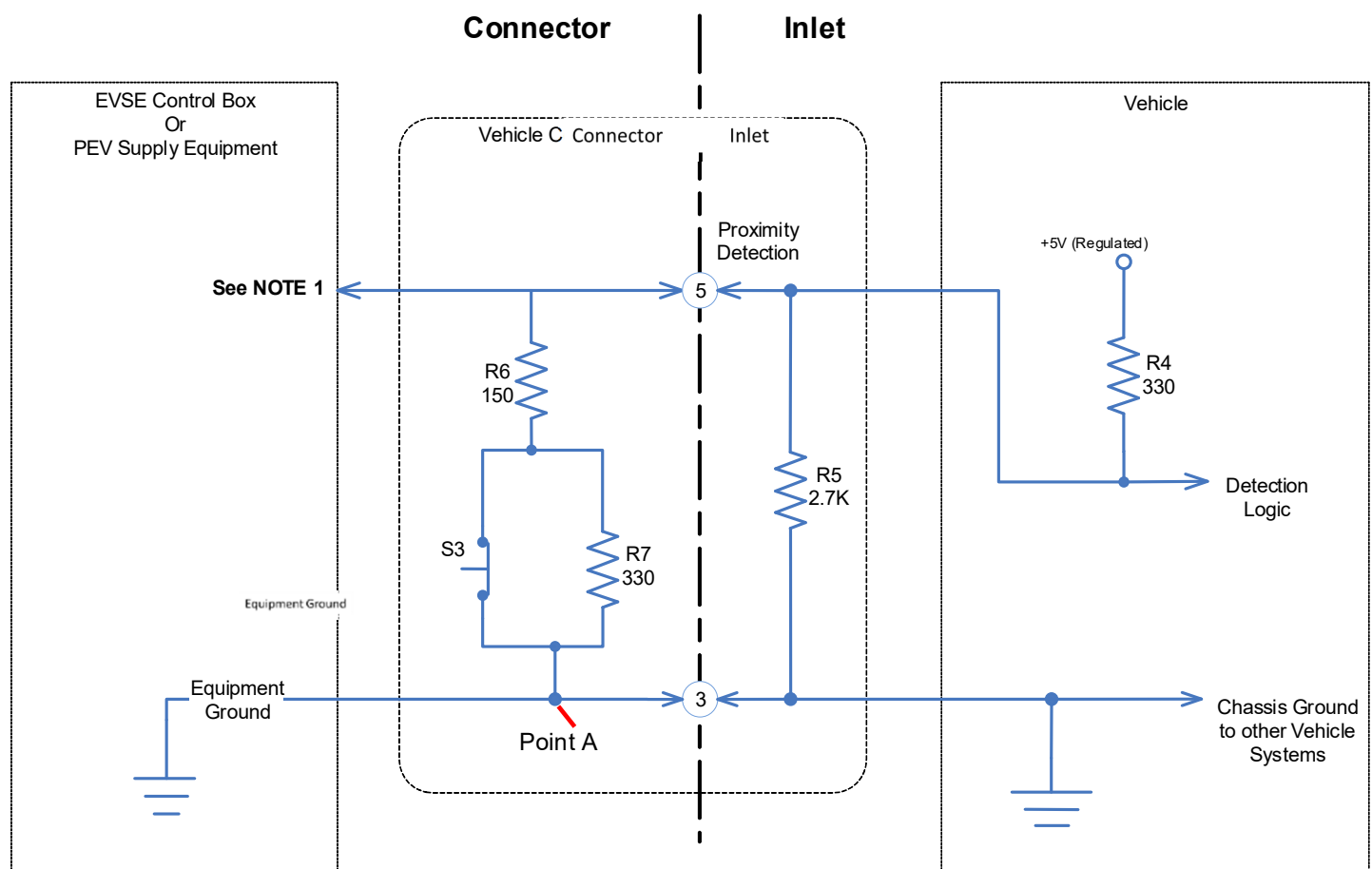


Figure 4 - Proximity detection circuit

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

4.2.2.2 Proximity Detection Circuit Parameters

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

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

⁽¹⁾ Tolerances to be maintained over the environmental conditions and useful life as specified by the manufacturer.

⁽²⁾ Maximum and minimum resistor values are ±10% about nominal.

⁽³⁾ Based on 5% tolerance.

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

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

⁽¹⁾ Tolerances to be maintained over the environmental conditions and useful life as specified by the manufacturer.

⁽²⁾ Maximum and minimum resistor values are ±10% about nominal.

⁽³⁾ Tolerance of voltage regulator on vehicle ±5%.

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

4.2.2.3 Charge Status Indicator

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

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

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

4.3 Digital Data Transfer

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

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

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

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

4.5 EV/PHEV and EVSE Additional Requirements for Power Transfer

4.5.1 Alternative Measures

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

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

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

Different measures may be used for different sections of a circuit

The requirements for protective provisions in 4.5.2 shall apply.

4.5.2 General Requirements for Protective Provisions

4.5.2.1 Requirements for Insulation

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

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

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

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

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

4.5.2.2 Requirements for Protective Barriers/Protective Enclosures

4.5.2.2.1 General

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

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

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

4.5.2.2.2 Degree of Protection for Protective Barriers/Protective Enclosures

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

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

4.5.2.2.3 Requirements for Connectors

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

Vehicle inlet shall comply with 4.5.3 in unmated condition.

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

- a. A connector shall comply with 4.5.2.2.2 in the unmated condition.
- b. It shall not be possible to unmate a connector without the use of tools.
- c. Voltage class B live parts of a connector shall be de-energized when it is unmated. One of the following conditions shall be met for the de-energized live parts:
 1. The voltage shall be reduced to a value below the lower limits of voltage class B.
 2. The total stored energy of the circuit shall be $\leq 0,2$ J and the touch current flowing between simultaneously accessible conductive parts shall not exceed 2 mA a.c. or 10 mA d.c. Compliance shall be tested according to 10.5 or demonstrated by calculation.

4.5.2.2.4 Insulation Coordination

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

4.5.3 Requirements for Unmated Vehicle Connectors

4.5.3.1 General

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

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

The requirements in 4.5.3.3 shall be fulfilled:

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

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

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

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

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

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

4.5.3.2 Normal Operation

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

- a. the contact shall be protected by the degree of protection IPXXD according to ISO 20653;
- b. the voltage between the contact and any other contact not protected by IPXXD according to ISO 20653, as well as the voltage between the contact and the electric chassis, shall be below 60 V DC and 30 V AC;
- c. the steady state touch current between the contact and any other contact not protected by IPXXD according to ISO 20653, as well as the steady state touch current between the contact and the electric chassis, shall be below 0.5 mA AC and 2 mA DC and the stored energy between the contact and any other contact not protected by IPXXD according to ISO 20653, as well as the stored energy between the contact and the electric chassis, shall not cause a startle reaction. The limit shall be specified by the OEM under the consideration of the IEC 60479 series.

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

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

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

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

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

4.5.3.3 Operation Under a Single Fault Condition

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

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

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

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

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

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

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

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

4.6 EV/PHEV Requirements

4.6.1 Environmental

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

4.6.2 Vehicle Movement with Mated Coupler

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

4.6.3 Control Pilot Continuity

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

4.7 EVSE Requirements

4.7.1 EVSE EMC Requirements

4.7.1.1 Electromagnetic Emissions

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

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

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

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

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

4.7.1.1.1 EVSE Conducted Emissions

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

4.7.1.1.2 EVSE Radiated Emissions

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

4.7.1.2 EVSE Electromagnetic Immunity

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

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

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

4.7.1.3 EVSE Electrostatic Discharge

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

4.7.1.4 EVSE Harmonic Distortion Immunity

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

4.7.1.5 EVSE Electrical Fast Transient Immunity

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

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

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

4.7.1.7 EVSE Magnetic Field Immunity

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

4.7.1.8 EVSE Capacitor Switching Transient Test

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

4.7.1.9 EVSE Voltage Surge Test

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

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

4.7.2 Installation Requirements

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

4.7.3 General Product Standards

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

4.7.4 Personnel Protection System

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

4.7.5 AC Present Indicator

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

4.7.6 Conductor Cord Requirements

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

4.8 Charge Coupler Requirements

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

The EV/PHEV coupler shall meet the requirements specified in the NEC Article 625, UL 2251, and 4.8 and 4.9 of this document.

4.8.1 Ergonomic Requirements

The coupler shall comply with the following ergonomic requirements.

4.8.1.1 Ease of Use

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

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

4.8.1.2 Indexing

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

4.8.1.3 Tactile Feel

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

4.8.1.4 Latching

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

4.8.1.5 Locking Function

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

4.8.2 Safety Requirements

The coupler shall comply with the following safety requirements.

4.8.2.1 Surface Temperature

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

4.8.2.2 Hazardous Conditions

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

4.8.2.3 Unauthorized Access

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

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

4.8.3 Performance Requirements

The coupler shall comply with the following performance requirements:

4.8.3.1 Design Life

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

4.8.4 Environmental Requirements

The coupler shall comply with the following environmental requirements:

4.8.4.1 Temperature Range

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

4.8.4.2 Temperature Rise

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

4.8.4.3 Insulation Resistance

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

4.8.4.4 Fluid Resistance

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

4.8.5 General Coupler Physical Description

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

4.8.6 Contact Sequencing

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

4.8.7 Charge Coupler Optional Markings

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

4.9 Vehicle Inlet

4.9.1 Physical Dimensions

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

4.9.2 Inlet Access Zone

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

4.9.3 Alignment

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

4.9.4 Isolation

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

4.9.5 Exposure of Contacts

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

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

4.9.6 Sharp Edges

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

4.9.7 Environmental Considerations

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

4.9.8 Mechanical Requirements

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

- a. Vibration Test Procedure - A vehicle inlet as mounted on a test fixture shall be securely bolted to the table of the vibration test machine and subjected to vibration according to the following test parameters:
 1. Frequency: Varied from 10 to 55 Hz and return to 10 Hz at a linear sweep period of 2 minutes/complete sweep cycle.
 2. Excursion: $1.0 + 0.1/-0.0$ mm peak to peak over the specified frequency range.
 3. Direction of Vibration: Vertical axis of the vehicle inlet as it is mounted on the vehicle.
 4. Test Duration: $60 + 1/-0$ minutes.
 5. Pass/Fail Criteria: After completion of the test, there shall be no observed rotation, displacement, cracking, or rupture of parts of the device that could result in failure to operate as intended or cause it to fail any of the other test requirements specified in this document. Cracking or rupture of the parts of the device that affect mounting shall constitute a failure.

4.9.9 Sealing Requirements

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

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

4.10 Vehicle Connector

4.10.1 Physical Dimensions

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

4.10.2 Exposure of Contacts

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

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

4.10.3 Sharp Edges

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

4.10.4 Impact Resistance

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

4.10.5 Vehicle Drive-Over

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

5. AC CHARGING

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

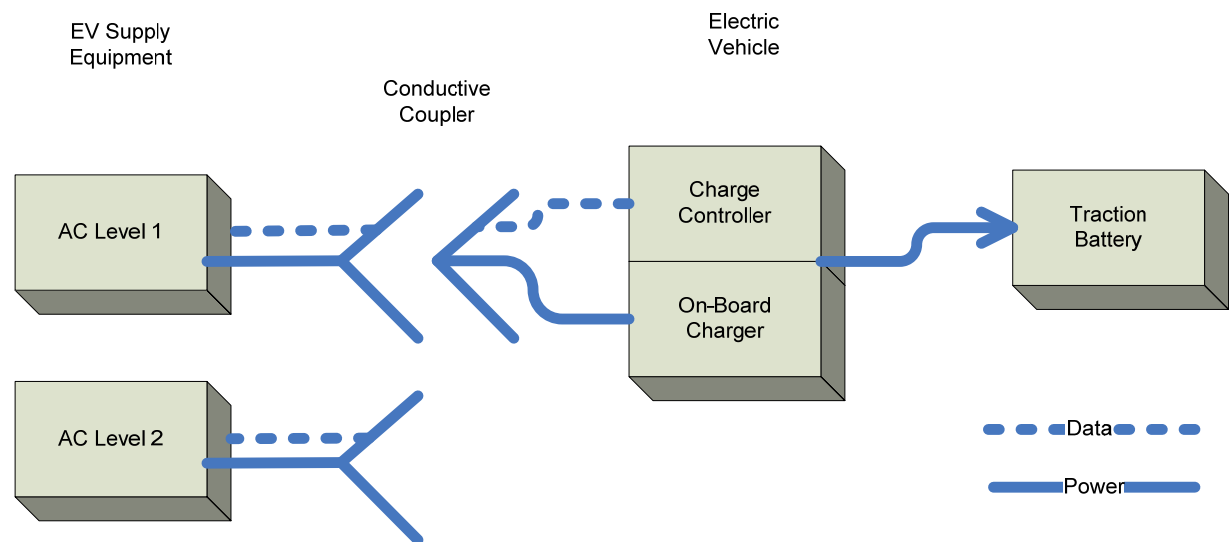


Figure 5 - AC conductive EV/PHEV charging system architecture

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

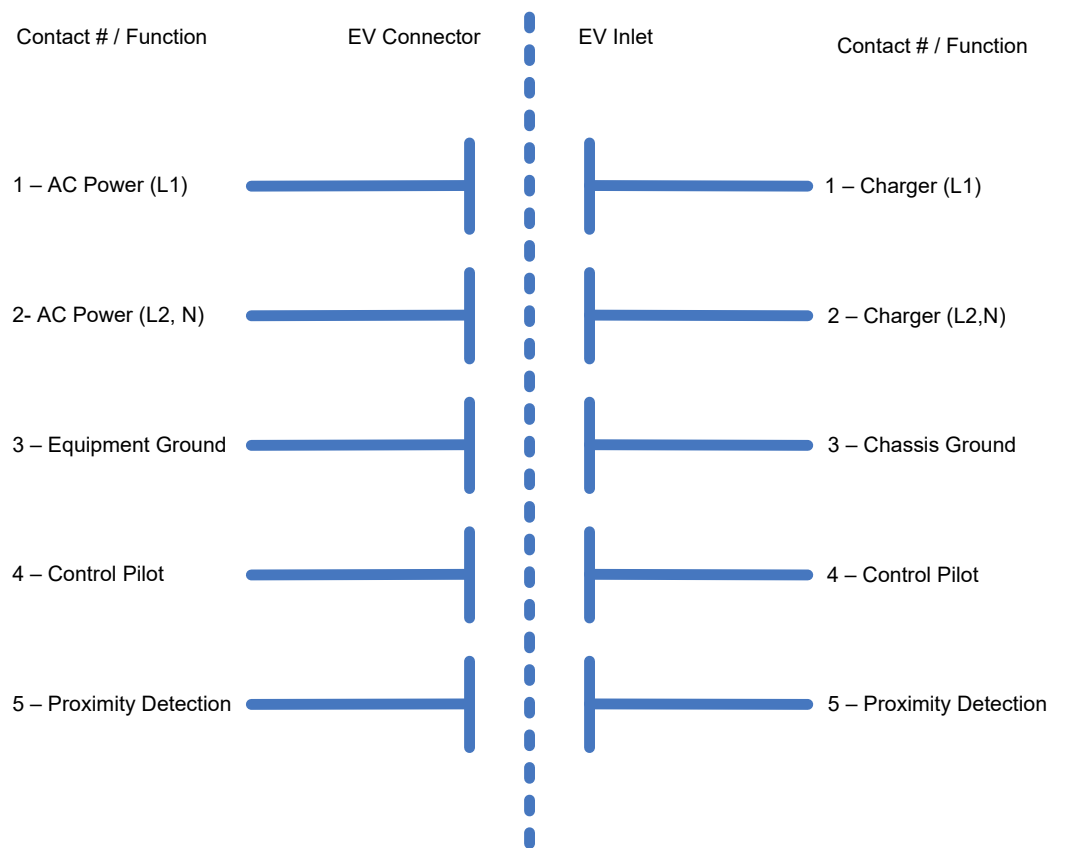


Figure 6 - AC level 1 and AC level 2 conductive coupler contact interface functions

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

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

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

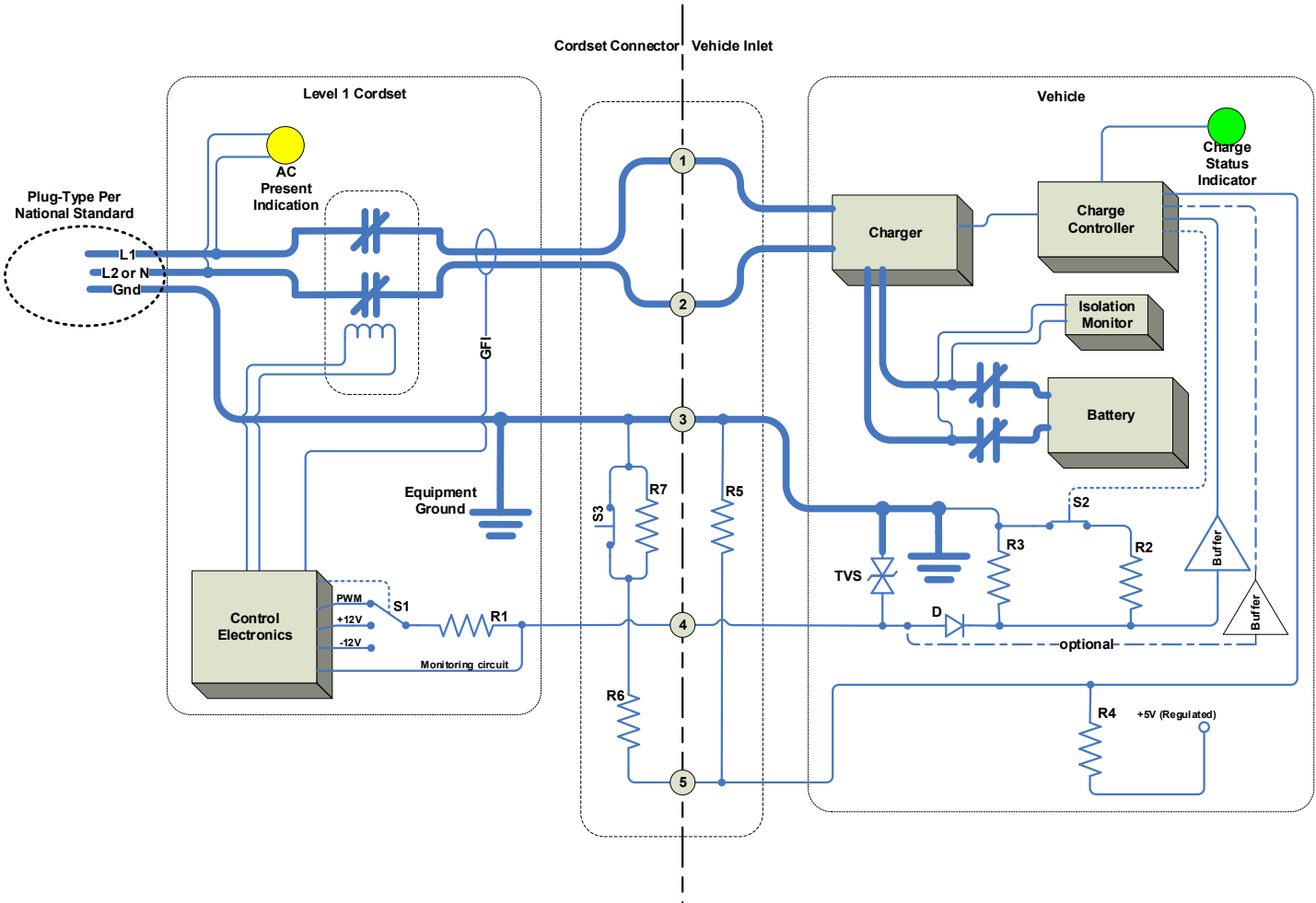


Figure 7 - AC level 1 system configuration
(figure illustrates vehicle charging)

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

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

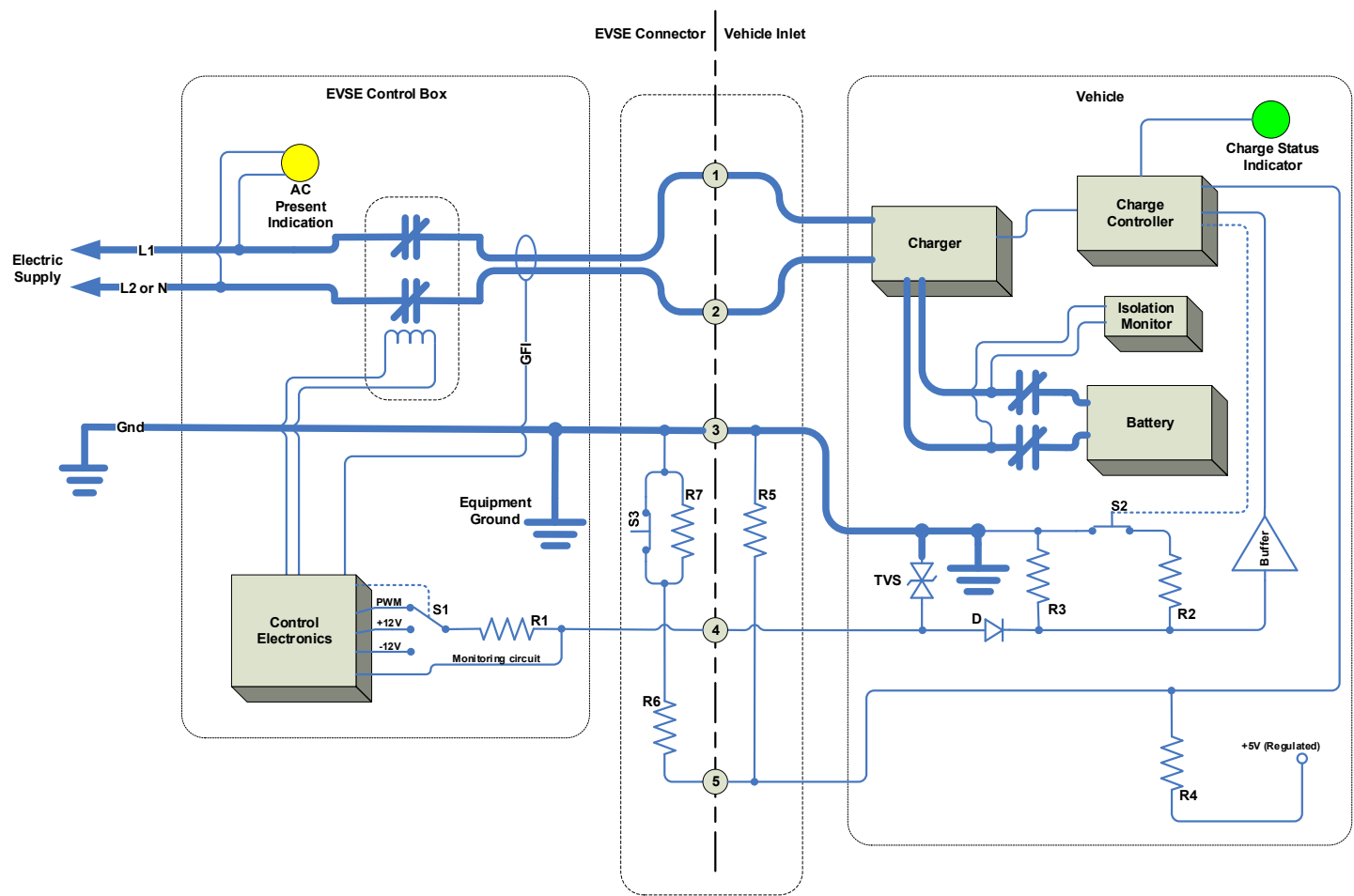


Figure 8 - AC level 2 system configuration
(figure illustrates vehicle charging)

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

5.1 Electrical Ratings

Table 10 - AC charging electrical ratings*

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

Note:
*Branch circuit rating governed by local regulation.

5.2 Charging Control and Information

5.2.1 Control Pilot

As defined in 4.2.1.

5.2.2 Proximity Detection

As defined in 4.2.2.

5.2.3 Digital Data Transfer

As defined in 4.3.

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

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

Digital data transfer is specified in the following SAE documents:

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

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

As defined in Appendix E.

5.4 EV/PHEV Requirements

As defined in 4.6.

5.4.1 EV/PHEV Cable Ampacity Coordination

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

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

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

5.4.2 Coupler Disconnect Current Limit

Under consideration.

5.5 EVSE Requirements

As defined in 0 with addition below.

5.5.1 Radiated Immunity

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

- a. The test bench shall be covered with a ground plane, located 800 mm above the test site ground plane, or absorber lined shield enclosure (ALSE) floor.
- b. The back edge of the test bench ground plane shall be connected to the test site ground plane or ALSE floor or wall, using a series of straps. Refer to SAE J1113-21 for bench grounding requirements.
- c. The AC receptacle or Level 2 EVSE (if applicable) shall be mounted on a dielectric support, 200 mm above the front edge of the bench ground plane.
- d. Level 1 EVSE (if applicable) shall be positioned at a minimum height of 700 mm above the test site, or ALSE ground plane, and connected to the AC receptacle with a cord having a maximum length of 305 mm.
- e. The AC receptacle (or Level 1 EVSE) mains conductors shall be connected to a pair of 50 μ H line impedance stabilization networks (LISNs), using conductors having a maximum length of 200 mm. The 50 Ω LISN ports shall be terminated with 50 Ω loads. The ground conductors from the AC receptacle and the incoming mains line shall connect to the test bench at a point near the LISN terminals on the EVSE side of the LISNs. Refer to CISPR 16-1-2 for LISN specifications.
- f. The cordset length shall be in accordance with NEC Article 625. Excluding the vertical section exposed to the test field, the remainder of the cordset shall lay on the floor in a non-inductive pattern (i.e., "zig-zag," not coiled).
- g. A grounded plate shall be provided on the floor for mounting of the vehicle charge coupler and vehicle electrical/electronic equipment necessary for operation of the EVSE. Representative RF loading of conductive coupler circuits shall be included.
- h. The standard tolerance for radiated immunity test setup dimensions shall be 5%, unless otherwise specified.

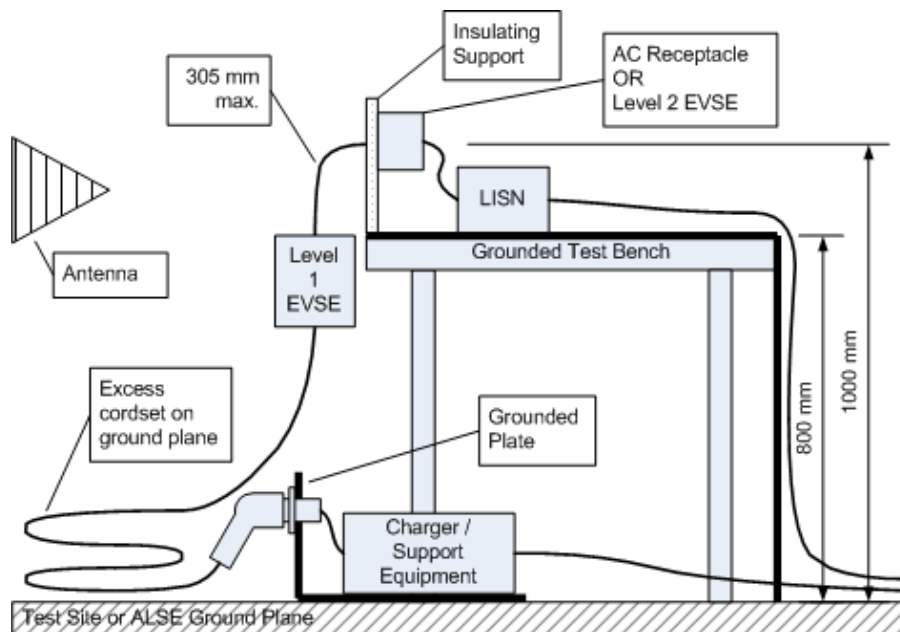


Figure 9 - Radiated immunity test setup

5.6 Charge Coupler Requirements

As defined in 4.8.

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

Table 11 - Contact size electrical ratings

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

5.7 Vehicle Inlet

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

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

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

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

5.8 Vehicle Connector

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

Table 11 defines contact requirements.

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

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

6. DC CHARGING

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

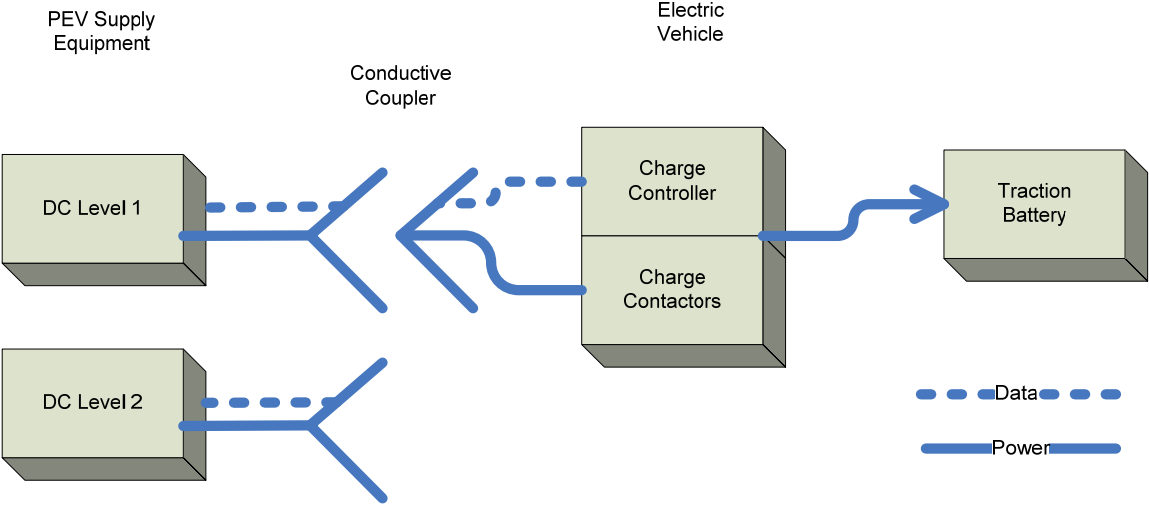


Figure 10 - DC conductive EV/PHEV charging system architecture

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

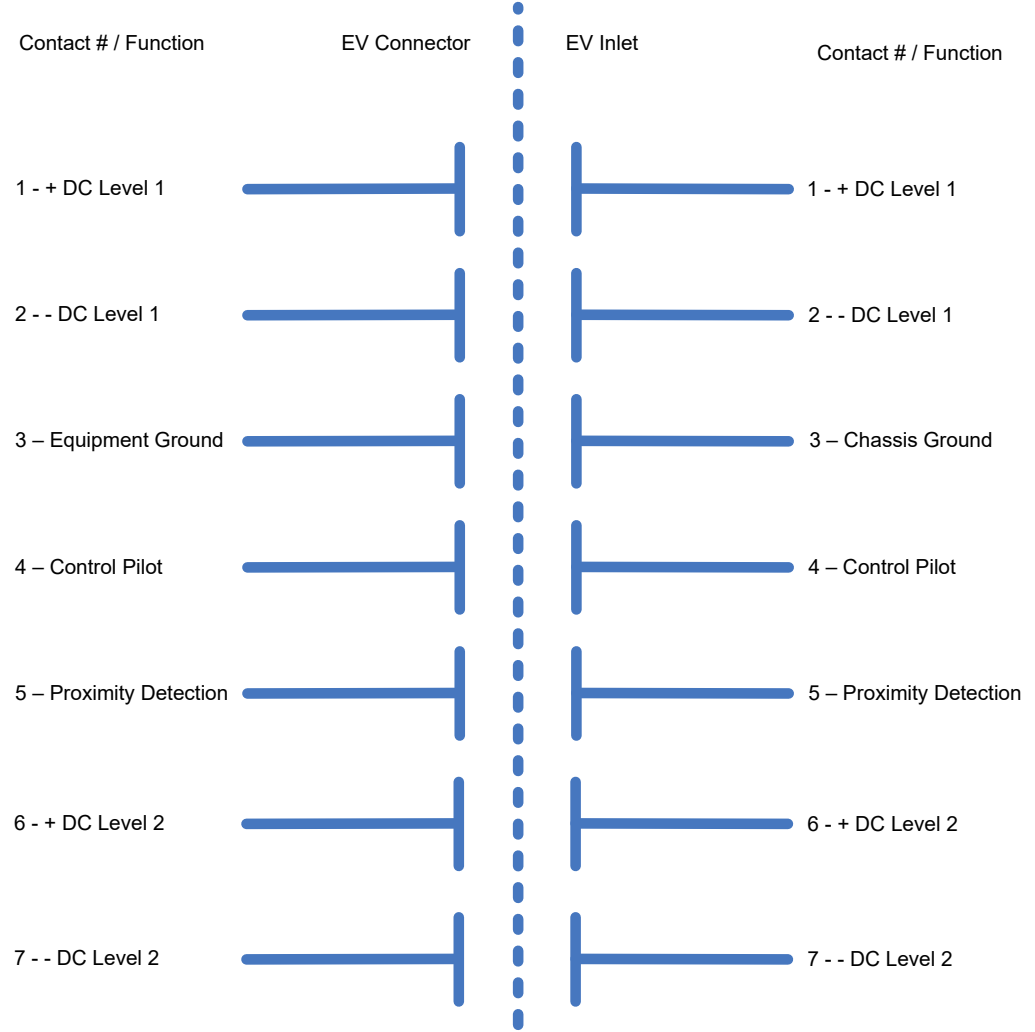


Figure 11 - DC level 1 and DC level 2 conductive coupler contact interface functions

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

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

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

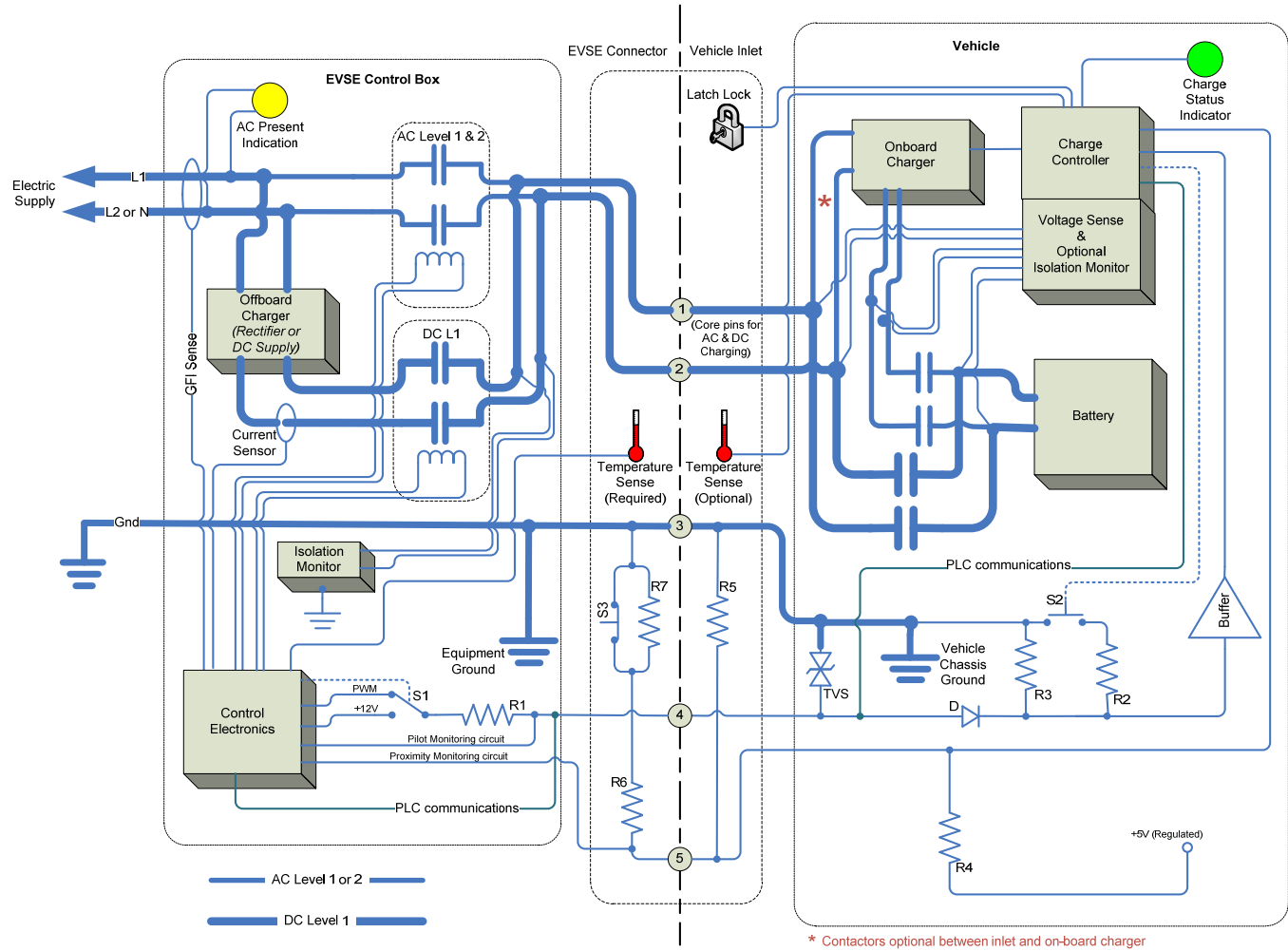


Figure 12 - DC level 1 system configuration figure illustrates vehicle not charging

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

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

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

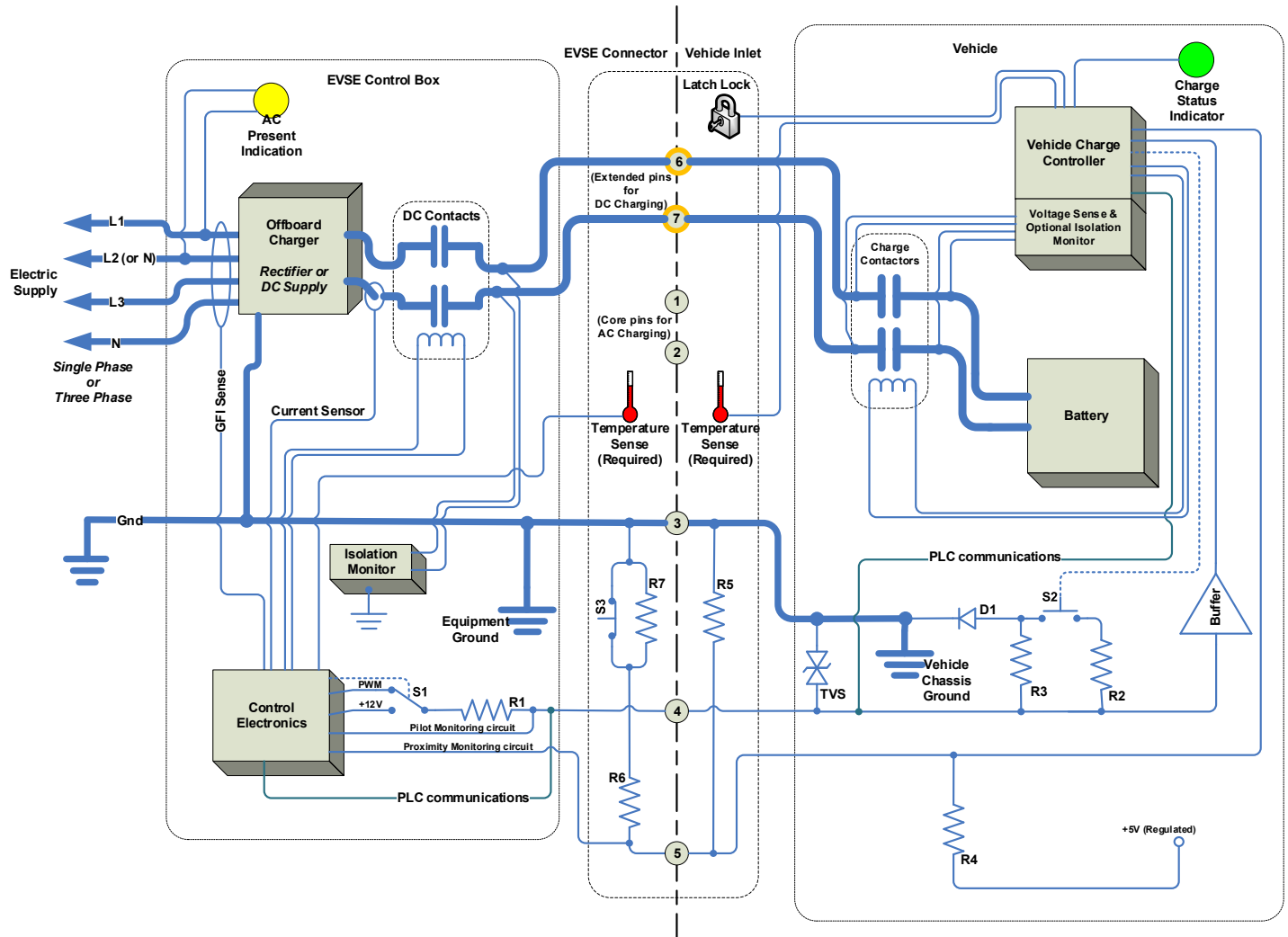


Figure 13 - DC level 2 system configuration
figure illustrates vehicle not charging

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

6.1 Electrical Ratings

Table 13 - DC charging electrical ratings

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

Notes:

*Operational range; not a requirement.

**This is a nominal current limit, and value is subject to change depending on specified design requirements of SAE J1772 and IEC 62196-3-1.

6.2 Charging Control and Information

6.2.1 Control Pilot

As defined in 4.2.1 with addition below.

6.2.1.1 EVSE Shutdown - Control Pilot

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

6.2.1.2 EV/PHEV Shutdown - Control Pilot

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

6.2.2 Proximity Detection

As defined in 4.2.2 with addition below.

6.2.2.1 EVSE Shutdown - Proximity Detection

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

6.2.2.2 Valid proximity circuit voltages are defined in Table 8. EVSE input impedance shall have high input impedance ($\geq 10\text{ M}\Omega$) to prevent loading of vehicle proximity voltage monitoring circuit.

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

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

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

6.2.3 Digital Data Transfer

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

Digital data transfer is specified in the following documents:

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

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

As defined in APPENDIX F.

6.3.1 EVSE and EV/PHEV Message Table

As defined in APPENDIX G.

6.4 EV/PHEV Requirements

As defined in 4.6 with the addition below.

6.4.1 Lock Function Diagnostics

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

6.4.2 Manual Lock Release

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

6.4.3 EV/PHEV Isolation Monitoring

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

6.4.4 EV/PHEV Maximum Y Capacitance

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

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

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

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

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

6.4.5 Loss of Communications

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

6.4.6 Inlet Contact Area Temperature Monitor

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

- If the temperature exceeds 90 °C for 8 consecutive seconds, the EV/PHEV shall transfer to error shutdown sequence within 1 second.
- If the temperature exceeds 95 °C for 1 second, the EV/PHEV shall transfer to error shutdown sequence within 1 second.

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

6.4.7 Charge Contactors During Charging

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

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

- a. performing a normal shutdown and reinitiating a new charging session by the restart sequence, as specified in 6.4.8, and then continue to t1 in the normal start up sequence F.1.8; or
- b. performing a renegotiation as defined in F.1.13.

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

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

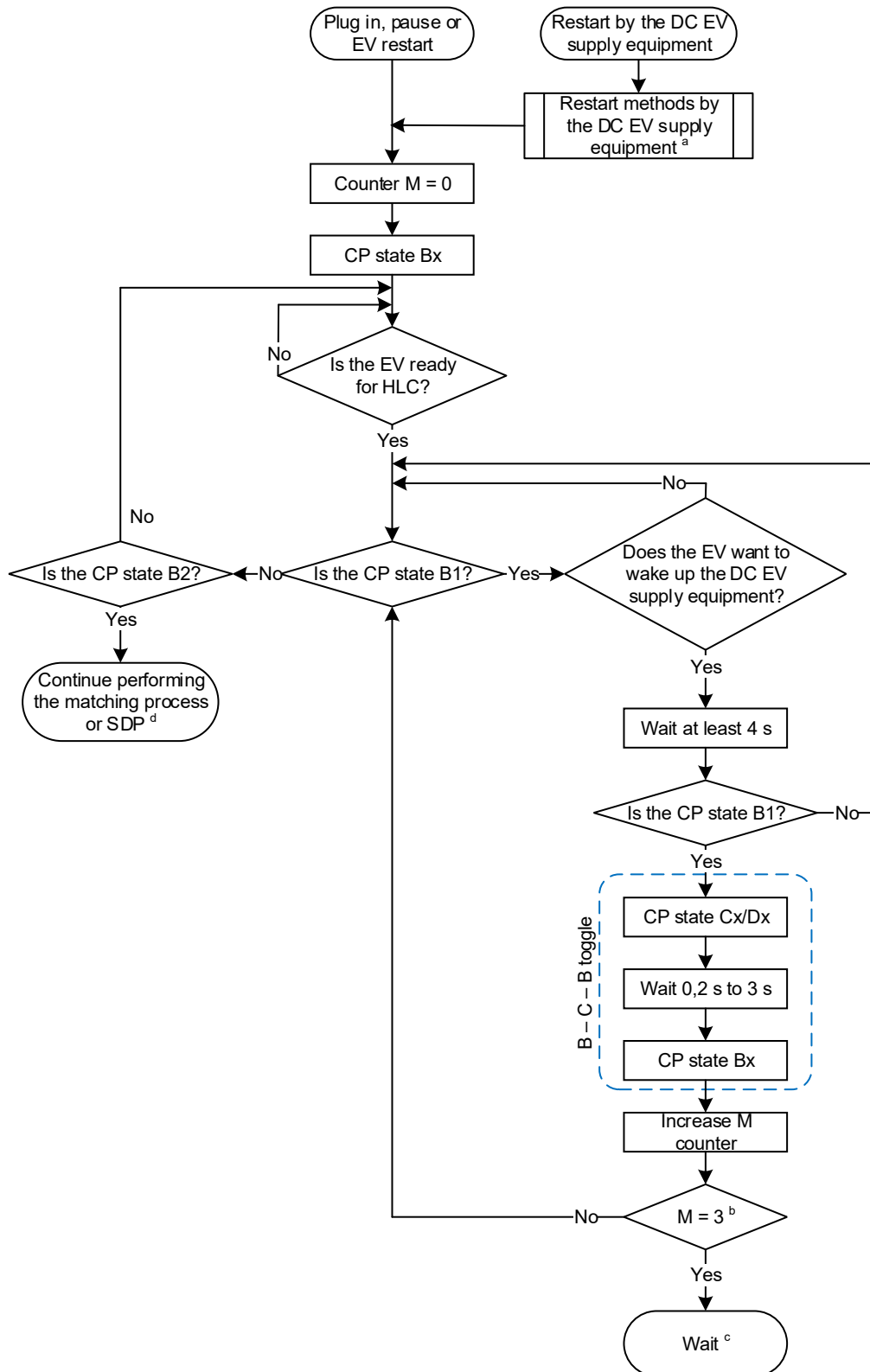
The EV/PHEV can request a pause of the charging session, after which both EV/PHEV and EVSE can enter sleep mode.

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

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

6.4.8.1 Restart by the EV/PHEV

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

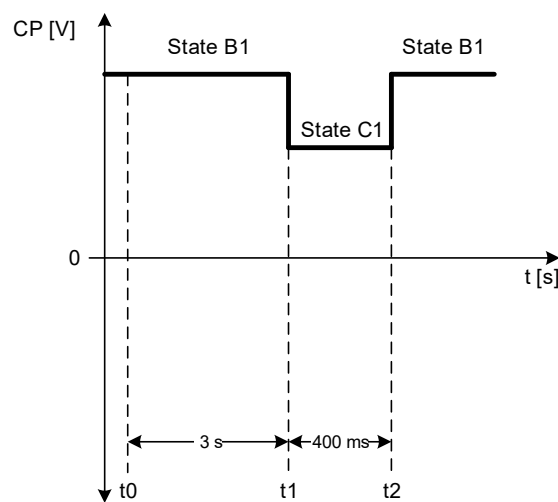


Notes:

- a The EVSE may perform different restart methods to wake up the EV/PHEV, according to Figure 15.
- b The EV/PHEV manufacturer can specify a different number of restart cycles.
- c The EV/PHEV manufacturer can perform additional restarts, enter sleep mode or the EVSE can decide to perform a restart.
- d Supply Equipment Charge Controller (SECC) Discovery Protocol.

Figure 14 - Restart methods sequence for the EV/PHEV

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

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

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

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

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

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

6.4.9 EV/PHEV Pre-Charge

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

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

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

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

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

6.4.10 Loss of Electrical Continuity of the Protective Conductor

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

- a. the EV/PHEV shall check the PP circuit before each initiating a charging session for correct values specified by the EV/PHEV manufacturer. This includes the continuity of the protective conductor from point A up to the EV/PHEV; and
- b. the EV/PHEV shall check the PP circuit during energy transfer and, in case of loss of electrical continuity of the protective conductor, the EV/PHEV shall trigger an emergency shutdown in 150 ms or less.

6.5 EVSE Requirements

6.5.1 EVSE Electromagnetic Emissions

As defined in 4.7.1.

6.5.2 Installation Requirements

As defined in 4.7.2.

6.5.3 General Product Standards

The following replaces the requirements in 4.7.3.

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

6.5.4 Personnel Protection System

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

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

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

6.5.4.1 General

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

- Basic protection and fault protection (see 6.5.4.2 and 6.5.4.3).
- Enhanced protective provisions (see 6.5.4.4).

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

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

6.5.4.1.1 Intended Use and Reasonably Foreseeable Misuse

Considering intended use and reasonably foreseeable misuse:

- a. hazardous-live-parts shall not be accessible and accessible-conductive-parts shall not be hazardous live, and
- b. hazardous voltage shall not be disconnected with the vehicle connector.

6.5.4.1.2 Limitation of Touch Current or Touch Voltage

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

- a. limiting the touch current and the touch energy, or
- b. limiting the touch voltage.

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

6.5.4.1.3 Threshold of Perception and Startle Reaction

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

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

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

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

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

- 0.5 mA AC/2 mA DC under normal operation.
- 3.5 mA AC/10 mA DC under single fault condition.

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

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

- 5 μ J under normal operation.
- 0.5 mJ under single fault condition.

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

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

The following parameters shall be used:

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

6.5.4.2 Basic Protection

6.5.4.2.1 General

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

6.5.4.2.2 Protection by Basic Insulation

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

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

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

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

6.5.4.2.3 Protection by Enclosures or Barriers

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

Enclosures shall meet the packaging requirements of UL 2202.

6.5.4.2.4 Protection by Limitation of Voltage

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

- a. steady-state touch voltage under normal operation is less than the values in Table 14;
- b. steady-state touch voltage under single fault condition is less than the values in Table 15;
- c. a nonrecurring DC touch voltage under normal operation is less than the limit of in Table 14;
- d. a nonrecurring DC touch voltage for fingertip to feet under single fault condition is less than the limit of in Figure 16;

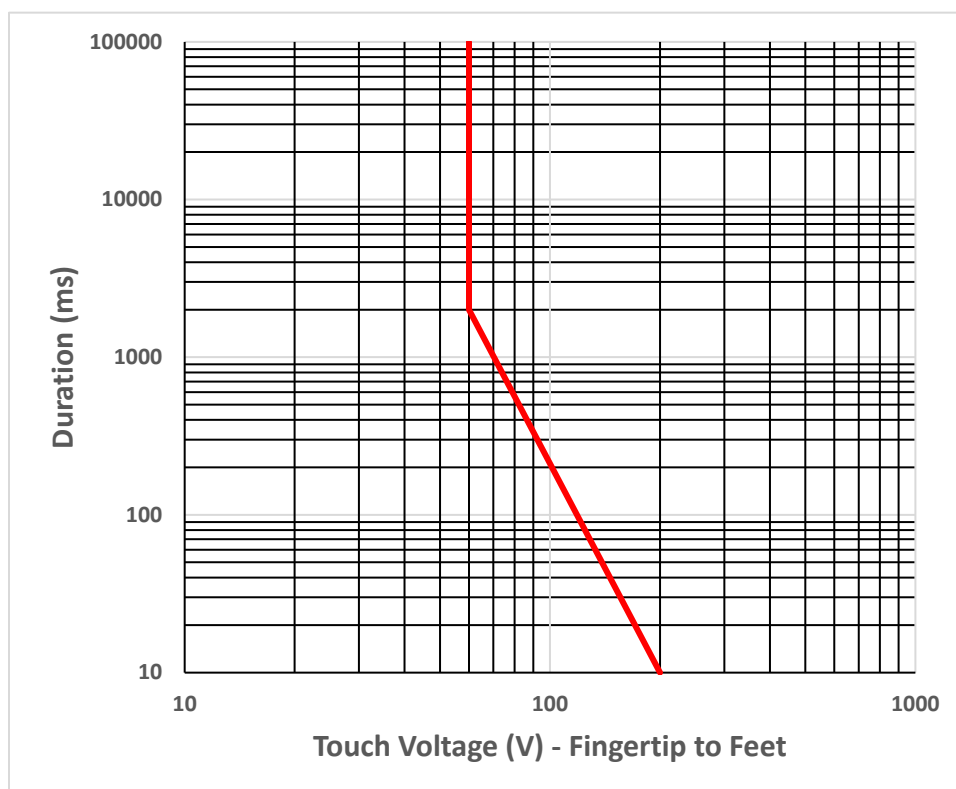


Figure 16 - Touch time for DC voltage - single fault condition, water wet, fingertip to feet

- e. the voltage is supplied by one of the following sources:
 1. a safety isolating transformer for the auxiliary circuit including control pilot;

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

2. a source of voltage providing a degree of safety equivalent to that of a safety isolating transformer;
3. electrochemical (for example, a battery system).

Table 14 - Touch voltage, normal operation

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

Note:

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

