SURFACE VEHICLE STANDARD	J1772™	OCT2017
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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, correct errors found in the previous version and to reflect the addition of higher power capacity DC 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 116 pages, including this page, and should not be used as a design tool if any of the pages are missing.

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

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1. SCOPE

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

2. REFERENCES

2.1 Applicable Documents

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

2.1.1 SAE Publications

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

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

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

SAE J2931-1 PLC Communications for Plug-In Electric Vehicles

SAE J2953 Plug-In Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE) SAE USCAR 2 Performance Specification for Automotive Electrical Connection Systems

2.1.2 Canadian Standards Association Publication

Available from Canadian Standards Association, 170 Rexdale Boulevard, Rexdale, Ontario, Canada M9W 1R3, www.csa.ca.

Canadian Electrical Code Part 1, Section 86

CSA C22.2 NO. 107.1-01 (R2006) General Use Power Supplies

2.1.3 Federal Communication Commission Publications

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

CFR 40 Code of Federal Regulations - Title 40, Part 600, Subchapter Q

CFR 47 Code of Federal Regulations - Title 47, Parts 15A, 15B, and 18C

2.1.4 International Electrotechnical Commission Publication

Available from International Electrotechnical Commission, 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, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

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

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

2.1.5 ISO Publications

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

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

2.1.6 National Fire Protection Association Publication

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

National Electrical Code, NFPA 70 Article 625 (2008 edition)

2.1.7 Underwriters Laboratories Inc. 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 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

2.2 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, Broadband, 9 kHz to 30 MHz

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

2.2.2 International Electrotechnical Commission Publications

Available from International Electrotechnical Commission, 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, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

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

IEC 61851-1 Electric Vehicle Conductive Charging System - Part 1: General Requirements

IEC 61851-21 Electric Vehicle Conductive Charging System - Part 21: Electric Vehicle Requirements for Connection to an AC / DC Supply

IEC 61851-22 Electric Vehicle Conductive Charging System - Part 22: AC Electric Vehicle Charging Station

IEC 61851-23 Electric Vehicle Conductive Charging System - Part 23: DC Electric Vehicle Charging Station

2.2.3 Underwriters Laboratories Inc. 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

UL 2202 EV Charging System Equipment

UL 2594 Electric Vehicle Supply 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 9. 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.

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 alternating current (AC) electric vehicle supply equipment. The maximum power supplied for AC Level 2 charging shall conform to the values in Table 9.

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 CONDUCTIVE

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

3.6 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.

3.7 CONTACT (CHARGE)

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

3.8 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

3.9 COUPLER (CHARGE)

A mating vehicle inlet and connector set.

3.10 DC 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.

3.11 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 lb), which has a curb weight of not more than 2721.6 kg (6000 lb), and which has a basic frontal area of not more than 4.18 m^2 (45 ft^2).

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

3.12 ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE)

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

3.13 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.

3.14 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.

3.15 INSULATOR

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

3.16 INVALID CONTROL PILOT

A Control Pilot outside of the frequency definition of Table 3 or any Control Pilot duty cycle which is defined as an error state in Table 5.

3.17 OFF-BOARD CHARGER

A charger located off of the vehicle.

3.18 ON-BOARD CHARGER

A charger located on the vehicle.

3.19 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.

3.20 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.

3.21 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 3 functions, 2 electrical and 1 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 60Hz. 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 (this section) - 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 amp (40 amp branch breaker) unless the EVSE is part of an energy management system per NEC Article 750 (2014). Residential EVSEs with input current ratings of greater than 32 amp 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

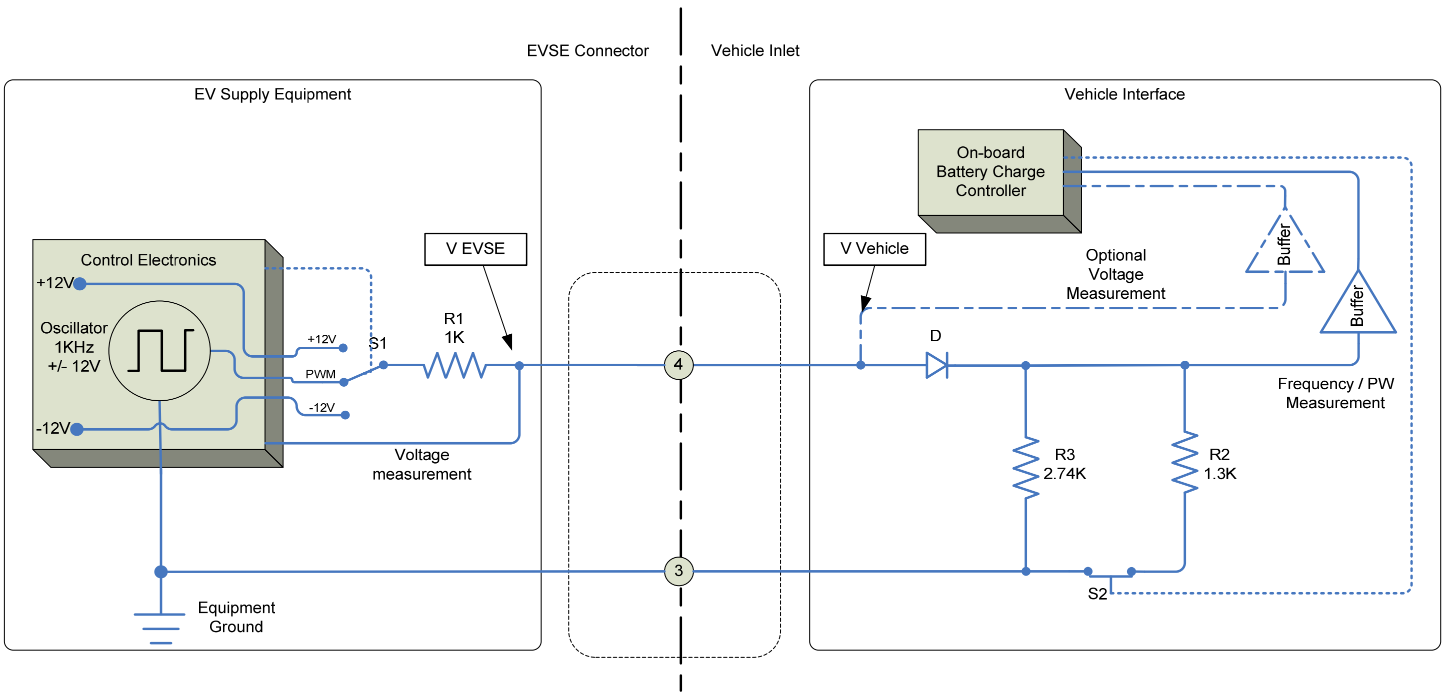


Figure 1 - Control pilot circuit

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 Table 1, 2, 3, and 4.

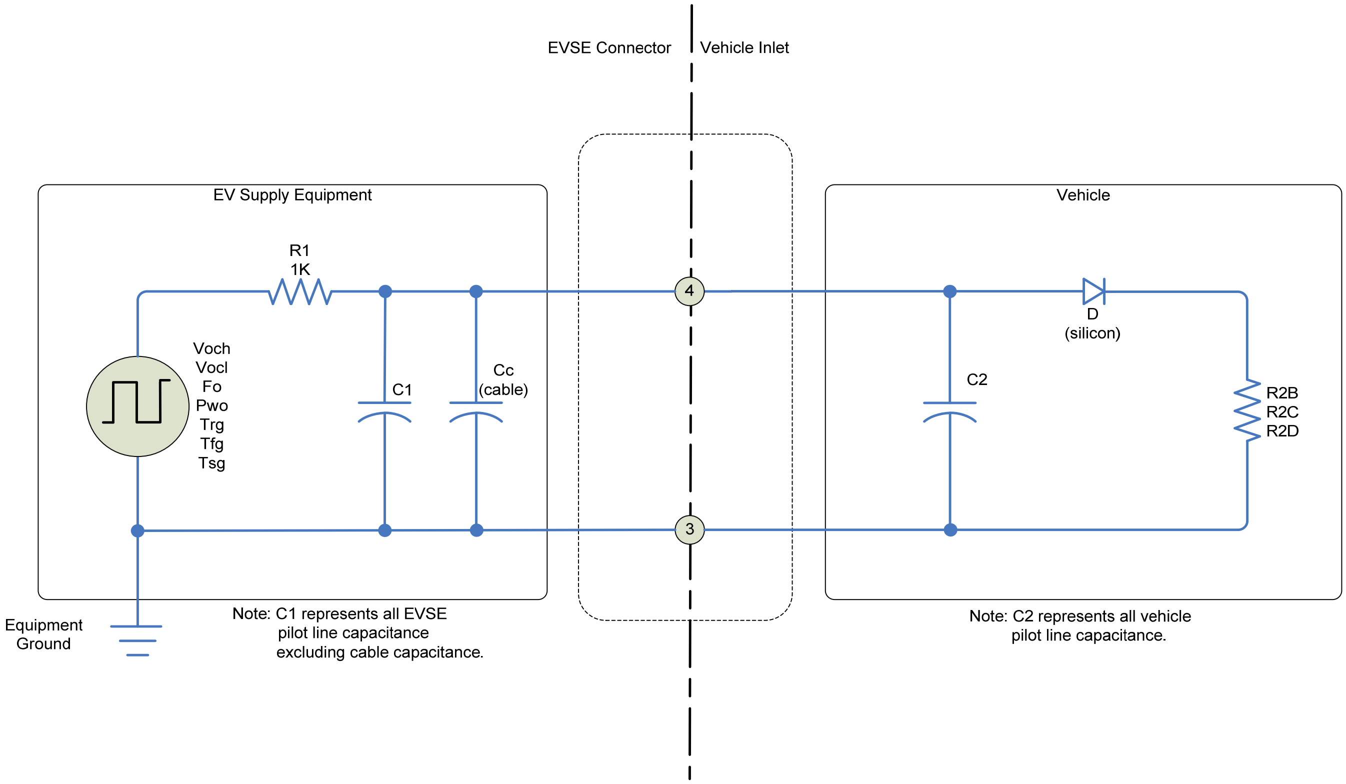


Figure 2 - Control pilot equivalent circuit

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 re-tries shall be allowed with a 15 Minute minimum time interval between re-tries. If the EVSE does not recover within a maximum of 20 re-tries, 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

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 0.3V offset have been observed /measured, with worst case calculated offset of 0.7V.

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

Table 2B - 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 3 - 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	Microsec	Per Figure 3	Nom, + 5 μs	Nom, - 5 μs
rise time[3]	Trg	Microsec	n.a.	2	n.a.
fall time[3]	Tfg	Microsec	n.a.	2	n.a.
settling time[4]	Tsg	Microsec	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	Picofarads	n.a.	n.a.	300[6]
total equivalent EVSE capacitance, including cable	C1 + Cc	Picofarads	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 1KΩ source resistor with a ±12V square wave. This circuitry shall have rise/fall times faster than 2 μsec. Rise/fall times slower than this will begin to add noticeably to the output rise/fall times dictated by the 1KΩ 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 4 - EV/PHEV control pilot circuit parameters (see Figure 2)

Parameter[1]	Symbol	Units	Nominal value	Max value	Min value
Equivalent load resistance - State B1&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	picofarads	n.a.	2400	n.a.
Equivalent diode voltage drop[5]	Vd	V	0.70	0.85	0.55

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

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, D1, 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 D1 (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 D1 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. Refer to 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 Table 1 & 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 Table 1 & 2. If required, the EVSE shall provide a signal to turn on the indoor charging area ventilation system according to National Electrical Code – 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 5 and shown in Figure 3.

4.2.1.3.7 EVSE Current Capacity

The EVSE shall maintain ± 0.5% tolerance on control pilot PWM duty cycle generation over the whole range, 5% to 96%. The EVSE is not required to end a charge session if the EV/PHEV draws more than the available current. If the EVSE does initiate a termination of the charge session, due to excess current draw, it should only do so after 1.3 amps above the EVSE nominal available current for currents under 12 amps, or after 111% of EVSE nominal available current for currents above 12 amps. For EVSE nominal available current see Table 5.

Table 5 - 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% ≤ Duty Cycle ≤ 5.5%	Indicates that digital communication is needed
3, 7		7% < Duty Cycle < 8%	Error state; no charging allowed
4		9.5% ≤ Duty Cycle < 10%	6A
	10% ≤ Duty Cycle ≤ 20%	10% ≤ Duty Cycle ≤ 20%	Maximum current = (duty cycle %) x 0.6
	20% < Duty Cycle ≤ 85%	20% < Duty Cycle ≤ 85%	Maximum current = (duty cycle %) x 0.6
	85% < Duty Cycle ≤ 96%	85% < Duty Cycle ≤ 96%	Maximum current = (duty cycle % - 64) x 2.5
5		96% < Duty Cycle ≤ 96.5%	80A
6, 7	Duty Cycle = 100%		State B1, C1 or D1; no charging allowed

Note 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%.
Note 2	Based on ± 0.5% of the duty cycle tolerance. It will be up to OEM to decide whether to extend the digital communications zone up to the error states above and below.
Note 3	Legacy carryover from previous editions. Need to remain to create the separation between digital communications and charging duty cycle values.
Note 4	Based on ± 0.5% EVSE duty cycle tolerance. Vehicle shall interpret 9.5% duty cycle as 10%.
Note 5	Based on ± 0.5% of the duty cycle tolerance. Vehicle shall interpret 96.5% as 96%.
Note 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%.
Note 7	No charging allowed: no active charging is allowed - an unintentional leakage current of less than 1A is acceptable.

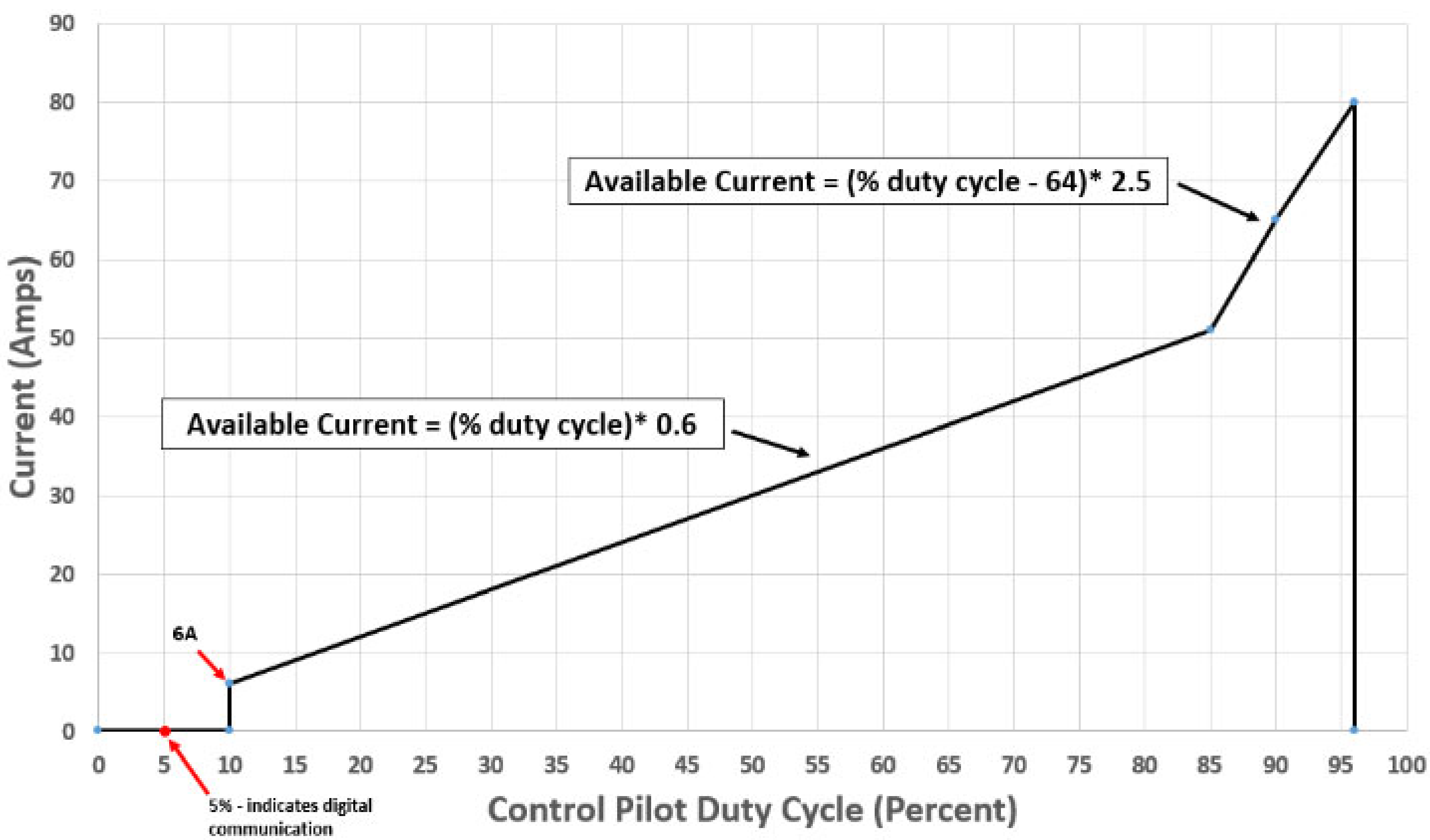


Figure 3 - Supply current rating vs. pilot circuit duty cycle

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 insure that the EVSE equipment ground is safely connected to the EV/PHEV vehicle chassis ground during charging. Loss of this signal shall result in the automatic de-energization at the EVSE.

4.2.1.4 Control Pilot Tolerance

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

Based on an overall tolerance of 2% duty cycle (see Table 5):

4.2.1.4.1 If the EV/PHEV reads a duty cycle of 3-7%, the EV/PHEV shall interpret this as a valid digital communications command. See section 0.

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 reads a duty cycle less than or equal to 85.0% the EV/PHEV shall base the current on the Amps = (% duty cycle) * 0.6 formula.

4.2.1.4.4 If the EV reads a duty cycle greater than 85.0%, the EV/PHEV shall base the current on the Amps = (% duty cycle – 64) * 2.5 formula.

4.2.1.4.5 If the EV 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 6 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, Coupler Disconnect Current Limit and 4.5.2, Vehicle Movement With Mated Coupler.

4.2.2.1 Proximity Detection Circuit

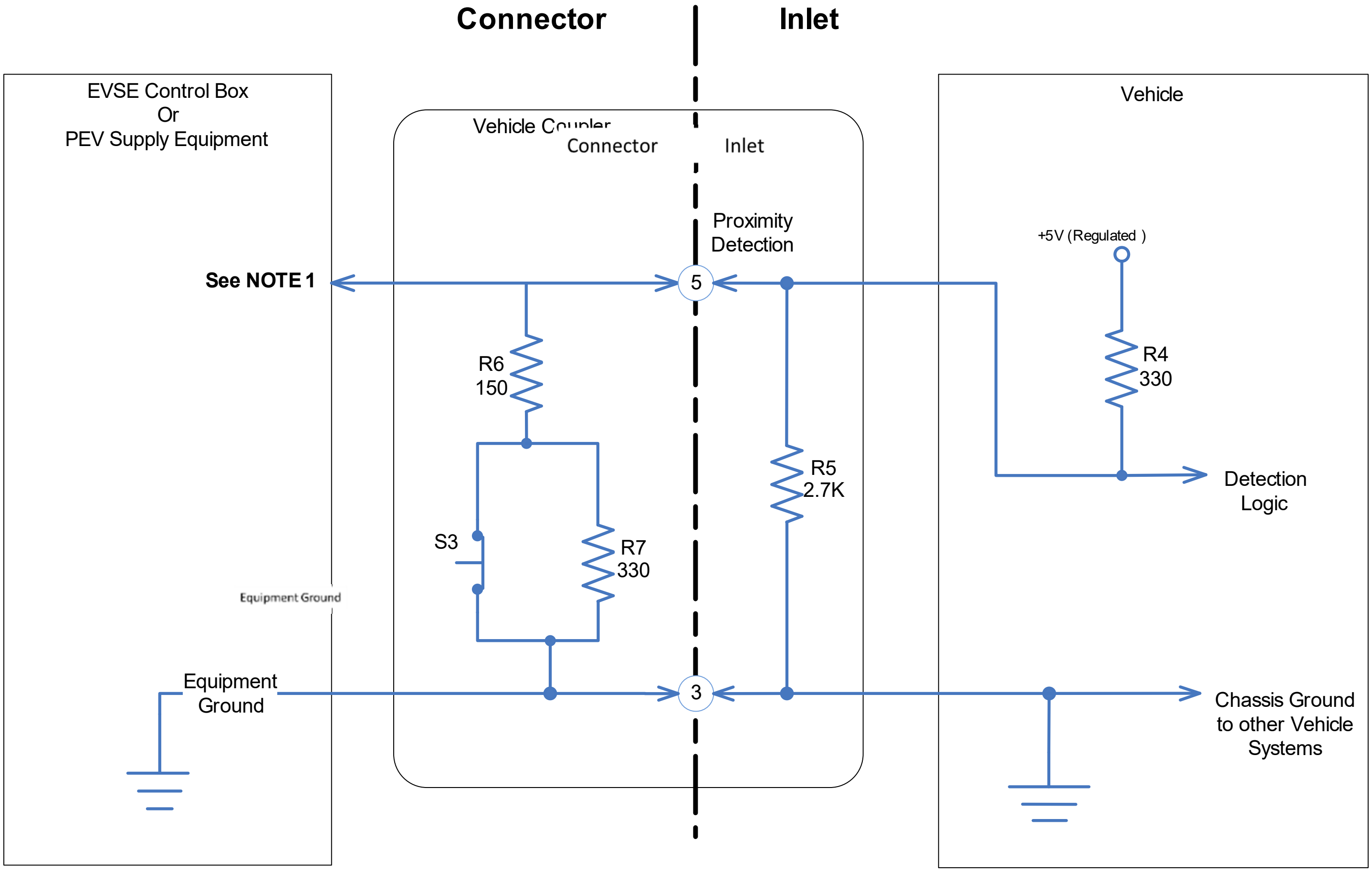


Figure 4 - Proximity detection circuit

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 6 - 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 7 - 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

NOTE: The tolerances described in Table 7 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 7. 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.

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%.

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 (4.6.5) 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 Requirements

4.5.1 Environmental

The on-board EV/PHEV charging system electronic components shall meet the requirements specified in SAE J1211 Handbook for Robustness Validation of Automotive Electrical/Electronic Modules.

4.5.2 Vehicle Movement with Mated Coupler

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

4.5.3 Control Pilot Continuity

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

4.6 EVSE Requirements

4.6.1 EVSE EMC Requirements

4.6.1.1 Electromagnetic Emissions

The following electromagnetic compatibility (EMC) paragraphs (4.6.1.1 thru 4.6.1.9) apply to the off-vehicle EVSE. SAE test methods for on-vehicle EV/PHEV charging equipment are under consideration.

The FCC Code of Federal Regulations – 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 CFR47, Title 47, Parts 15A, 15B as a separate device.

NOTES:

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.

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. See FCC rules for composite systems incorporating carrier current communication systems.

3. Additionally, some markets may regulate EMC via the relevant sections of IEC 61851-21, “Electric Vehicle Charging Systems”. Specific market requirements are outside the scope of this document

4.6.1.1.1 EVSE Conducted Emissions

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

4.6.1.1.2 EVSE Radiated Emissions

The EVSE shall meet FCC Part 15 radiated limits for unintentional radiators. See 4.6.1.1, Note 1.

4.6.1.2 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 Section 4.2 shall perform as designed during and after testing at the specified levels. Additional requirements may optionally be specified. See SAE J1812 for methods of specification of test levels and function performance status.

NOTES:

1. The UL 2231-2 standard specifies radiated immunity testing from 150 kHz to 1000 MHz, using IEC 1000-4-3. To avoid technical issues with the application of the IEC standard below its specified lower frequency limit of 80 MHz, it is recommended that immunity testing below 80 MHz be performed in accordance with IEC 61000-4-6, using a 20 volt rms emf test severity level. From 80 to 1000 MHz, IEC 61000-4-3 is recommended with a 20 V/m carrier test severity level.

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

4.6.1.3 EVSE Electrostatic Discharge

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

4.6.1.4 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.

4.6.1.5 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.

4.6.1.6 EVSE Voltage Dips, Short Interruptions and Voltage Variations Immunity

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

4.6.1.7 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.

4.6.1.8 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.

4.6.1.9 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.

4.6.2 Installation Requirements

The EVSE shall meet the requirements specified in the National Electrical Code – Article 625 and Canadian Electrical Code – Part 1, Section 86.

4.6.3 General Product Standards

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

4.6.4 Personnel Protection System

The EVSE shall incorporate a listed system of personnel protection as specified in UL 2231 Personnel Protection Systems for EV Charging Circuits.

4.6.5 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.

4.6.6 Conductor Cord Requirements

The conductor cord shall meet the requirements specified in the National Electrical Code – Article 625 and UL 2594 Electric Vehicle Supply Equipment.

4.7 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 National Electrical Code – Articles 625, UL 2251 Plugs, Receptacles, and Couplers for Electric Vehicles, and 4.7 and 4.9 of this document.

4.7.1 Ergonomic Requirements

The coupler shall comply with the following ergonomic requirements.

4.7.2 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.

4.7.3 Indexing

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

4.7.4 Tactile Feel

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

4.7.5 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.

4.7.6 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.

4.7.7 Safety Requirements

The coupler shall comply with the following safety requirements.

4.7.7.1 Surface Temperature

The maximum external surface temperature of the coupler shall be as specified in UL 2251 Plugs, Receptacles, and Couplers for Electric Vehicles. Surface Temperature test shall be conducted as per the requirements of “Surface Temperature” test in UL 2251.

4.7.7.2 Hazardous Conditions

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

4.7.7.3 Unauthorized Access

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

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

4.7.8 Performance Requirements

The coupler shall comply with the following performance requirements

4.7.8.1 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 4.7.9 of this document.

4.7.9 Environmental Requirements

The coupler shall comply with the following environmental requirements:

4.7.9.1 Temperature Range

The coupler shall be designed to withstand continuous ambient temperatures in the range of –30 to +50 °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.

4.7.9.2 Temperature Rise

The temperature rise of the coupler shall be as specified in UL 2251 Plugs, Receptacles, and Couplers for Electric Vehicles.

4.7.9.3 Insulation Resistance

The insulation resistance of the coupler shall be as specified in UL 2251 Plugs, Receptacles, and Couplers for Electric Vehicles.

4.7.9.4 Fluid Resistance

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

4.7.10 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.

4.7.11 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.

4.7.12 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.

4.8 Vehicle Inlet

4.8.1 Physical Dimensions

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

4.8.2 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.

4.8.3 Alignment

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

4.8.4 Isolation

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

4.8.5 Exposure of Contacts

The vehicle inlet shall be designed to prevent direct contact with live parts according to UL 2251 Plugs, Receptacles, and Couplers for Electric Vehicles.

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 Plugs, Receptacles, and Couplers for Electric Vehicles.

4.8.6 Sharp Edges

The vehicle inlet shall be free of sharp edges and potentially injurious protrusions per UL1439 Determination of Sharpness of Edges on Equipment.

4.8.7 Environmental Considerations

The vehicle inlet shall meet the performance requirements specified in 4.7.10 under weather and environmental conditions specified by the individual automobile manufacturers.

4.8.8 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 min/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 min.

   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.

4.8.9 Sealing Requirements

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

a. When de-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: Standard for Enclosures for Electrical Equipment as specified in UL 2251 Plugs, Receptacles, and Couplers for Electric Vehicles.

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: Standard for Enclosures for Electrical Equipment as specified in UL 2251 Plugs, Receptacles, and Couplers for Electric Vehicles.

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

4.9 Vehicle Connector

4.9.1 Physical Dimensions

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

4.9.2 Exposure of Contacts

The connector shall be designed to prevent direct contact with live parts according to UL 2251 Plugs, Receptacles, and Couplers for Electric Vehicles.

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 Plugs, Receptacles, and Couplers for Electric Vehicles

4.9.3 Sharp Edges

The vehicle connector shall be free of sharp edges and potentially injurious protrusions per UL 1439 Determination of Sharpness of Edges on Equipment.

4.9.4 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 Plugs, Receptacles, and Couplers for Electric Vehicles.

4.9.5 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 Plugs, Receptacles, and Couplers for Electric Vehicles.

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.

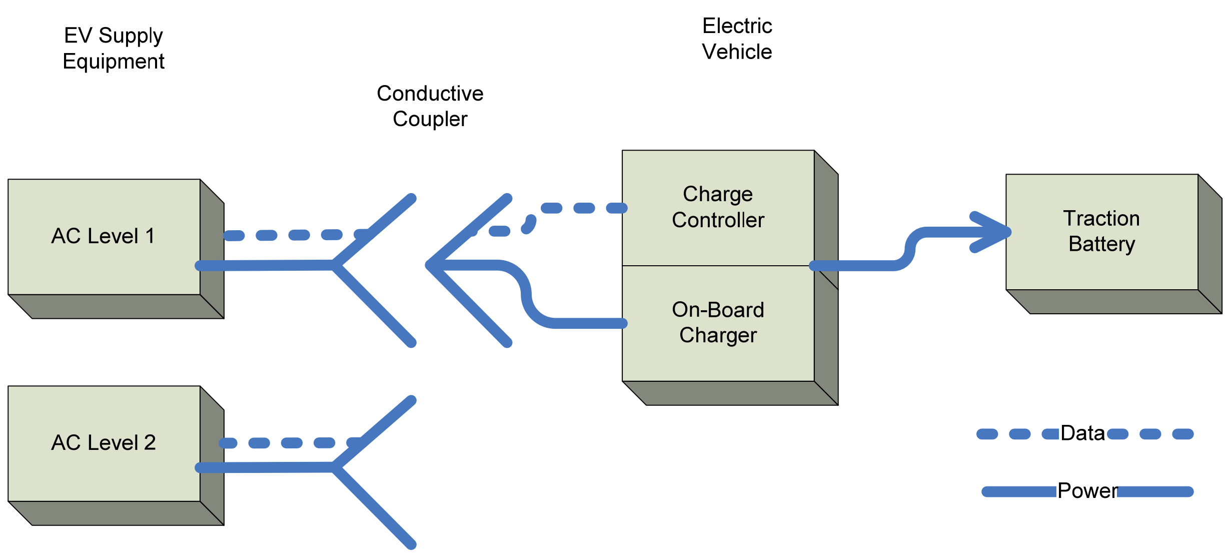


Figure 5 - AC conductive EV/PHEV charging system architecture

The interface consists of 5 contacts that perform the interface functions as shown in Figure 6 and specified in Table 8.

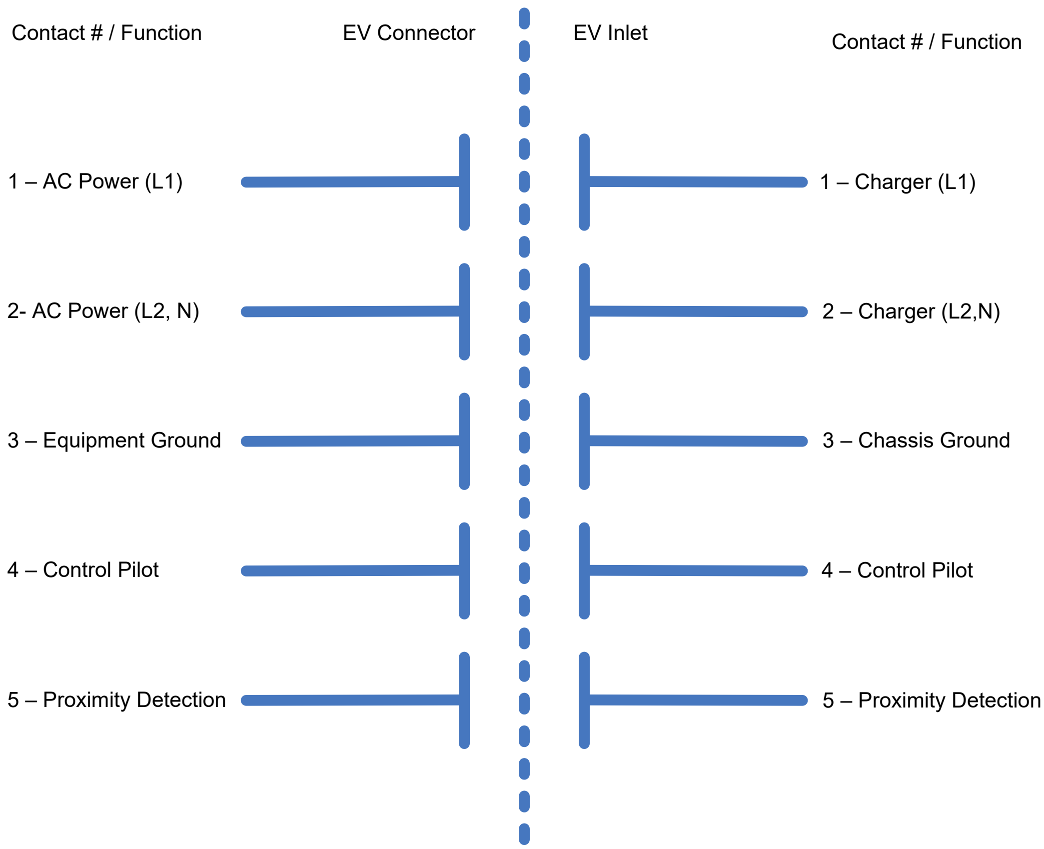


Figure 6 - AC level 1 and AC level 2 conductive coupler contact interface functions

Table 8 - 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 Section 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 9. AC level 1 allows connection to existing electrical receptacles in compliance with the National Electrical Code - Article 625.

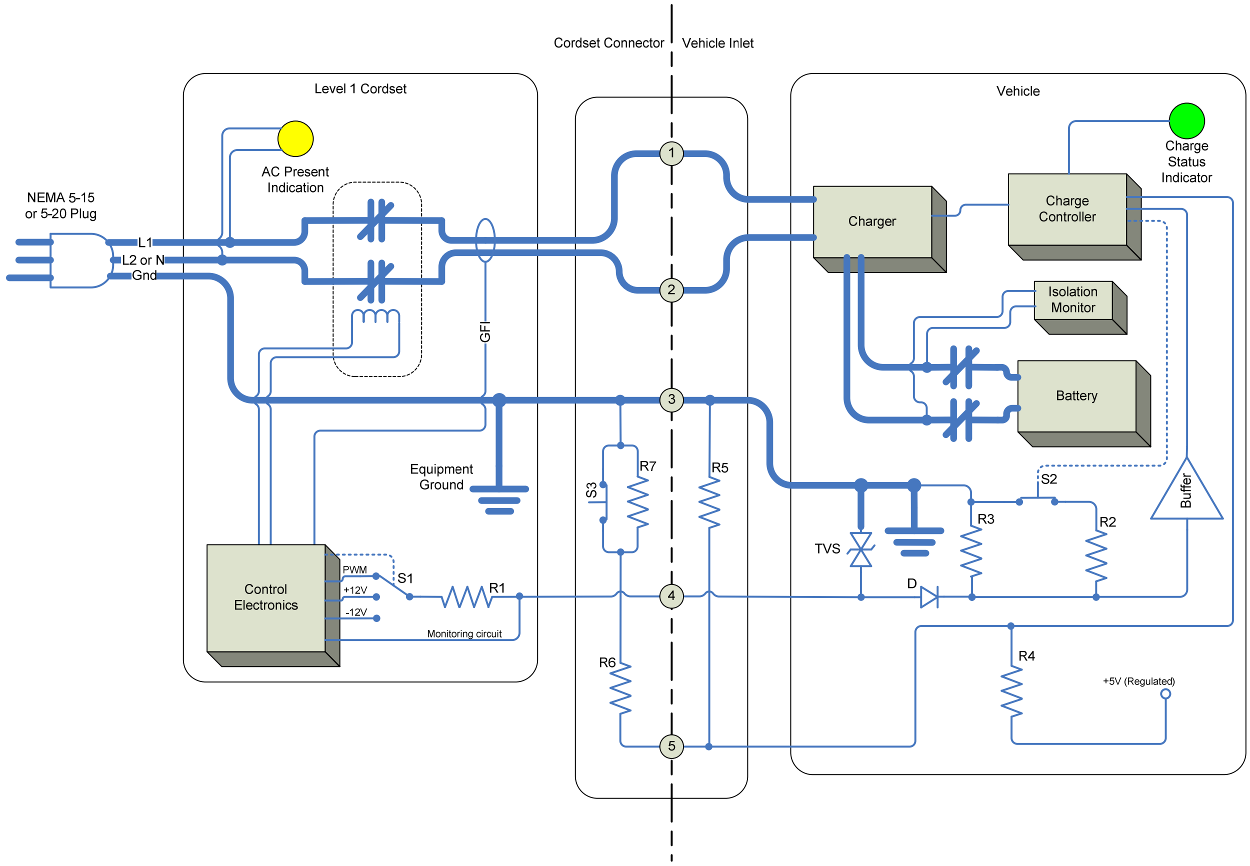


Figure 7 - AC level 1 system configuration
figure illustrates vehicle charging
Figure for illustration only. Not intended to constrain EVSE or EV/PHEV design.

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 9. AC Level 2 may be utilized at home, workplace, and public charging facilities.

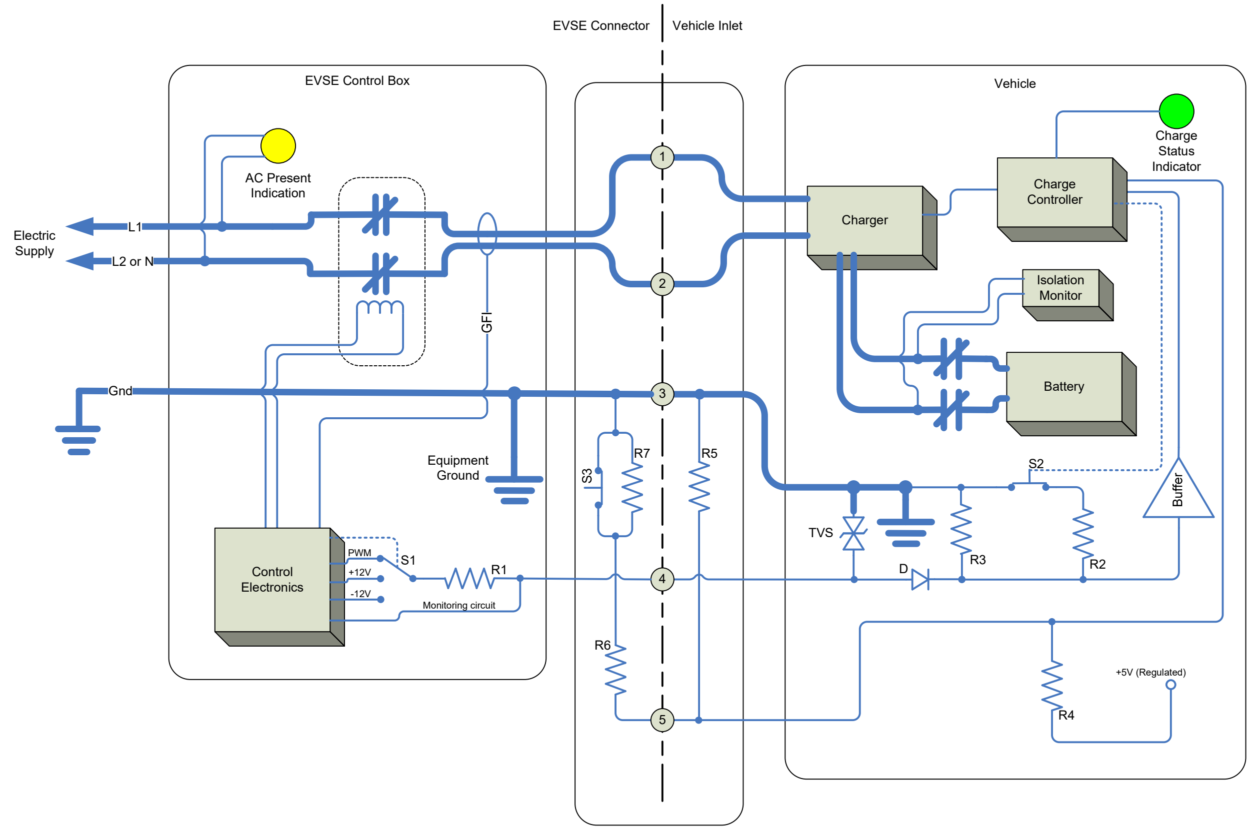


Figure 8 - AC level 2 system configuration
figure illustrates vehicle charging
Figure for illustration only. Not intended to constrain EVSE or EV/PHEV design.

5.1 Electrical Ratings

Table 9 - AC charging electrical ratings (North America)

Charge Method	Nominal Supply Voltage (V)	Max Current (Amps-continuous)	Branch Circuit Breaker rating (Amps)
AC Level 1	120 V AC, 1-phase	12 A	15 A (min)
	120 V AC, 1-phase	16 A	20 A
AC Level 2	208 to 240 V AC, 1-phase	≤ 80 A	Per NEC 625

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.

5.3 Digital Data Transfer

As defined in 0.

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

When optionally used with AC Level 1 & 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
- SAE J2931/1 & 4 - PLC Communication for Plug-in Electric Vehicles
- SAE J2953 - Plug-In Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE)

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

As defined in Appendix E.

5.5 EV/PHEV Requirements

As defined in 4.5.

5.5.1 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 240V AC energy transfer is Level 2 which is 80A using a 100A 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.

5.5.2 Coupler Disconnect Current Limit

Under consideration.

5.6 EVSE Requirements

As defined in 4.6 with addition below.

5.6.1 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. See SAE J1113-21 for bench grounding requirements.

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

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

e. The AC receptacle (or Level 1 EVSE) mains conductors shall be connected to a pair of 50 uH line impedance stabilization networks (LISNs), using conductors having a maximum length of 200 mm. The 50 Ohm LISN ports shall be terminated with 50 Ohm 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. See CISPR 16.1.2 for LISN specifications.

f. The cordset length shall be in accordance with NEC 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.

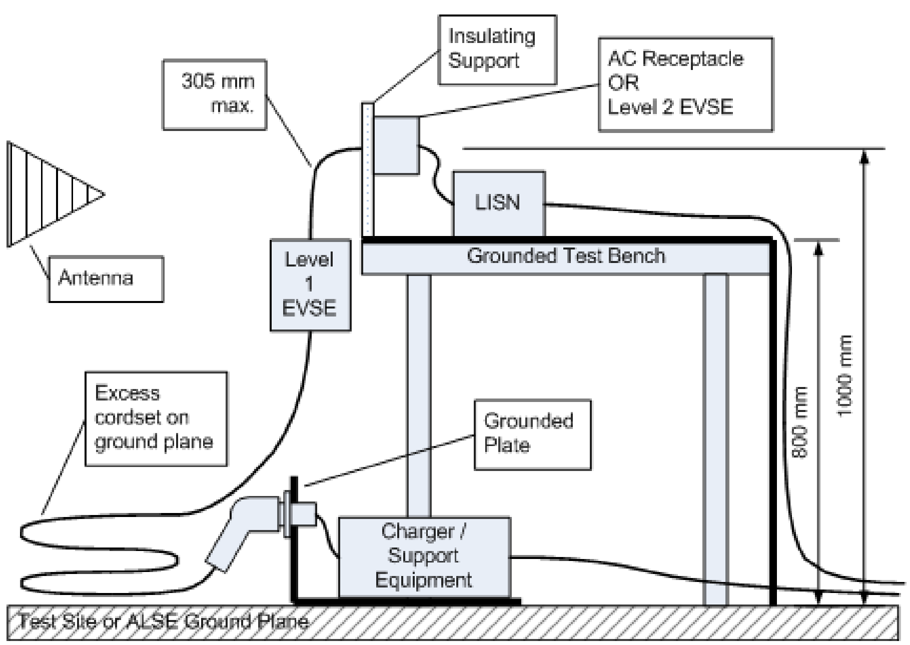


Figure 9 - Radiated immunity test setup

5.7 Charge Coupler Requirements

As defined in 4.7.

The general contact sizes at the coupler interface shall comply with the dimensions as specified in Table 10.

Table 10 - 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

5.8 Vehicle Inlet

A standard configuration shall be capable of AC Level 1 and AC Level 2 charging. The contact requirements shall be as specified in Table 10.

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.

5.9 Vehicle Connector

The connector shall be fitted with a cord corresponding to its intended usage and shall meet the requirements specified in the National Electrical Code – Article 625 for the power conductors, and UL 2251 - Plugs, Receptacles, and Couplers for Electric Vehicles, Table 15.1 for ground conductors.

Table 10 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-B3.

6. DC CHARGING

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

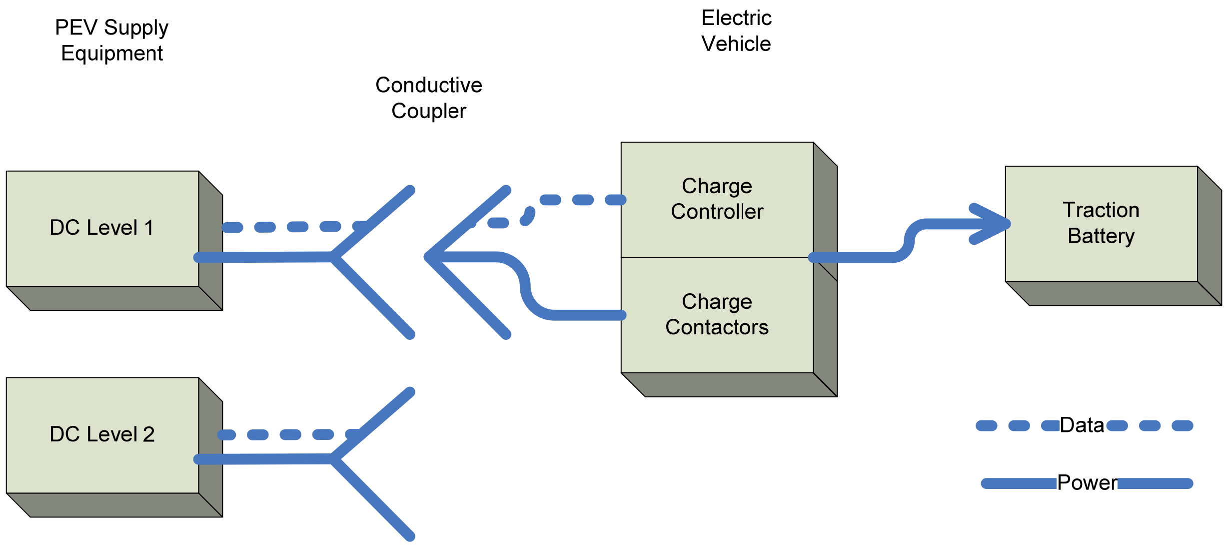


Figure 10 - DC conductive EV/PHEV charging system architecture

The interface consists of 7 contacts that perform the interface functions as shown in Figure 11 and specified in Table 11.

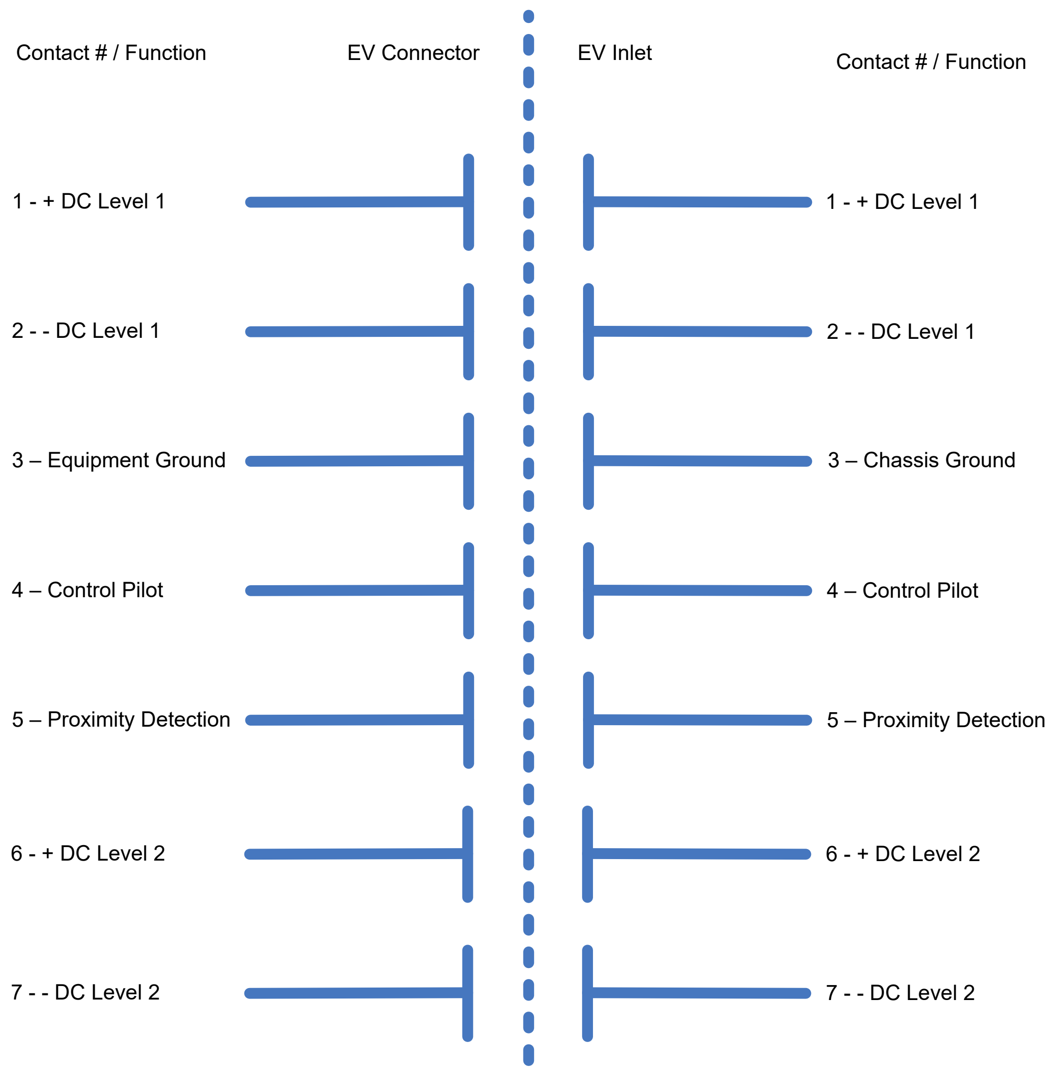


Figure 11 - DC level 1 and DC level 2 conductive coupler contact interface functions

Table 11 - 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 12. 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 & L2 between the PEV and EVSE, refer to APPENDIX I, Figures 22 & 23.

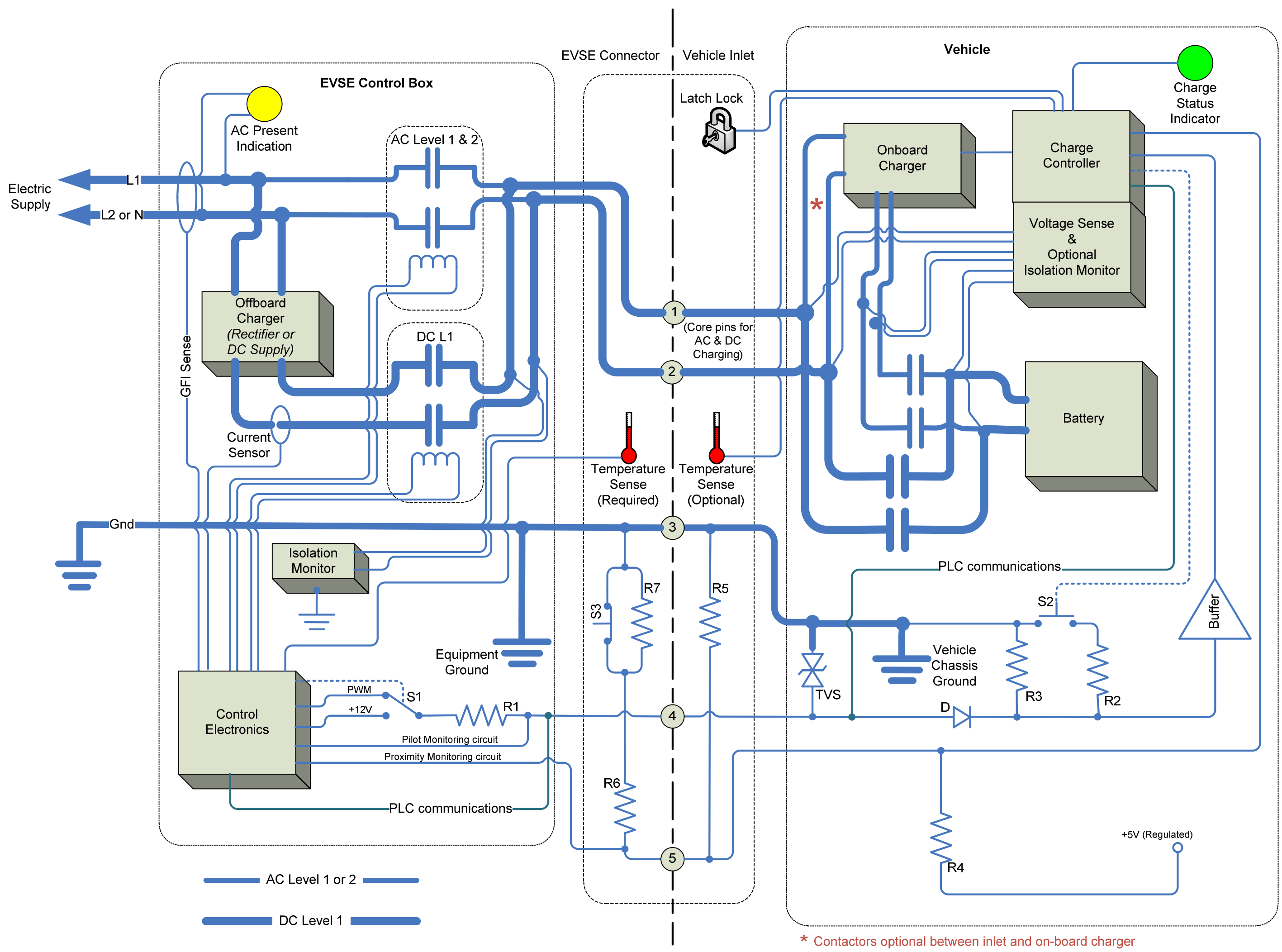


Figure 12 - DC level 1 system configuration
figure illustrates vehicle not charging
Figure for illustration only. Not intended to constrain EVSE or EV/PHEV design.

A method of DC EV/PHEV charging is shown in Figure 13 at the electrical ratings specified in Table 12. 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 & L2 between the PEV and EVSE, refer to APPENDIX I, Figures 22 & 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.

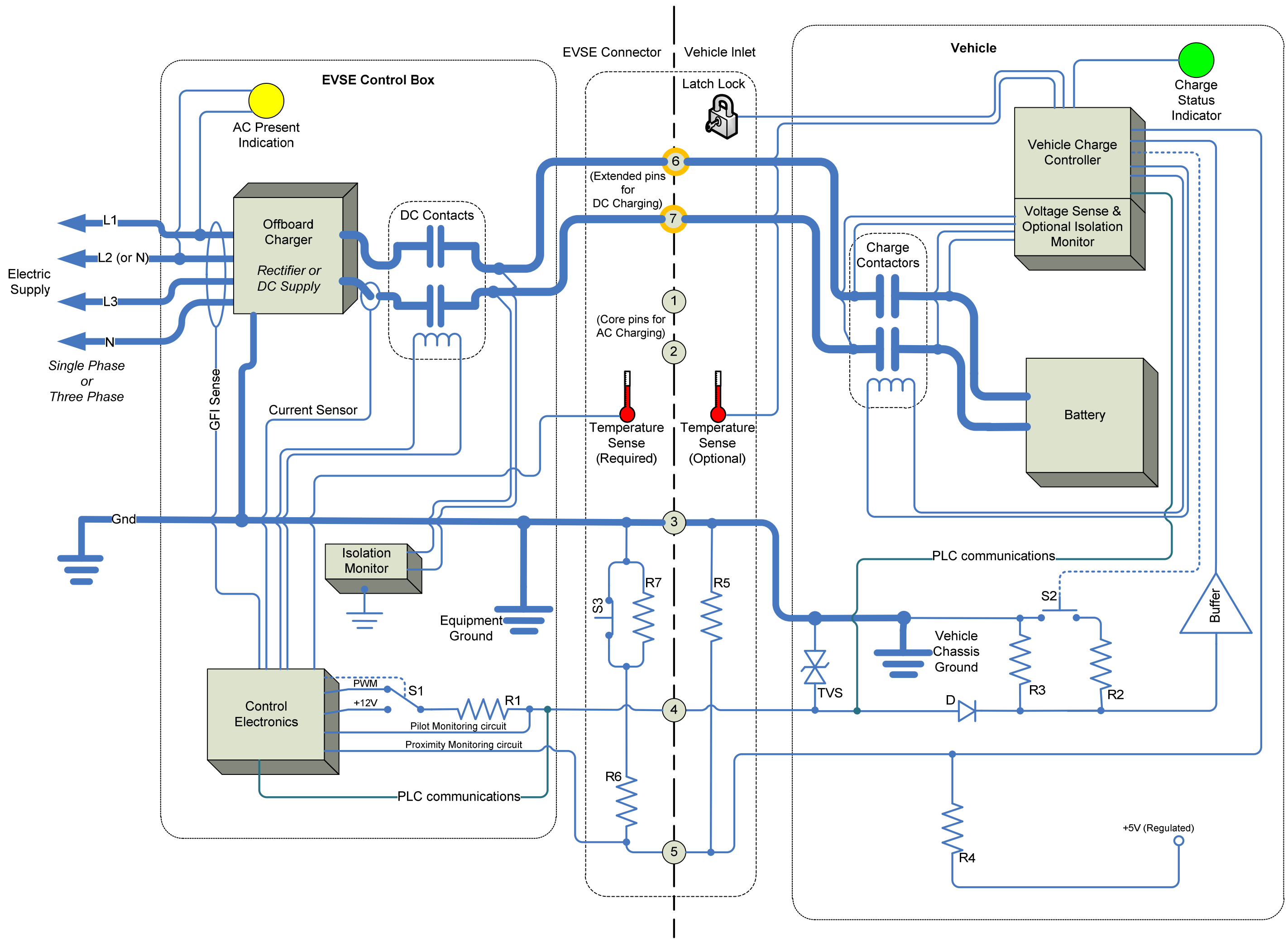


Figure 13 - DC level 2 system configuration
figure illustrates vehicle not charging
Figure for illustration only. Not intended to constrain EVSE or EV/PHEV design.

6.1 Electrical Ratings

Table 12 - DC charging electrical ratings (North America)

Charge Method	EVSE DC Output Voltage (V DC)	Max Current (Amps-continuous)
DC Level 1	50-1000	80
DC Level 2	50-1000	400

6.2 Charging Control and Information

6.2.1 Control Pilot

As defined in section 4.2.1 with addition below.

6.2.1.1 EVSE Shutdown – Control Pilot

The EVSE shall detect the loss of the Control Pilot (Control Pilot transition from State C (or D) to State A) and interrupt the DC output current to <= 5A within <= 30ms. See APPENDIX F.

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 4.

6.2.2.2 Valid Proximity Circuit voltages are defined in Table 7. EVSE input impedance shall have high input impedance (>= 10 MOhm) 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 7.

6.2.2.4 The EVSE shall not initiate a charge cycle unless a Proximity Circuit voltage (S3 closed) according to Table 7 is detected.

6.2.2.5 During a charge cycle the EVSE shall detect an invalid Proximity Circuit voltage and interrupt the DC output current to <= 5A within <= 30m s. Invalid Proximity Circuit voltage means any other voltage level than a Proximity Circuit voltage with S3 closed according to Table 7. See APPENDIX F.

6.2.2.6 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 SAE documents:

- SAE J2847/2 - Communication Between Plug-in Vehicles and Off-Board DC Chargers
- SAE J2931/1 & 4- PLC Communication for Plug-in Electric Vehicles
- SAE J2953 - Plug-In Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE)

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 section 4.5 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 manufacture. The Lock Function diagnostic shall be complete prior to the EV/PHEV closing S2.

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.

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 equation given below, and plotted in Figure 14:

$$C_{t,\max} = \begin{cases} \dfrac{0.4}{V_{\max}^2} & \text{for} \quad V_{\max} < 240 \\ \dfrac{0.0016}{V_{\max}} & \text{for} \quad 240 \le V_{\max} < 612 \\ 0.01387 \cdot V_{\max}^{-4/3} & \text{for} \quad 612 \le V_{\max} \end{cases}$$

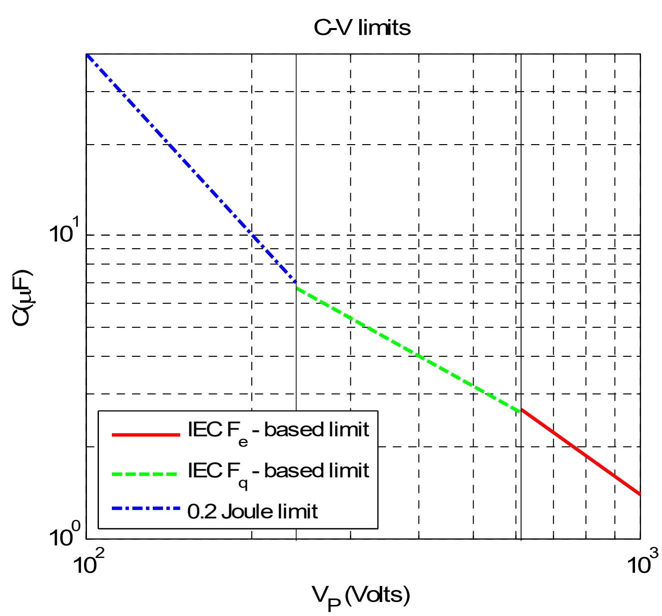


Figure 14 - Combined Y capacitance limit

The EV/PHEV total combined parallel Y capacitance ($C_{v,max}$) shall not exceed the calculated value ($C_{t,max}$) minus 1 uF allocated for the EVSE, reference 6.5.5. This implies equal Y capacitance of ½ $C_{v,max}$ 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. The specified values are based on IEC 60479-2 for voltages equal to 240 V and above, per the derivation of Appendix J. Capacitance limits are based on a capacitor energy limit of 0.2 Joules for voltages less than 240 V.

6.4.5 Loss of Communications

When DC charging control communications with the EVSE is lost, the EV/PHEV shall use the vehicle initiated shutdown sequence, see APPENDIX F. After the current output achieves <= 1 amp, the EV/PHEV shall open charge contactors <= 500mSec. This will allow the EVSE to discharge the HV bus.

6.5 EVSE Requirements

6.5.1 EVSE Electromagnetic Emissions

As defined in 4.6.1.

6.5.2 Installation Requirements

As defined in 4.6.2.

6.5.3 General Product Standards

The following replaces the requirements in 4.6.3.

The EVSE shall meet and be listed to the general product requirements for isolated circuits specified in UL 2202 Electric Vehicle (EV) Charging System Equipment.

6.5.4 Personnel Protection System

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

6.5.4.1 DC Output Isolation

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. The Total Isolation of the EVSE DC output shall be >= 1.25M ohm including any measurement/monitoring devices. This implies >= 2.5M ohm isolation between each DC rail and ground for an EVSE with isolation equally distributed between each DC rail and ground.

NOTE: Vehicle isolation requirements of 100 ohm/volt (DC) or 500 ohm/volt (AC or AC/DC) are stated in multiple documents including ECE 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 ohm/volt. 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 ohm/volt may not be able to charge.

6.5.4.2 DC Output Isolation Monitoring States

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

6.5.4.2.1 Invalid State

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

6.5.4.2.2 Valid State

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

6.5.4.2.3 Warning State

The EVSE shall send a Warning message to the vehicle and also log the warning internally when the isolation of either rail to ground < 250k Ω (500 ohm/V @ 500V) with an accuracy of +50k Ω, - 0 Ω. The EVSE shall detect the Warning state and send a Warning message <= 2 consecutive minutes of the isolation resistance <= 250kΩ.

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

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

6.5.4.2.4 Fault State

The EVSE shall terminate charge per section 6.5.4, send a Fault message to the vehicle, and log the fault internally when the isolation of either rail to ground < 50k Ω (100 ohm/V @ 500V) with an accuracy of +10k Ω, - 0 Ω. The EVSE shall detect the Fault state and indicate the Invalid State (6.5.4.2.1) <= 2 consecutive minutes of the isolation resistance <= 50kΩ.

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

NOTE: For EVSEs that measure total isolation resistance, the EVSE shall accommodate the unbalanced case where one rail to ground isolation is at the 50k ohm minimum value but the other rail to ground isolation is extremely high isolation resistance.

6.5.4.3 EVSE Measured Isolation Value

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

6.5.5 Maximum EVSE Output Y Capacitance

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

6.5.6 AC Present Indicator

As defined in 4.6.5.

6.5.7 Conductor Cord Requirements

As defined in 4.6.6.

6.5.8 Diagnostics Using High Voltage or High Energy

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

6.5.9 Vehicle Connector Interlock and Latch Diagnostics

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

6.5.10 DC Output Current Measurement Accuracy

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

6.5.11 DC Output Voltage Measurement Accuracy

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

6.5.12 DC Output Current Regulation

When in current regulation mode, the EVSE shall provide direct current to the vehicle. The maximum allowable error between the actual average DC current value and the vehicle commanded current value is:

± 150 mA when the commanded current value is less than or equal to 5A.

± 1.5 A when the commanded current value is greater than 5 A but less than or equal to 50A.

± 3% of the charger's maximum current output when the commanded current value is greater than 50A.

6.5.13 DC Output Descending Current Output Slew Rate

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

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

6.5.14 DC Output Current Ripple

During regulation the EVSE shall maintain a peak-to-peak current ripple as shown below.

Current ripple	**Frequency range**				
Present output current	**0 Hz < f < 10 Hz**	**f < 200 Hz**	**f < 5 kHz**	**f < 150 kHz**	**f >= 150 kHz**
0 A - 5 A	+/- 500 mA	+/- 500 mA	+/- 1.5 A	+/- 4.5 A	see IEC 61851-21
5 A - 50 A	+/- 0.75 A	+/- 3 A	+/- 3 A	+/- 4.5 A	
50 A - 100 A	+/- 1.5 A	+/- 3 A	+/- 3 A	+/- 4.5 A	
100 A - 400 A	+/- 3% of EVSEMaxCurrent	+/- 3% of EVSEMaxCurrent	+/- 3% of EVSEMaxCurrent	+/- 4.5% of EVSEMaxCurrent	

6.5.15 DC Output Voltage Ripple - No Load Voltage Regulation

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

6.5.16 DC Output Voltage Transient

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

Measuring point	between positive (+) and negative (-)	between positive (+) and ground	between negative (-) and ground
Limit	+/- 50 V	+/- 50 V	+/- 50 V

6.5.17 DC Output Current Overshoot Time

If Vehicle Maximum Current Limit (message defined in SAE J2847/2) is exceeded by more than the amount specified in 6.5.12 for more than 400mSec, the EVSE shall shut down due to a fault condition. This is the case where the current output is no longer under the control of the vehicle, and the charging station will use its conversion circuitry to reduce current flow.

6.5.18 DC Output Inrush

The EVSE shall limit its output inrush to <= 20% of the EVSE maximum rated current and shall not exceed 20A.

6.5.19 DC Output Short Circuit Test

Prior to enabling its high voltage DC output, the EVSE shall check for a short circuit between the high voltage DC+ and DC-in the charge cable, connector, vehicle inlet and vehicle cabling up to the vehicle DC charging disconnect. Short circuit is defined as minimum current of 1 amp up to 4% of max output current rating with a maximum of 5 amps. See Appendix F.

6.5.20 Loss of Communications

When DC charging control communications with the EV/PHEV is lost, the EVSE shall use the EVSE initiated shutdown sequence, see Appendix F. After the current output reaches <= 1 amp, the EVSE shall allow 500 mSec for the EV/PHEV to open its charge contactors before discharging the HV bus.

6.5.21 Connector Contact Area Temperature Monitor

The EVSE shall monitor the connector contact area temperature monitor and terminate charge when the temperature exceeds 105 °C.

6.5.22 Protection Against Unintended Reverse Power Flow

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

6.5.23 User Initiated Charge Termination

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

6.5.24 Available Current PWM Slew Rate Changes

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

6.5.25 DC Output Voltage Overshoot Time

If Vehicle Maximum Voltage Limit (message defined in SAE J2847/2) is exceeded by more than the amount specified in 6.5.12 for more than 400mSec, the EVSE shall shut down due to a fault condition. This is the case where the voltage output is no longer under the control of the vehicle, and the charging station will use its conversion circuitry to reduce current flow.

6.5.26 Voltage Deviation During Pre-Charge

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

6.5.27 Maximum Voltage Slew Rate in Normal Operation

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

6.6 Charge Coupler Requirements

As defined in section 4.7.

The general contact sizes at the coupler interface shall comply with the dimensions as specified in Table 13.

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

Table 13 - Contact size and electrical ratings

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

6.6.1 Retention Force

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

6.6.1.1 Axial Force

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

6.6.1.2 Torque

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

6.6.1.3 Cable Retention

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

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

6.6.2 Breaking Capacity

The coupler DC contacts are not rated for current interruption.

6.7 Vehicle Inlet

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

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

6.7.1 DC Level 1

The contact requirements for DC Level 1 shall be as specified in Table 13, contacts 1 through 5.

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

6.7.2 DC Level 2

The contact requirements for DC Level 2 shall be as specified in Table 13, contacts 3 through 7.

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

6.8 Vehicle Connector

The connector shall be fitted with a cord corresponding to its intended usage and shall meet the requirements specified in the National Electrical Code – Article 625 for the power conductors, and UL 2251 - Plugs, Receptacles, and Couplers for Electric Vehicles, Table 15.1 for ground conductors.

6.8.1 DC Level 1

The contact requirements for DC Level 1 shall be as specified in Table 13, contacts 1 through 5.

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

6.8.2 DC Level 2

The contact requirements for DC Level 2 shall be as specified in Table 13, contacts 3 through 7.

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

6.8.3 Connector Contact Area Temperature Monitor

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

7. NOTES

7.1 Revision Indicator

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

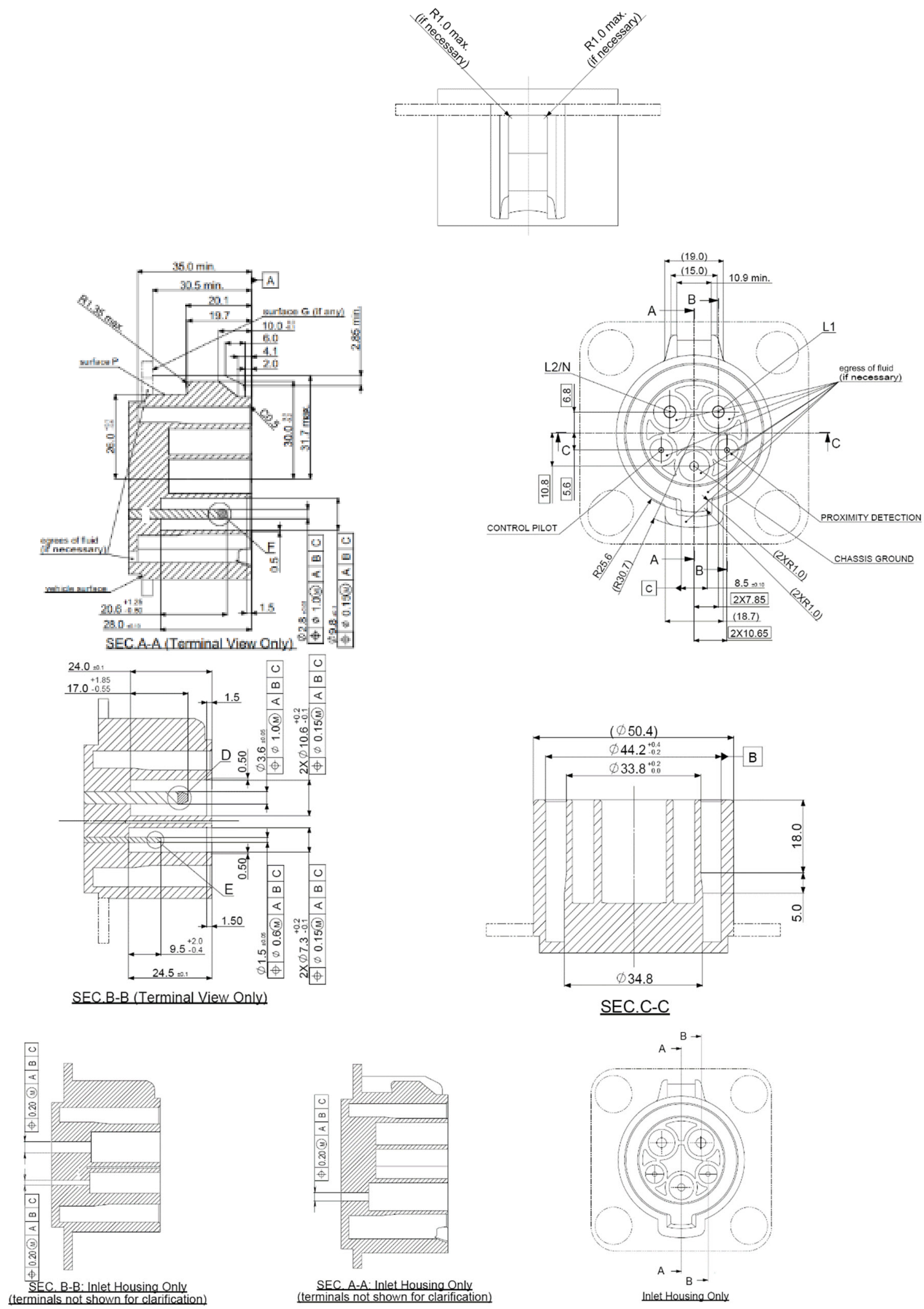
PREPARED BY THE SAE HYBRID - EV COMMITTEE

APPENDIX A - CHARGE COUPLER DIMENSIONAL REQUIREMENTS (NON LOCKABLE)

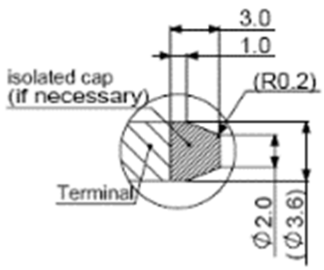
A.1 SCOPE

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

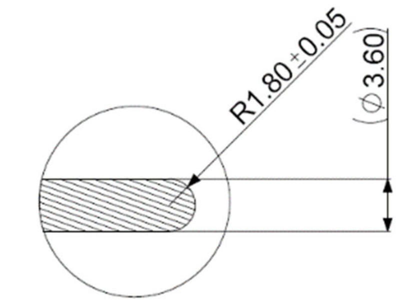
SHEET A-1
VEHICLE INLET



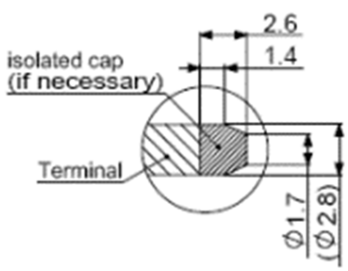
SHEET A-1
PIN DETAILS



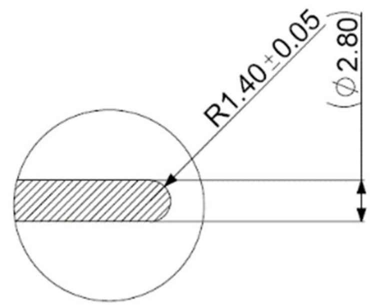
DETAIL D(L1,L2/N)



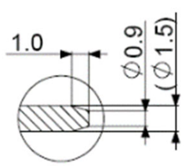
OPTIONAL CONSTRUCTION
(L1, L2/N)



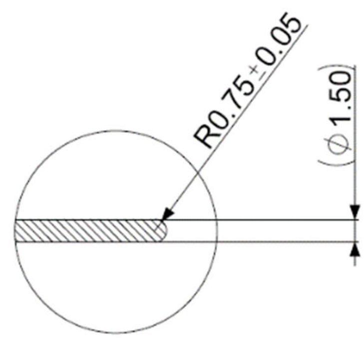
DETAIL F(Chassis Ground)



OPTIONAL CONSTRUCTION
(Chassis Ground)



DETAIL E
(Control Pilot, Proximity Detection)

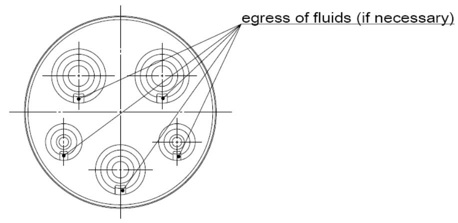


OPTIONAL CONSTRUCTION
(Control Pilot, Proximity Detection)

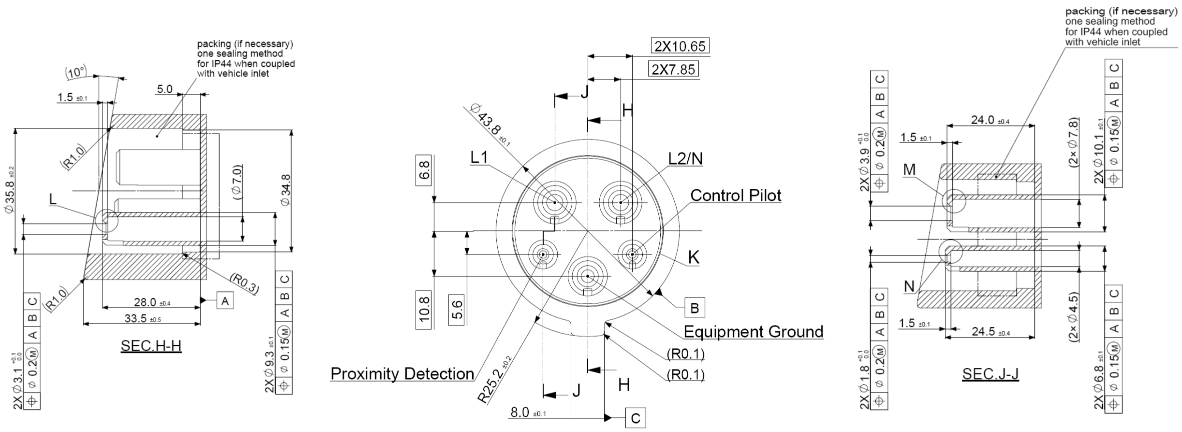
GENERAL TOLERANCE			
10 MAX	50MAX	100MAX	ANGLE
±0.15	±0.2	±0.3	±30'

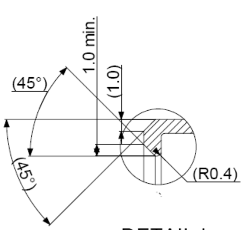
SHEET A-2
VEHICLE CONNECTOR

Third angle projection
Dimensions in millimeters
Values in parenthesis is for reference

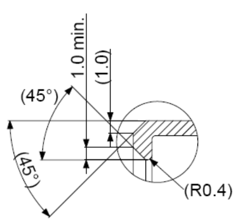


DETAIL K

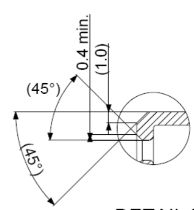




DETAIL L



DETAIL M



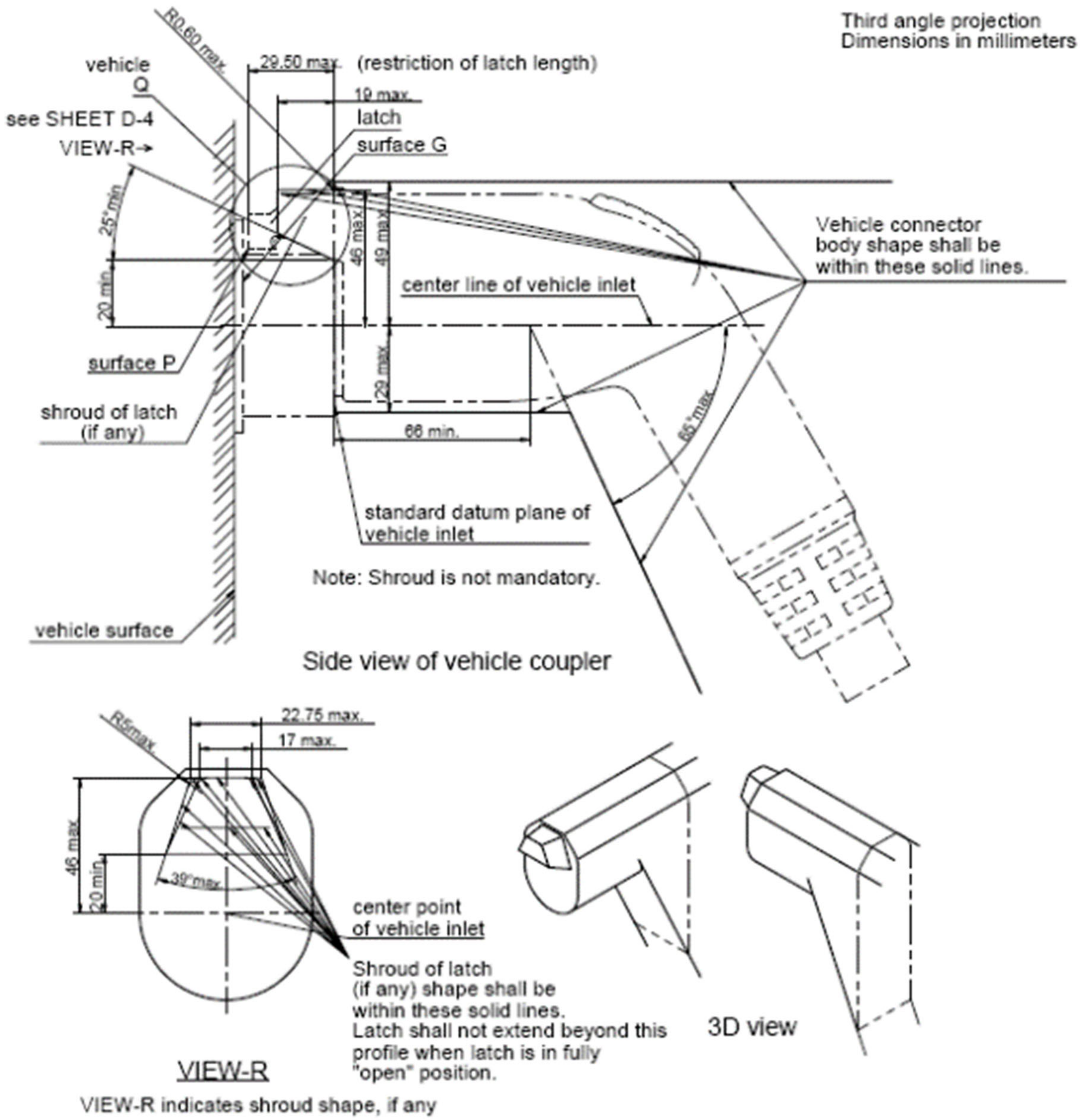
DETAIL N

GENERAL TOLERANCE			
10MAX	50MAX	100MAX	ANGLE
±0.15	±0.20	±0.30	±30'

SHEET A-3

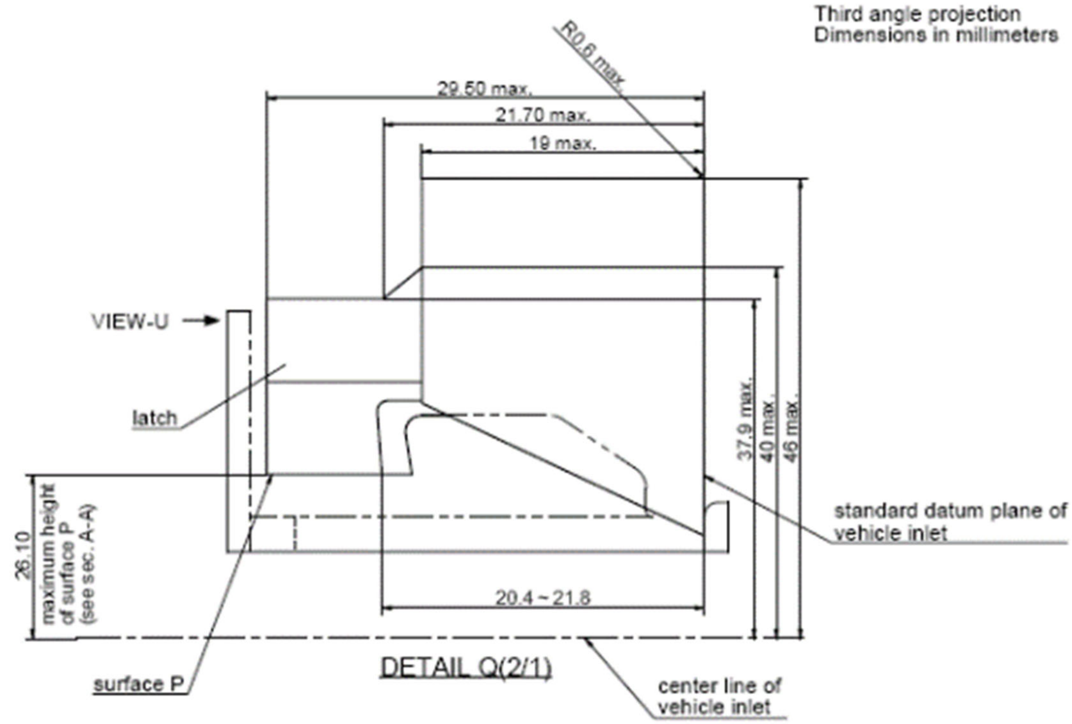
Latch shown in latched position

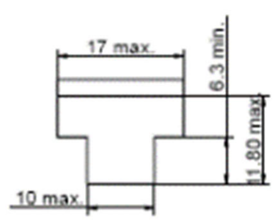
Note: Not recommended for new coupler designs.



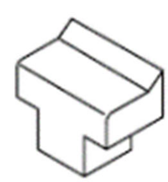
The sketches are not intended to govern design of vehicle connector body and latch shape except for dimensions shown.

SHEET A-4
MAXIMUM OUTLINE OF LATCH
Latch shown in touching surface P
Note: Not recommended for new coupler designs.
Refer to Sheets B-1 to B-3.





VIEW-U (indicates maximum outline of latch)

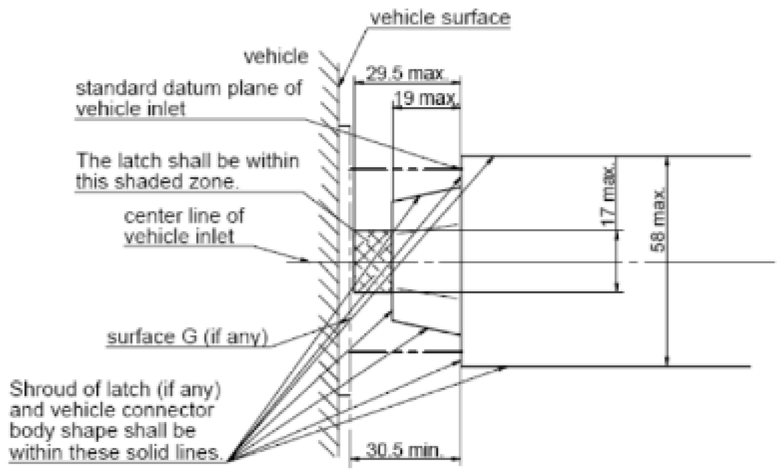


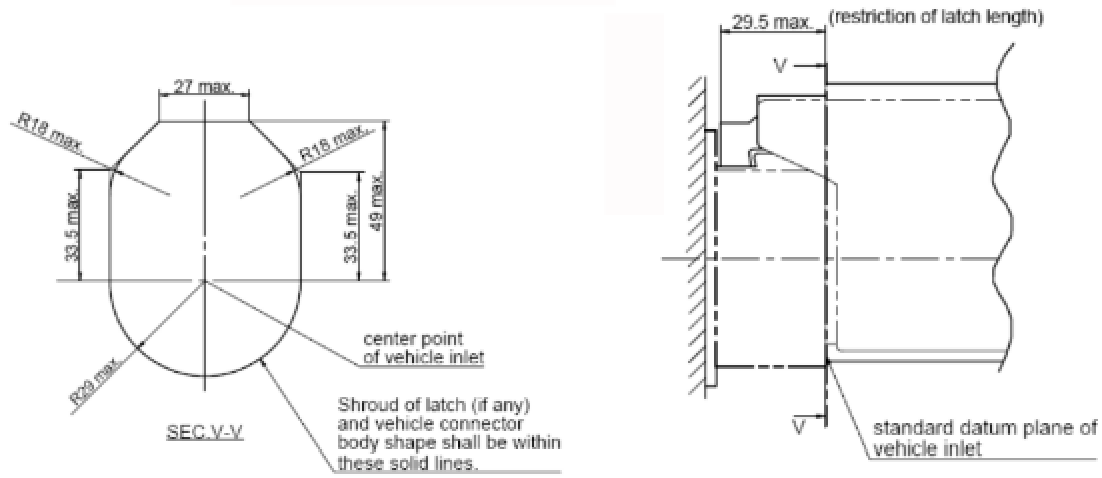
3D view

The sketches are not intended to govern design of latch shape except for the dimensions shown.

SHEET A-5
MAXIMUM DIMENSIONS OF VEHICLE CONNECTOR BODY AND LATCH OUT LINE
Note: Not recommended for new coupler designs
Refer to Sheets B-1 to B-3

Third angle projection.
Dimensions in millimeters





The sketches are not intended to govern design of vehicle connector body and latch shape except for the dimensions shown.

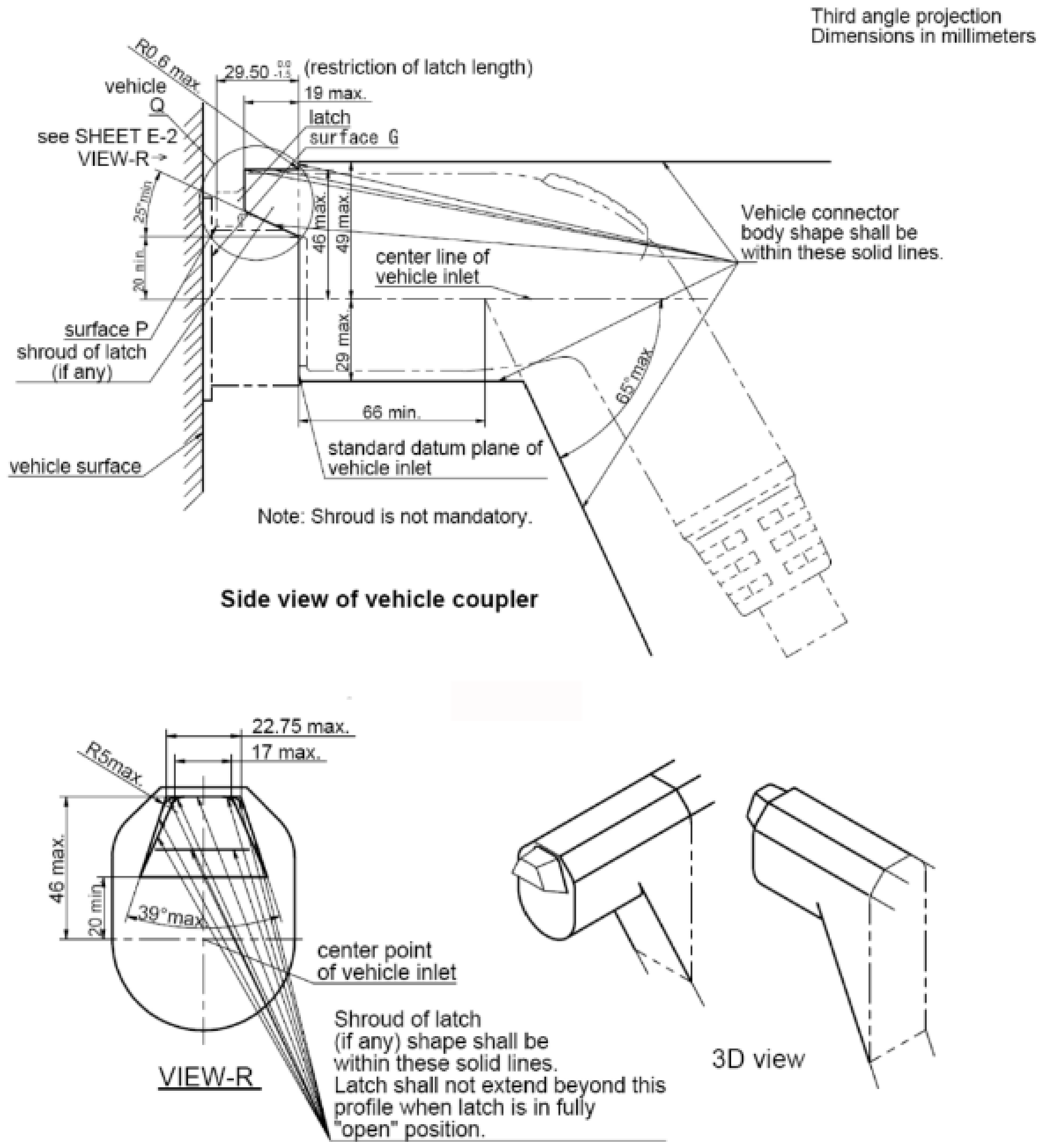
APPENDIX B - CHARGE COUPLER DIMENSIONAL REQUIREMENTS (LOCKABLE)

B.1 SCOPE

This appendix provides vehicle inlet access zone dimensional requirements for an optional lockable vehicle coupler. See sheets B 1-3.

SHEET B-1

Latch shown in latched position



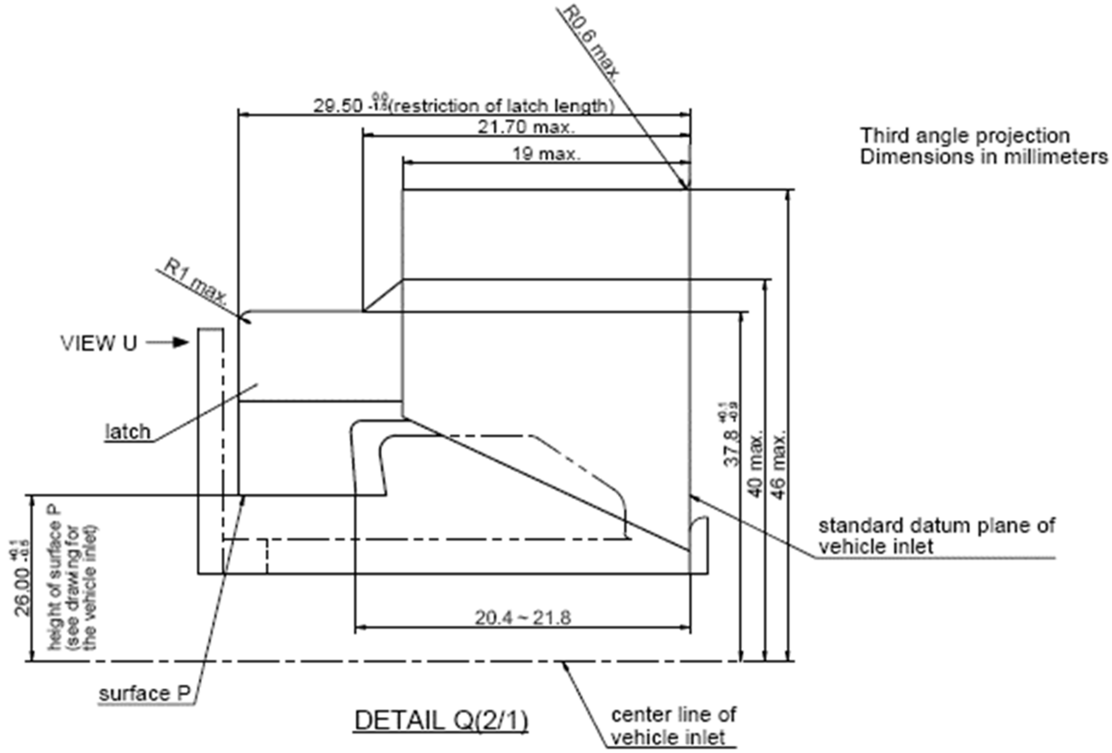
VIEW-R indicates shroud shape, if any

The sketches are not intended to govern design of vehicle connector body shape and latch shape except for the dimensions shown.

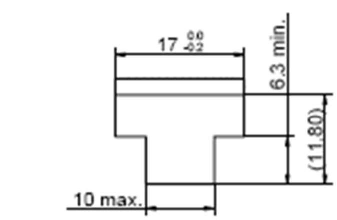
SHEET B-2

MAXIMUM OUTLINE OF LATCH

Latch shown in touching surface P



DETAIL Q(2/1)



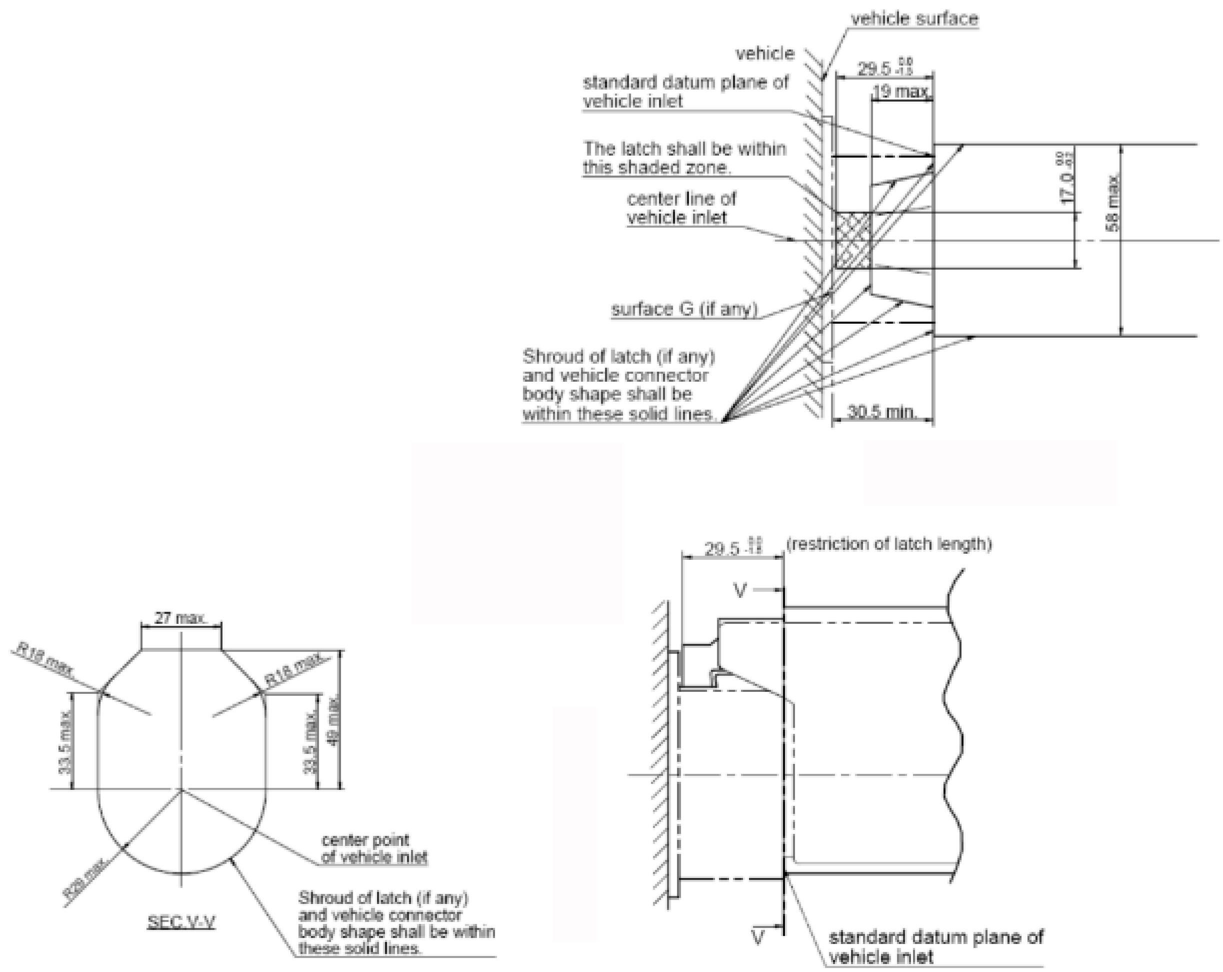
VIEW-U (indicates outline of latch.)

3D view

The sketches are not intended to govern design of latch shape except for the dimensions shown.

SHEET B-3
MAXIMUM DIMENSIONS OF VEHICLE CONNECTOR BODY AND LATCH OUT LINE

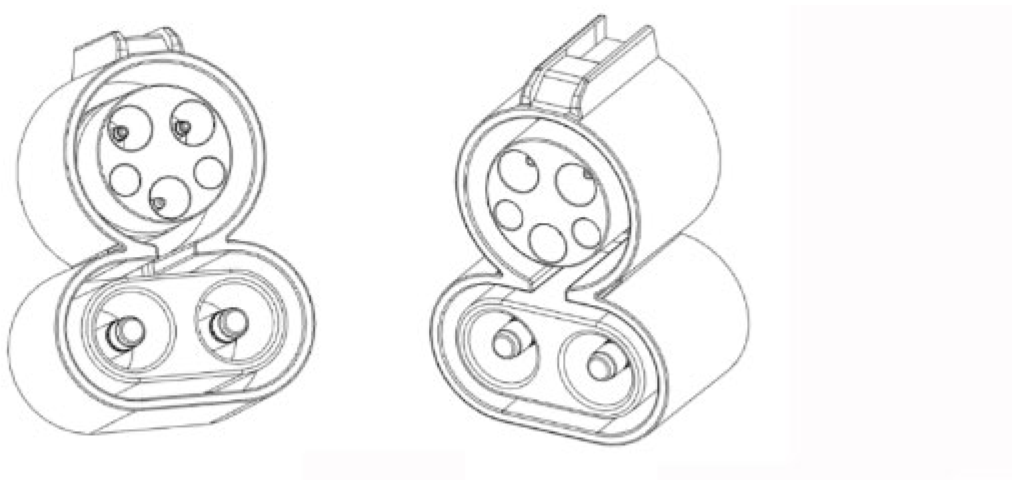
Third angle projection.
Dimensions in millimeters



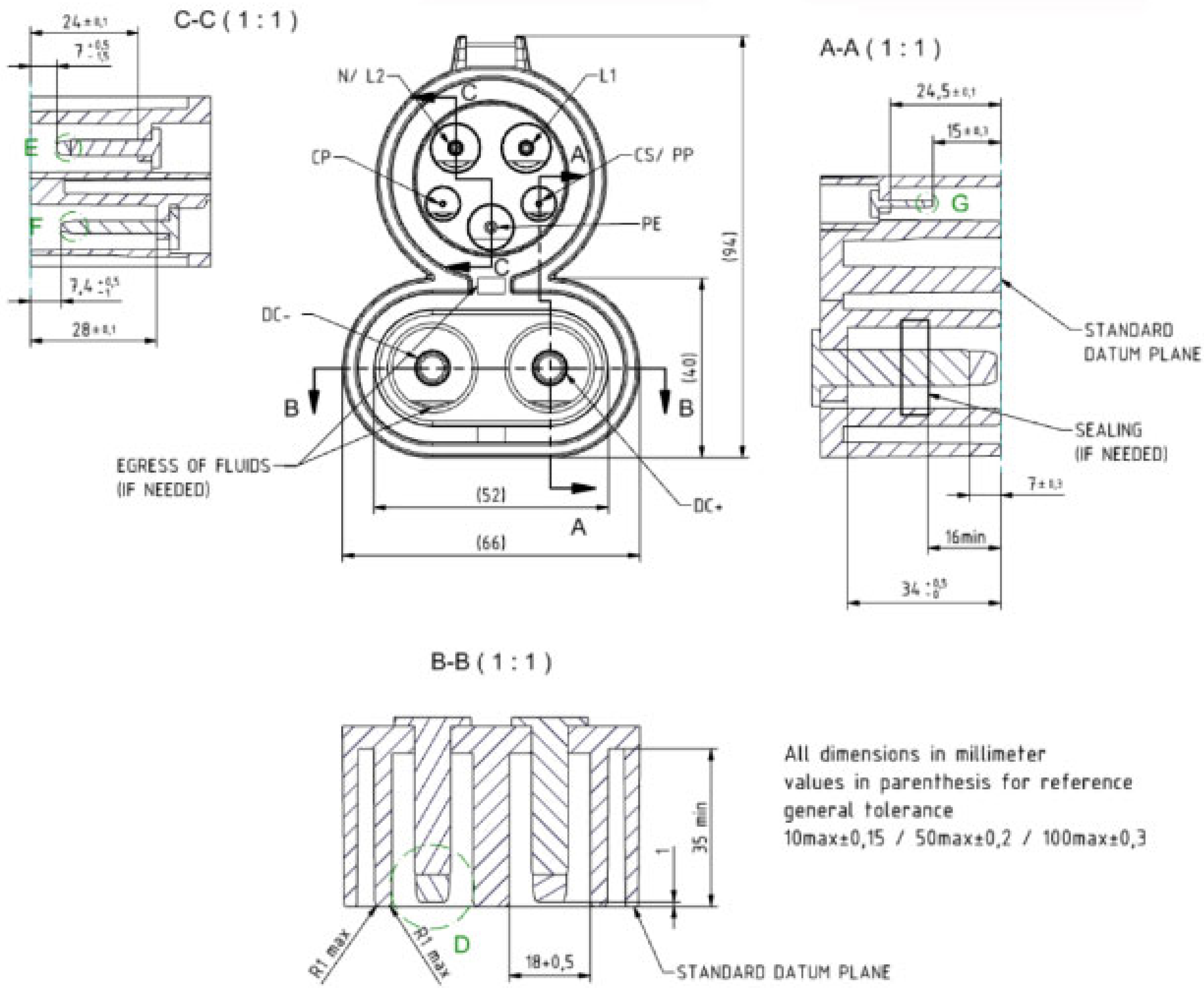
The sketches are not intended to govern design of vehicle connector body and latch shape except for the dimensions shown.

APPENDIX C - DC LEVEL 2 COUPLER

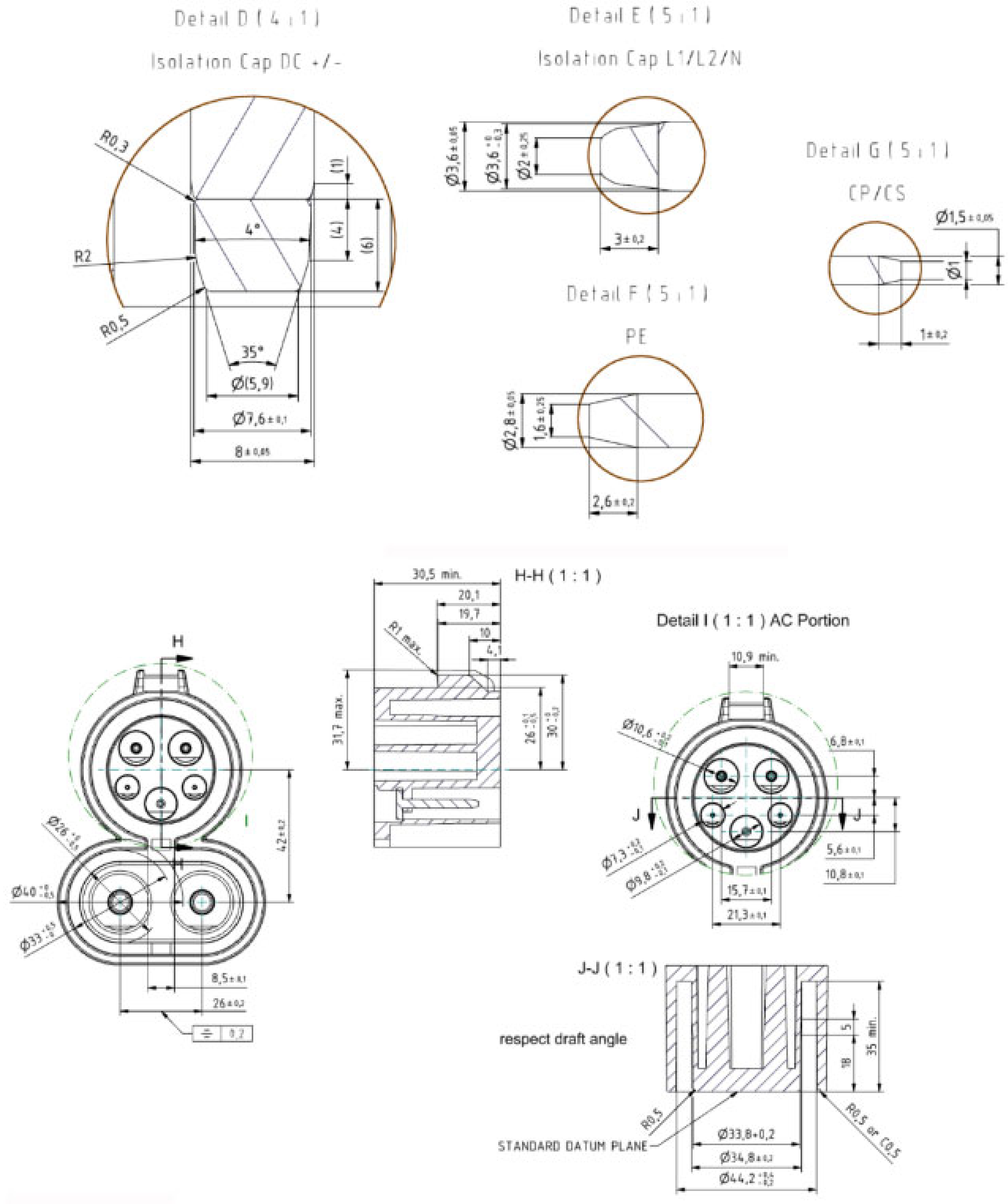
Sheet C-1



FOR ILLUSTRATION PURPOSES ONLY

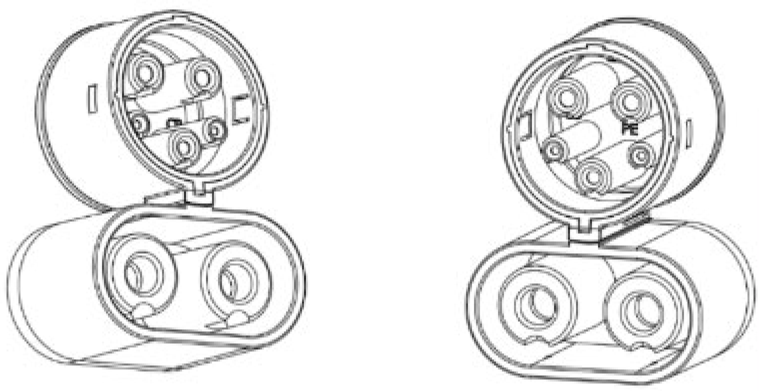


Sheet C-2

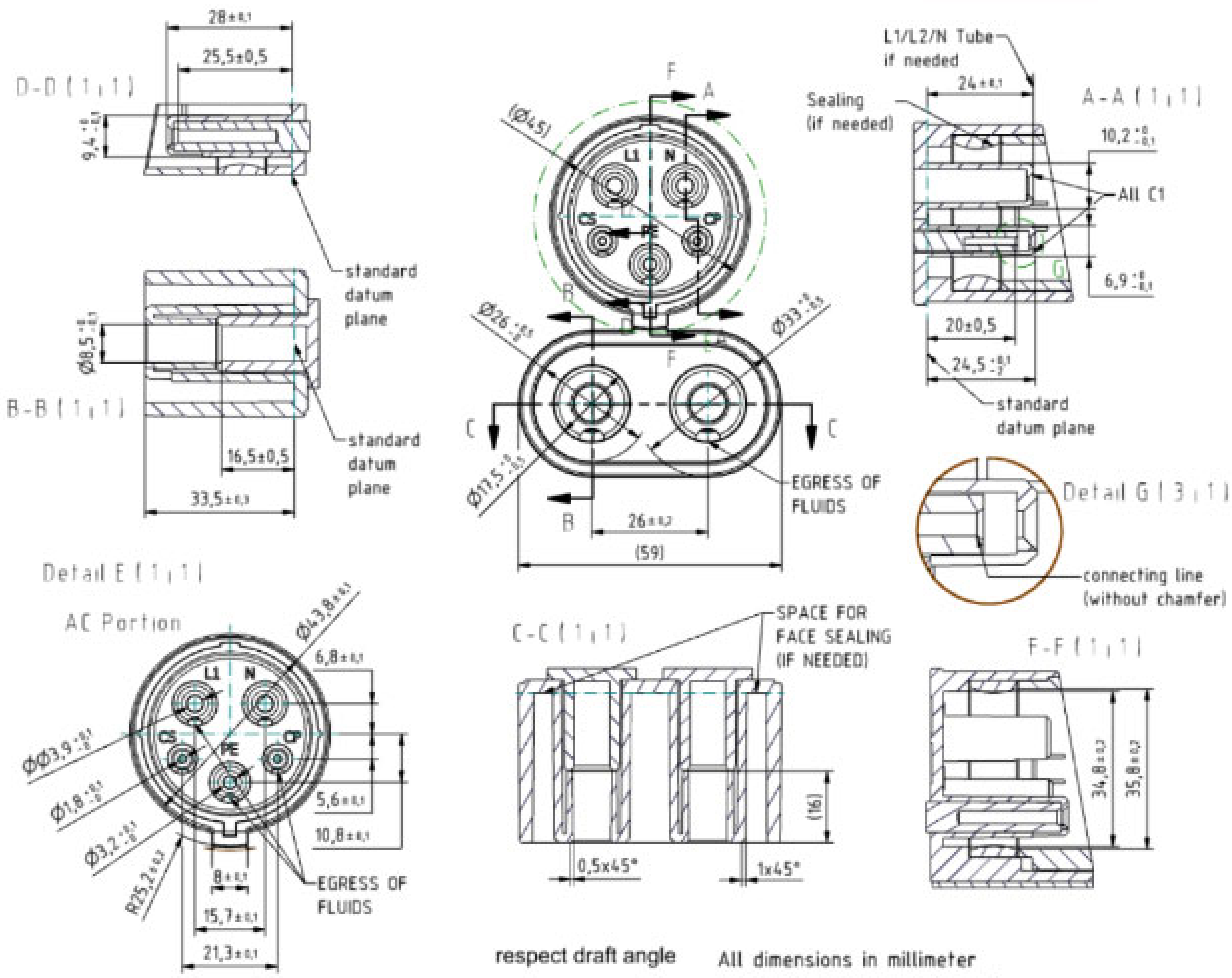


All dimensions in millimeter
values in parenthesis for reference
general tolerance:
10max±0,15 / 50max±0,2 / 100max±0,3

Sheet C-3



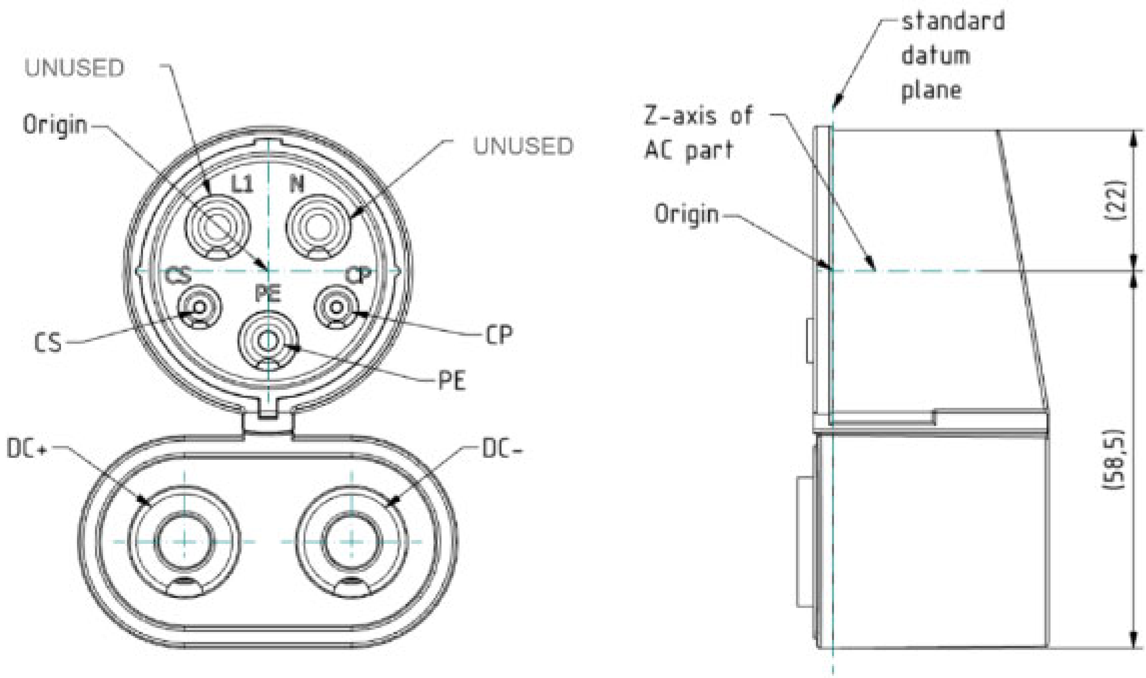
FOR ILLUSTRATION PURPOSES ONLY



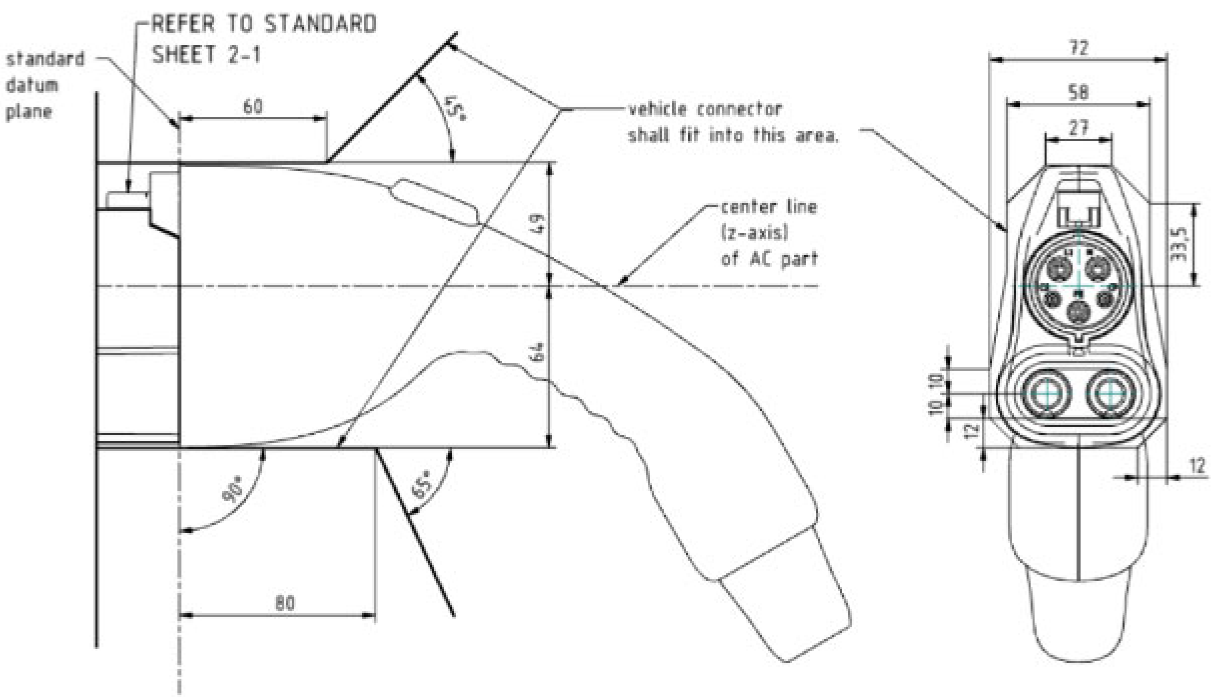
respect draft angle

All dimensions in millimeter
values in parenthesis for reference
general tolerance:
10max±0,15 / 50max±0,2 / 100max±0,3

Sheet C-4



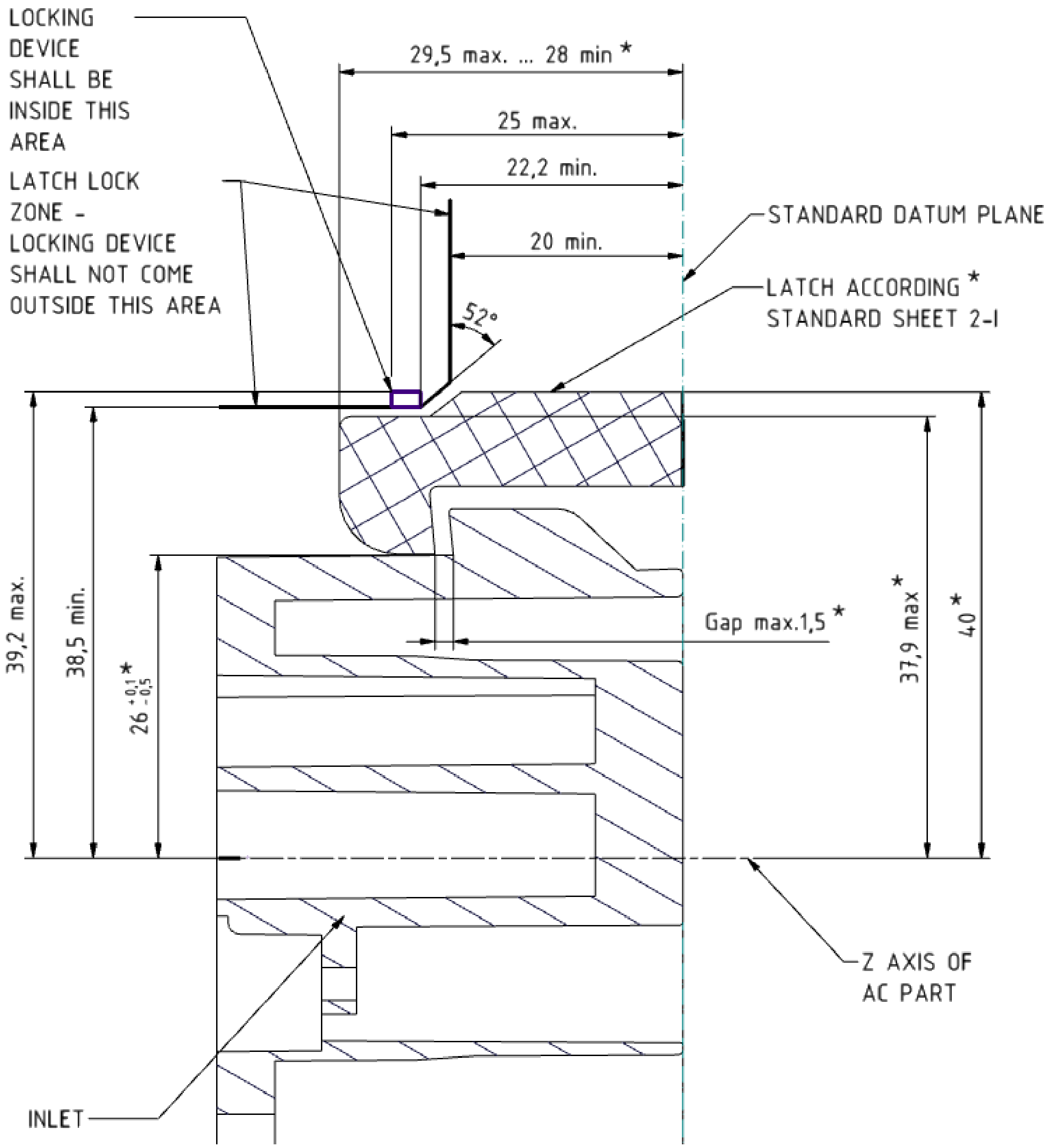
Dimension of vehicle connector body outline



All dimensions in millimeter
values in parenthesis for reference
general tolerance:
10max±0,15 / 50max±0,2 / 100max±0,3

APPENDIX D - VEHICLE INLET LOCK FUNCTION ZONE DEFINITION

Sheet D-1



All dimensions in mm;

* reference dimensions
according IEC 62196-2
standard sheet 2-I

Vehicle connetor switch - S3;
Switch should not abort while press button
during charging process.

APPENDIX E - EVSE AND EV/PHEV SEQUENCE AND RESPONSE TIME SPECIFICATIONS

E.1 START UP SEQUENCE

The charge process shall commence sequentially according to the following steps as the connector is inserted into the vehicle inlet:

a. The control pilot activates the EV/PHEV charge controller, the proximity detection activates the drive interlock.

b. Verification of EV/PHEV connection is detected by EVSE, by detecting a change from State A to State B1. During this state change the oscillator is off. See switch S1.

c. EVSE indicates that it is ready to supply energy by turning on the oscillator and supplying PWM pilot signal to the EV/PHEV, State B2. See switch S1.

d. The EV/PHEV vehicle determines the nature of and available current from the EVSE according to 1 of the following 3 conditions by measuring the duty cycle of the signal and proceeding as follows (see 4.2.1.4.1 – 4.2.1.4.5 and Table 5):

    a. If the pilot duty cycle is between 10% and 96%, calculate available line current from the duty cycle and proceed to the next step.

    b. If the pilot duty cycle is between 3% and 7%, calculate available line current from the digital data link and proceed to the next step. See section 5.3.

    c. If the digital data link cannot be established as described in section 5.3, the process shall be terminated and a fault condition displayed by the EVSE

e. The EVSE determines that the equipment grounding conductor to the EV/PHEV chassis ground is in place by detecting the high side of the Pilot is in State B1, B2, C, or D, while the low side is at –12V.

f. The EVSE determines that the EV/PHEV pilot control circuitry is correctly configured by verifying the presence of the diode. The low side of the pilot pulse shall be within the range specified in Table 3.

g. EV/PHEV indicates that it is ready to accept energy from the EVSE by closing switch S2 and providing vehicle ventilation information to the EVSE, State C or State D.

h. The EVSE determines if indoor area ventilation is required or not. If indoor charging area ventilation is not required then proceed to the next step. If indoor charging area ventilation is required then 3 conditions can exist with corresponding EVSE responses. They are:

    a. Condition 1 – If the EVSE is listed for indoor charging of all vehicles, turn on the indoor area ventilation system and proceed to the next step.

    b. Condition 2 – If the EVSE is listed for outdoor charging of all vehicles, proceed to the next step

    c. Condition 3 – If the EVSE is listed for vehicles not requiring indoor charging area ventilation, terminate the process and do not allow energization

i. The EVSE may now energize the system by closing the main power contactor and charging may commence at power levels up to the rated maximum continuous current of the EVSE for continuous rated conditions, or up to the rating of the protective circuit breaker for non-continuous conditions, or up to the maximum rated current of the EVSE for DC charging as provided by the digital data link. A continuous load is defined as operating at a given level for more than 3 hours.

j. The pilot signal shall be monitored, and charge current adjusted accordingly, continuously during the charge process. If pilot signal is lost or the pulse width goes outside of the allowable range, the EVSE shall terminate the charge process by opening the main contactor and turning off the pilot oscillator. The EVSE should also display a fault condition.

k. To terminate the charge process, turn the EVSE on/off switch to the off position and/or remove the connector from the vehicle inlet (see 4.2.2).

E.2 RESPONSE TIME SPECIFICATIONS

Table 14 - EVSE and EV/PHEV response time specifications for AC charging

Transition	Initial Condition(1)(2)(3)	New Condition	EVSE Response Time	EV/PHEV Response Time	Specification or Condition
1	State = x OSC = off	State = x OSC = on	no max		Delay until pilot oscillator will be turned on by EVSE.
2	State = x OSC = x	State = A OSC = x	100 ms max		Delay from disconnect until the contactor opens and terminates AC energy transfer
3	State = x OSC = x	State = E or State = F OSC = x		5 second max	Delay until EV/PHEV opens battery isolation contactor.
4	State = x OSC = on	State = A OSC = off	2 second max		Delay until oscillator is turned off after EV/PHEV is disconnected.
5	State = B2 OSC = on	State = C or State = D OSC = on	3 second max		Delay until contactor closes and initiates AC energy transfer in response to S2 closed.
6	State = C or State = D OSC = on	State = B2 OSC = on	3 second max		Delay until contactor opens and terminates AC energy transfer in response to S2 opened.
7	State = x OSC = x	State = A or State = E or State = F OSC = x		4 second max; timed from the invalid pilot condition	In response to an invalid pilot the EV/PHEV shall reduce charge to 1A or less within 4 seconds. ($I \leq 1.0A$ @ $t \leq 4.0$ seconds).
8	State = x OSC = x	State = E or State = F OSC = x	3 second max		Delay from EVSE setting invalid pilot until termination of AC energy transfer.
9	State = B2 or State = C or State = D OSC = on	invalid pilot frequency		4 second max	In response to an invalid pilot frequency the EV/PHEV shall reduce charge to 1A or less within 4 seconds. ($I \leq 1.0A$ @ $t \leq 4.0$ seconds).
10	State = x OSC = x	external signal to EVSE	10 second max		Delay from external load management signal until EVSE modifies pilot signal state, duty cycle or other required response.
11	State = C or State = D OSC = on	change in pilot duty cycle		5 second max	EV/PHEV modifies max current draw for on-board battery charger in response to pilot signal duty cycle modification.
12	State = C OSC = on	State = D OSC = x	3 second max		EVSE response to change of ventilation request.
13	State = C or State = D S3 closed	State = C or State = D S3 open		100 ms max	EV/PHEV terminates charge due to Proximity circuit opening (pressing of S3).
14	State = B1 OSC = off	State = B2 OSC = on	no max		EVSE transitions from not ready to supply energy to ready to supply energy.

1. Current State from Table 14 & 15 defining pilot voltage and vehicle state.
2. OSC = off for pilot oscillator turned off, OSC = on for pilot oscillator turned on.
3. x for state or oscillator indicates any condition or unknown condition.

NOTES: (Note number corresponds to transitions in Table 14):

1. The pilot signal oscillation indicates that the EVSE is ready to supply energy. Regardless of the state transition, there is no guarantee that the EVSE will be ready to supply AC energy within a minimum time period.

2. The transition from any State to State A indicates the vehicle connector has been removed. For safety reasons, it is important to de-energize the connector.

3. The transition from any State to State E or State F is an indication that the connector has been removed or that the EVSE is not available.

While in State F, the EVSE may optionally attempt to automatically restart the charge sequence while connected to an EV/PHEV. The EVSE shall limit the optional restarts to a maximum of 20 with a 15 minute minimum time interval between restart attempts. If the charge cycle does not restart within the maximum of 20 optional restarts, user intervention is required to reset the EVSE to restore normal operation.

4. After a transition from any State to State A, the EVSE should turn off the oscillator (S1). For the purpose of filtering and reasonable control response time, the EVSE shall not turn off the oscillator immediately. The connector may be immediately reinserted into the vehicle, and the EV/PHEV could see State C or State D with the oscillator turned on and no AC energy transfer for the listed maximum time before the oscillator is turned off.

5. After the vehicle closes S2 in order to request AC energy transfer, the vehicle can expect the contactor to close within a specified time period.

6. After the vehicle opens S2, in order to stop requesting AC energy transfer, it can expect the contactor to open within a specified time period.

7. The vehicle should respond to the pilot signal voltages. In this case, the EVSE could be experiencing a power outage, ground fault, or other condition that requires termination of the AC energy transfer mode. The vehicle shall reduce charge to 1A or less within 4 seconds timed from the invalid pilot condition. ($I \leq 1.0A$ @ $t \leq 4.0$ seconds).

8. If the EVSE transitions to State E or F, the EVSE shall open the contactor in less than 3 seconds.

9. The vehicle should respond to a pilot signal frequency that is significantly out of tolerance. The frequency of the EVSE oscillator is used to verify connection to a compatible EVSE and proper operation of the EVSE. If the frequency is incorrect, the vehicle shall reduce charge to 1A or less within 4 seconds. ($I \leq 1.0A$ @ $t \leq 4.0$ seconds). The recommended tolerance is ±2%, 1020 Hz to 980 Hz.

10. It is common for EVSE equipment to support an input signal for the purpose of external load control (utility service interrupt signal, etc.). This input is used for various purposes including off peak charging support, utility load shedding, and building load management controllers. A maximum response time should be specified to guarantee universal compatibility with the external controlling equipment.

11. The EVSE may modify the pilot signal duty cycle at any time, commanding the EV/PHEV to increase or decrease the maximum AC current draw. The vehicle shall adhere to the maximum response time in order guarantee universal compatibility with the external controlling equipment. (See Table 14, Transition 11)

12. The EVSE shall respond to ventilation state changes of the control pilot.

13. Switch S3 opens when the connector latch lever is actuated. This opens the Proximity Circuit. The EV/PHEV should terminate charge prior to connector disconnect to prevent connector contact arc damage. Charge resumption after S3 closing is OEM specific.

14. State B1 is used by the EVSE to indicate that the EVSE is not ready to supply energy. State B1 may be used by the EVSE to maintain the current charge session during load management, fee transaction, or other events. This state may last for an extended period of time. The EV/PHEV may enter a sleep mode during this state and wake upon detection of the EVSE turning on the oscillator and entering State B2.

Examples of charge scenarios making use of the B1 to B2 transition:

- EVSE Scheduled Charge:
  - Customer desires the EVSE to delay the vehicle charging process and the vehicle does not include this function. The customer knows when they need the vehicle next and may want to use controls in the EVSE to delay the start of charging until a lower price becomes available for the charge session, that is still within the overall time it is connected. They may also desire to delay the start of a charge if they know they have other high loads and don't want to stress the electrical system by charging at the same time.
    - It is expected the customer would have a means to program this so it is automatic but still could be overridden if desired. In this case the EVSE would stay in State B1 until the time to allow charge, and then move to B2. The vehicle would initially wake up, see State B1, time out and go to sleep until B2 is obtained, where it would wake up and then move to State C to allow charge.
  - Utility sends a Demand Response Load Control (DRLC) signal to the home to delay or curtail charging loads. The utility includes an actual DRLC device in the circuit to home air-conditioners, hot water heaters, pool pumps and other DRLC related devices as agreed to by the customer. This device could also be on the EVSE circuit so the utility could transmit a command according to the requirements to keep the grid stable.
    - For the load delay case, if the vehicle were charging in State C when the DRLC command is received, the EVSE would switch to State B1 and stop the charge. The vehicle would time out and goes to sleep until the delay period passes, then the EVSE would go back to B2 and the vehicle would wake up and move to State C to resume charging. If the DRLC is only a curtailment (reduction), the EVSE would reduce the Control Pilot PWM down to the 10% minimum value allowed for AC charging and the system would stay in State C and charge at a lower rate. As in the case of other DRLC devices, the customer has a means to "opt-out" and not participate in a particular event but could have consequences on energy cost depending on the agreed-to program.
  - Some EVSEs include a "Stop" and "Start" button. These do not need to be used unless desired. If the EVSE connector is inserted in the vehicle inlet as normal, the system would move from State B2 to State C and charging could start, without pressing either button. If the Stop button is then pressed, the EVSE changes to State B1 and charging stops. The vehicle would time out and waits for State B2. The customer would need to press the "Start" button to change the EVSE while still connected to the vehicle, to change back to State B2, then the vehicle would wake up, change to State C and charging would resume.
- PEV Scheduled Charge
  - If only the vehicle has a scheduled charge and connects to a EVSE that does not have scheduled charge (e.g. the PEV scheduled charge is 2am but is connected to a workplace EVSE at 8am, the next morning), the EVSE will stay in State B2 when connected, and the vehicle initially wakes up, then goes to sleep until the vehicle scheduled charge time is obtained, then the vehicle will wake up and move to State C.
    - To override the vehicle scheduled charge, one approach used by OEMs is to "double-plug" or connect the EVSE connector, remove it quickly, then reconnect. This could be included in the vehicle programming to override the PEV scheduled charge and "charge now".
  - Another approach is to include a switch in the vehicle interior (or on the center stack display) or on a phone app, that commands the vehicle to "charge now".
- EVSE and PEV Scheduled Charge
  - If both the EVSE and PEV have scheduled charges applied when connected, (e.g. the PEV scheduled charge is 2am but is connected to a workplace EVSE at 8am, the next morning) assuming the EVSE scheduled charge time is 2pm, the vehicle would not charge at the workplace EVSE until 2am, the next day. The EVSE would stay in State B1 from 8am to 2pm, and then move to State B2 at 2pm, but the PEV would still not move to State C until 2am. If charge-now is desired when connected, the EVSE needs the "start" button to override it's scheduled charge and the vehicle needs customer intervention as noted it item 2 above.

E.3 CHARGE START SEQUENCE

Figures 15 and 16 illustrates a charge start sequence.

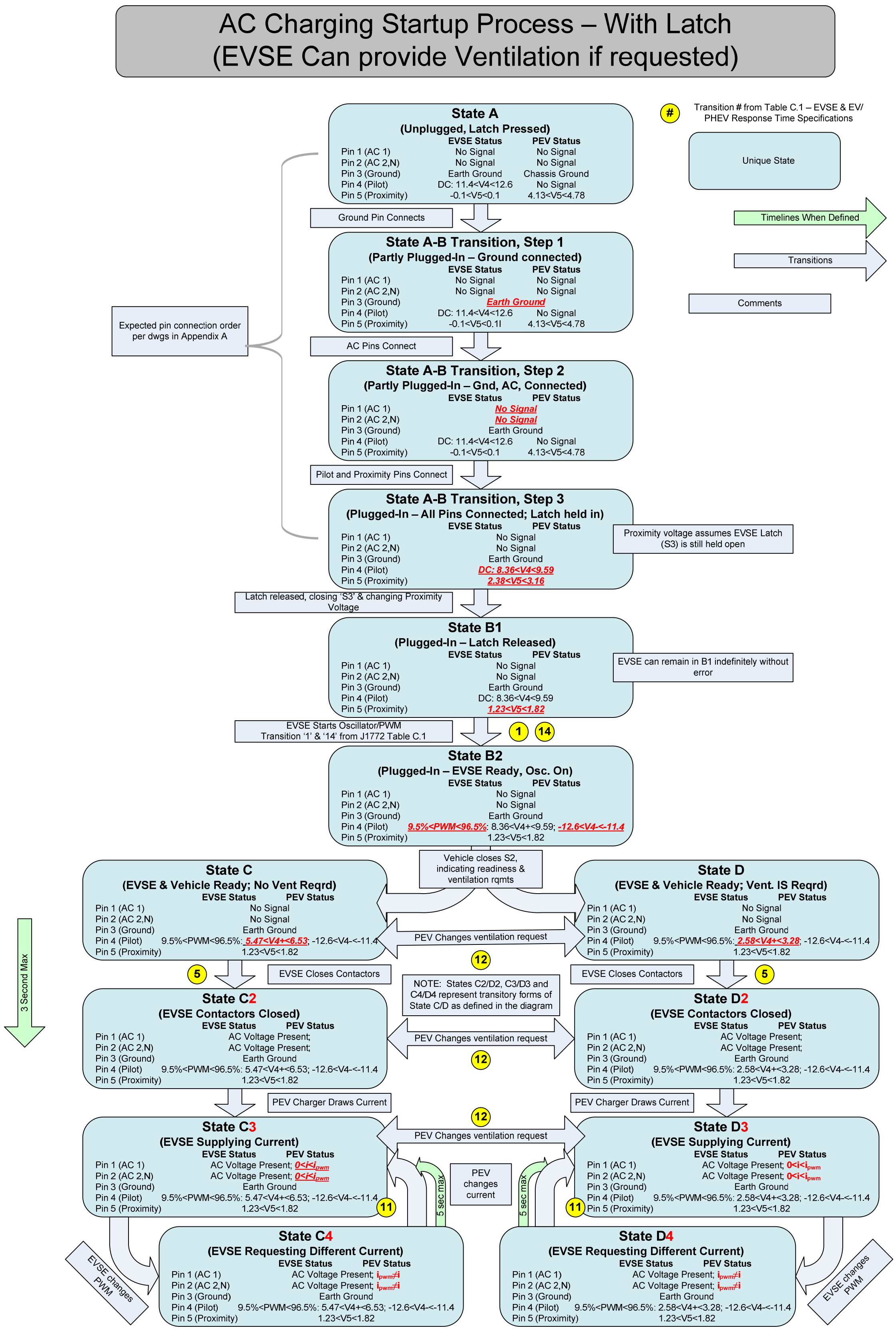


Figure 15 - Charge start sequence - EVSE capable of supporting ventilation

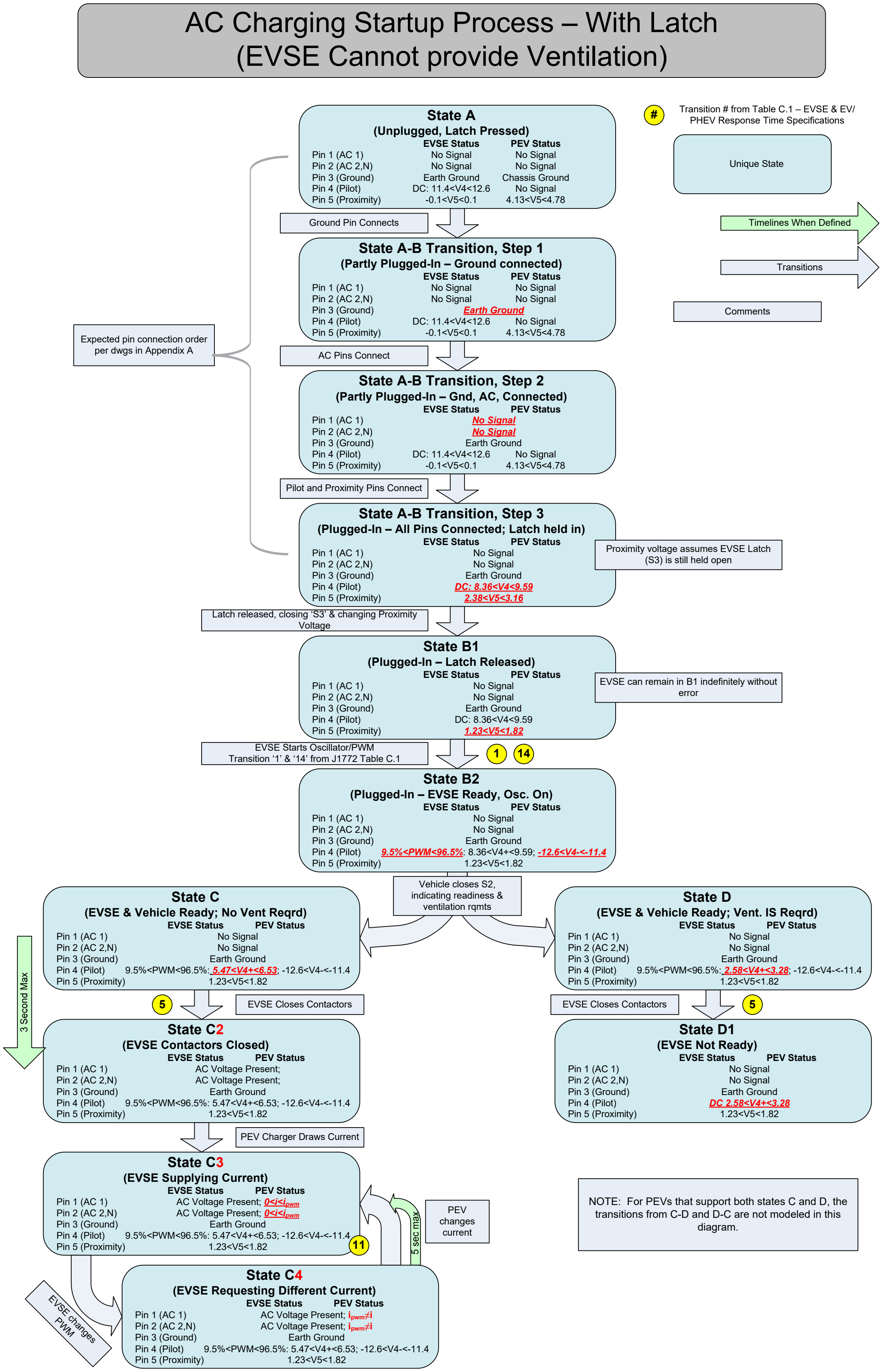


Figure 16 - Charge start sequence – EVSE does not support ventilation

E.4 CHARGE TERMINATION SEQUENCE

Figure 17 illustrates a charge termination sequence. The sequence assumes the vehicle is charging and charging is terminated by activation of the connector latch release.

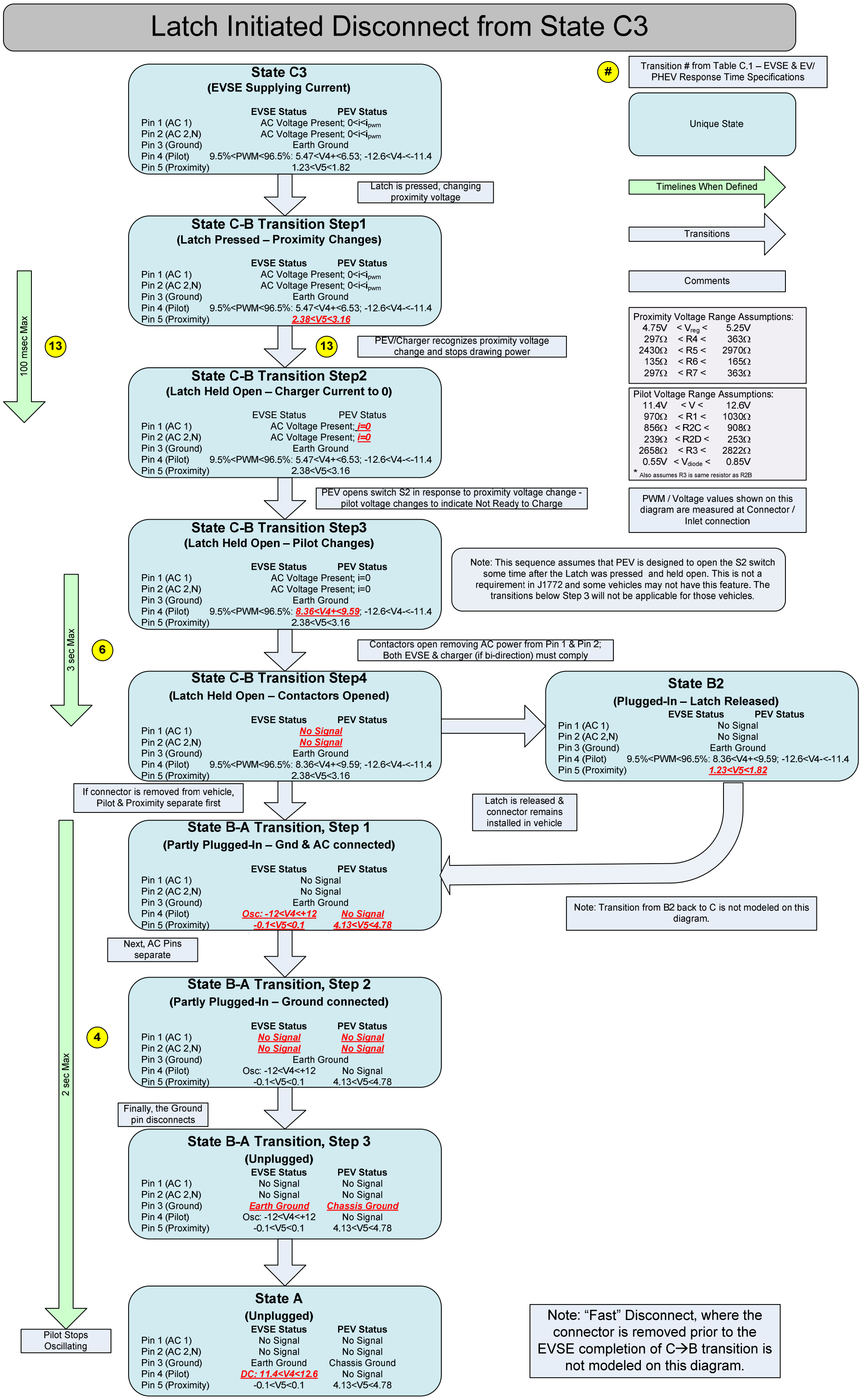


Figure 17 - Charge termination sequence

APPENDIX F - DC EVSE AND EV/PHEV SEQUENCE AND RESPONSE TIME SPECIFICATIONS

F.1 NORMAL CHARGING SESSION

A charging session is defined as the period when a connector is inserted in a vehicle inlet until the connector is removed from the vehicle inlet. Each charging session has three phases:

F.1.1 Handshaking (Initialization)

During this phase, the EV/PHEV and EVSE exchange their operating limits and parameters for the upcoming charging session. Some signals are required, such as the voltage and current limitations. Each side uses these values to perform a compatibility check and to ensure that the limits are maintained during the charge session.

After negotiating the charging session parameters, the EV/PHEV shall lock the connector to the vehicle inlet if the two systems are compatible. If incompatible, the information broadcasted can be used by a display unit on either the EVSE or EV/PHEV to inform the customer. The connector lock shall be released by the EV/PHEV when the onboard sensors determine that voltage and current~~s~~ at the vehicle inlet are within safe limits.

To ensure no damage (welding) to the EV/PHEV side contactors, the EVSE must be enabled and controlled to a voltage that the EV/PHEV can measure. Closing of EV/PHEV side contactors when there is a voltage differential present could result in damaged or welded contactors. EV/PHEV side welding of the contactor is a reliability concern. When the contactors are welded, high voltage could be exposed at the finger proof DC vehicle inlet pins.

Using the Vehicle Maximum Voltage Limit signal, the EV/PHEV shall control the Pre-Charge process. The power is delivered by the EVSE to reduce the voltage difference between the EV/PHEV RESS and the EVSE output. When the EV/PHEV determines the voltage measured at the EVSE is within acceptable difference to the RESS (exact tolerance threshold is at the discretion of the OEM), the EV/PHEV can then close contactors in the EV/PHEV to connect the EVSE output to the RESS.

When all the Initialization and pre-charge steps have completed, the system (EV/PHEV and EVSE) shall transition to the Energy Transfer phase. The EV/PHEV charging algorithm may establish maximum current, voltage and power limits at a fixed value at the beginning of the charging session, and proceed through the whole charge session without changing the limits. This method might be used if the algorithm uses a fixed voltage controlled charging algorithm.

F.1.2 Energy Transfer

During Energy Transfer, the EV/PHEV and the EVSE shall continuously monitor the voltage and current readings independently to ensure that the system remains within the negotiated limits. The EV/PHEV may reduce consumption to protect the RESS. The EVSE may reduce the output level to ensure that its voltage and current limits will not be violated.

The EVSE shall indicate the status of the energy transfer and will be able to signal to the EV/PHEV when it is operating at its maximum output capability. The EV/PHEV shall communicate the expected charge completion time so the information can be presented to the user on a display in the EVSE.

There are two modes of energy transfer: Bulk Charging and Full Charging. During Bulk Charging, the EV/PHEV shall request energy transfer at or near the negotiated limitations of the charging session. This will continue for the requested charging session time. When the Bulk threshold has been reached, the EV/PHEV shall end the charging session, or it shall reduce the energy consumption to allow charging the RESS to full. While charging to Full, the energy transfer requests shall be limited by the EV/PHEV to ensure the maintenance of the RESS. Charging to Full may last for a duration that continues for several hours.

The EV/PHEV shall control charge level based on EV/PHEV RESS and other EV/PHEV conditions. When the EV/PHEV determines that the charging session is complete, it shall send a unique signal to the EVSE. At that point, the EV/PHEV shall reduce its requested energy transfer to near zero, and may open the charging contactors in the EV/PHEV.

When the EV/PHEV has determined that it has reached Full or Bulk charge level, the system shall transition to Normal Shutdown. It is up to the EV/PHEV manufacturer when to switch from bulk to full charge.

F.1.3 Normal Shutdown

Normal shutdown occurs when the RESS reaches the desired State of Charge limit and any accessory load consumption of the EV/PHEV has completed. After completion of the charge session, the Shutdown phase allows the EV/PHEV and EVSE to return to a safe condition so the user can remove the connector from the vehicle inlet. The EV/PHEV shall have reduced its charge current request to zero, and shall indicate Charge complete. When the current is near zero (exact tolerance threshold is at the discretion of the OEM), the EV/PHEV shall open its onboard charge contactors, and wait for the inlet voltage to drop to a safe level. Once at the safe level (below 60V DC as defined by SAE J2344), the connector may be unlocked by the EV/PHEV. The user can then remove the connector from the vehicle inlet.

The EV/PHEV and EVSE may exchange some signals that may be used for energy reporting and consumption displays.

Normal shutdown may be entered by an action from the user. For example, a "Stop" button on the EVSE could have been pressed which will immediately cause the EV/PHEV to reduce the request even if the RESS has not reached Full or Bulk level. The EV/PHEV shall enter the normal shutdown state, which shall lead to the charge coupler being unlocked for the user.

Based on user preferences, the EV/PHEV shall keep the charge coupler locked in the inlet until the user is ready to remove the charge cord connector. The EV/PHEV may remain in this state for a long time period.

Some signals are transmitted during the start of the session (handshaking). Critical signals are transmitted throughout the energy delivery phase. Some messages close out the session at the end of charging process (normal shutdown).

F.1.4 Examples of Emergency Shutdown

Certain fault conditions will cause the charging system to shut down before the normal shutdown. Either the EV/PHEV will initiate the shutdown, or the EVSE may initiate shutdown. Some examples are listed below:

F.1.4.1 Loss of safety ground

It occurs when continuity of the safety ground is lost.

F.1.4.2 Loss of high voltage isolation

It occurs when there is current leakage between the chassis and the high voltage system including the EV/PHEV RESS.

F.1.4.3 Loss of communication

In the event that reliable data communication between the EV/PEV and the EVSE cannot be established, it is understood that the EV/PHEV or the off board EVSE shall stop energy transfer.

F.1.4.4 Loss of power

It happens when the EVSE stops delivering power to the EV/PEV.

F.1.5 Examples of System Faults

Certain fault conditions will cause the charging system to shut down before the normal shutdown. Either the EV/PHEV will initiate the shutdown, or the EVSE will initiate shutdown. Some examples are listed below:

F.1.5.1 Welded Contactors

In case the EV/PHEV contactors are welded, the EV/PHEV should provide a fault indication and request zero current and voltage. The EV/PHEV may provide a means to manually unlock the connector in a safe manner. The manual unlock could open a EV/PHEV interlock that will remove HV from the vehicle inlet. The EV/PHEV should not be operated with HV present at an exposed vehicle inlet.

F.1.6 Connector Un-locking Requirements

F.1.6.1 An EV using an inlet according to “Sheet A-1” of this standard (“Configuration Type 1“ of IEC 62196-2) or “Sheet C-1” of this standard (“Configuration EE” of IEC 62196-3“), shall unlock the connector within 3 seconds after either of the following two events occur:

a. reception of the SessionStopRes message, if the charging session has terminated as a “Normal Shutdown” as per 0 of this standard

b. leaving Control Pilot State C2 (or D2, if ventilation is required), if an “Emergency Shutdown” as per F.1.4 of this standard has been executed

unless the voltage measured at the inlet is greater than or equal 60 VDC.

If the voltage at the inlet is greater than 60 VDC, the EV shall continue to measure the voltage at the inlet and, as soon as the voltage decreases to 60 VDC or less, unlock the connector.

F.1.6.2 After executing a “Normal Shutdown” as per F.1.9 of this standard, the EV shall keep S2 closed (i.e., maintain CP State B1) for at least 30 sec, and may then execute the following sequence of CP states: B1 -> C1 -> B1. This sequence indicates the EV’s intention to start another charge session. The CP state shall be C1 for a minimum of 500 ms and a maximum of 1 sec. After detecting this sequence, the EVSE may transition to CP State B2 by turning on the oscillator with a 5% duty cycle, and the charge session shall proceed as per F.1.8 of this standard, beginning at time t0’.

[Note: The PHEV/BEV usually does not need to resume charging after a “Normal Shutdown”].

F.1.6.3 After executing an “Emergency Shutdown” as per F.1.4 of this standard and having disabled PWM as per [V2G-DC-672] of SAE J2847/2, the EVSE shall keep PWM off for at least 30 sec, and may then re-enable PWM (i.e., execute a CP State transition x1 -> x2) in order to attempt to initiate another charging session. Without an explicit interaction by the user, e.g., unplugging and re-plugging of the connector, or by the EV, e.g., a CP State transition B1 -> C1(*), indicating the user’s/EV’s intend to start another charging session, the EVSE shall limit the number of attempts to initiate another charging session to 20 or fewer.

(*) CP State transitions B2 -> C2 caused by the EV during a charging session shall not constitute such an explicit interaction by the EV indicating the EV’s intention to start another charging session.

[Note: The PHEV/BEV should be able to resume charging after an “Emergency Shutdown”].

F.1.7 DC Timing Requirements

Transition	Transition Description	DC EVSE Response Time (s)	PEV Response Time (s)	Comment	Start Condition	End Condition
1	State B1 to State B2	≤ 9*	-	Timing from plug-in to pilot oscillator on (EVSE Ready)	Enter State B1 (t0)	Enter State B2 (t0’)
2	State B2 to PEV Reception of Message 1b	≤ 20	-	Timing from DC EVSE turning on oscillator until the PEV receives the SessionSetupRes Message	Enter State B2 (t0’)	Reception of SessionSetupRes Message (t0’’)
3	Transmission of Message 4a to reception of final message 4b	≤ 40	-	Maximum time to allow DC EVSE to perform isolation monitoring	PEV transmission of first CableCheckReq Message (t2)	PEV reception of final CableCheckReq Message with ResponseCode equal to “OK” and EVSEProcessing equal to “Finished” (t4)
4	Reception of first message 4a while in state B2 to State C or D	-	≤ 1.5	Timing from DC EVSE receiving the CableCheckReq Message to S2 closed in PEV	DC EVSE reception of CableCheckReq Message (t2’)	Enter State C or D (t2’’)
5	Transmission of first Message 5a to output of voltage being within ± 5 V of target voltage request	≤ 7	-	Maximum time to allow DC EVSE to precharge bus	PEV transmission of first PrechargeReq Message (t5)	PEV reception of final PrechargeReq Message and bus voltage being within ± 5 V of target voltage request (t6)
6	State B2 to PEV Reception of Message 6b	≤ 150	-	Maximum time to allow DC EVSE to enable its output once the pilot oscillator is turned on	Enter State B2 (t0’)	PEV reception of PowerDeliveryRes message and DC EVSE output Enabled (t8)
7	Unexpected State C or D to State B2 transition while transferring energy to output; current ≤ 5 A	≤ 1	-	Vehicle Initiated Emergency Shutdown	Unexpected State C to State B2 transition (t18)	DC EVSE Output current ≤ 5 A (t20)
8	Unexpected Oscillator off while transferring energy to output; current ≤ 5 A	≤ 1	-	DC EVSE Initiated Emergency Shutdown	DC EVSE turns off oscillator (State C1 or D1) (t24)	DC EVSE Output current ≤ 5 A (t26)
9	Invalid Pilot/Prox while transferring energy to output; current ≤ 5 A	≤ 0.03	-	Invalid Pilot/Prox Shutdown	Invalid Pilot State, Prox State or Both invalid (t30)	DC EVSE Output current ≤ 5 A (t32)
10	Reception of Message 8a to output; current ≤ 5 A	≤ 2	-	Normal Shutdown	DC EVSE reception of PowerDeliveryReq with the ReadyToChargeState Signal set to False	DC EVSE Output current ≤ 5 A
11	Reception of Message 8b while in State C to State B2	-	≤ 1.5	Time allowed for the PEV to open S2 after receiving PowerDeliveryRes message after Energy Transfer Stage	PEV Reception of PowerDeliveryRes to disable EVSE output while in State C (t12)	State B2 (t13)
12	Reception of Message 10b to oscillator off	1.5	-	Timing from DC EVSE sending SessionStopRes message to DC EVSE shutting off pilot oscillator	DC EVSE transmission of SessionsStopRes message (t15’)	Pilot Oscillator Turned Off (State B1) (t16’)
13	Disconnect Connector with oscillator on (State A2) to oscillator off (State A1)	≤ 2	-	Time allowed for EVSE to keep oscillator on after disconnect	Connector Disconnect with oscillator on (State A2) (t23)	Oscillator off (State A1) (t23’)

NOTES for DC Timing Requirements Table:

Transition 1

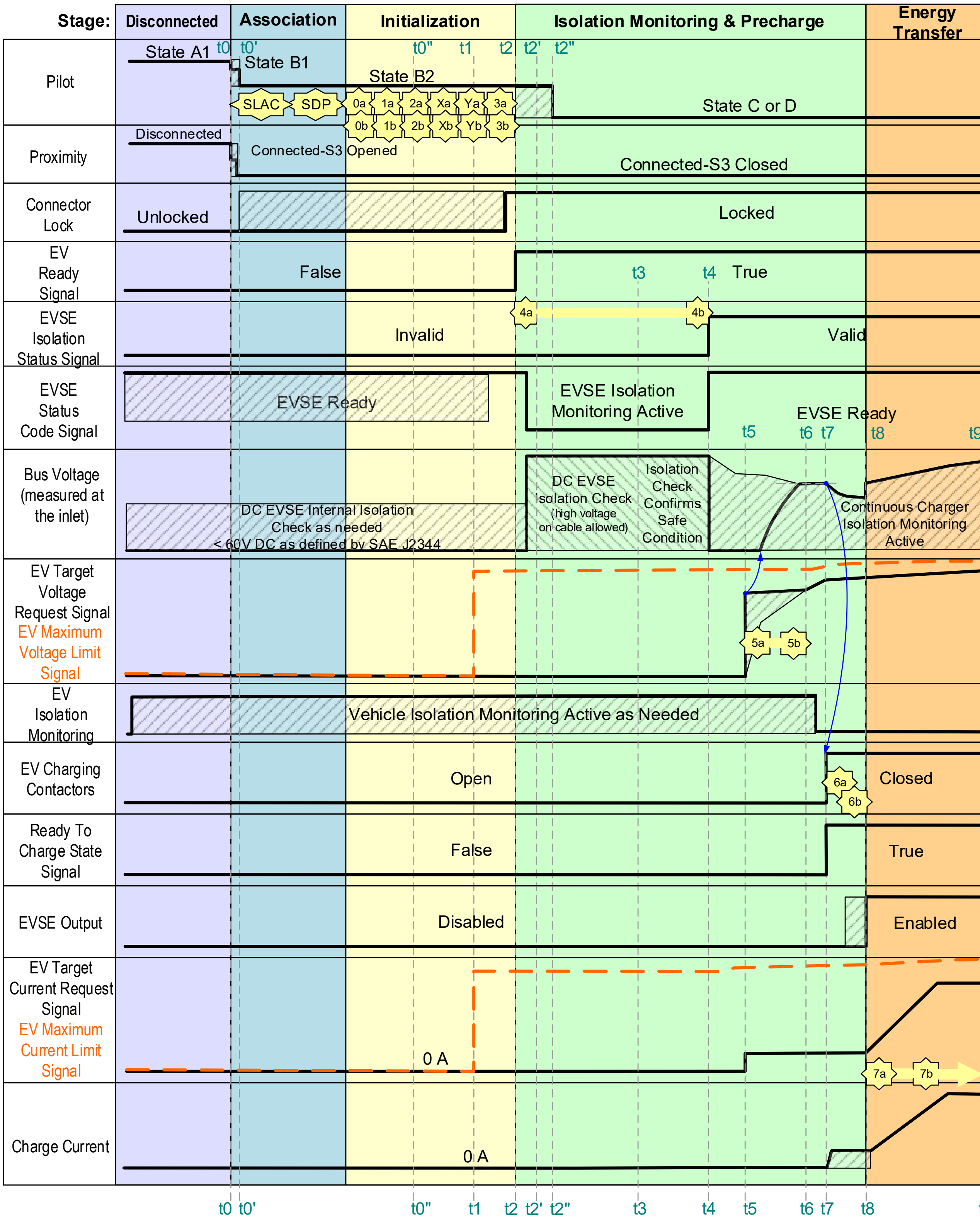
- DIN SPEC 70121 2014-12 is defining a concrete time range for turning on the oscillator. (according to Requirements V2G-DC-507 and V2G-DC-564) --> T_conn_max_comm (8 seconds) + 1 second = 9 seconds

- Otherwise it is not defined when the charging process is starting (at the latest). Our goal is to start the charging process as soon as possible but if not defined, there is a gap in specification.

General:

- Refer to SAE J2847/2 for missed messages timing.

F.1.8 Normal Startup Sequence



Engaging the inlet lock prior to time t2 is allowed if a means to unlock is included (see section 6.4.2). This allows the operator to disconnect the vehicle from the EVSE in event the communication session stops within this initialization stage. The lock is used at the beginning of the Initialization stage, per IEC 61851-23, to mechanically stabilize the Type 2 connector to the inlet since this connector does not include the AC terminals. The same approach is allowed for the Type 1 connector but is not needed for mechanical stability.

Normal Startup Sequence

SAE J1772™ Pilot Signal states:

- State A1 (12V), Oscillator Off, EVSE is Disconnected from PEV
- State B1 (9V), Oscillator off, EVSE is Connected to PEV
- State B2 (9V), Oscillator on with 5% duty cycle, EVSE is Connected to PEV
- State C (6V) or D (3V) when Vehicle Ready (S2 switch closed by PEV)

(t0)

- The DC EVSE connector is plugged into the PEV inlet. The DC EVSE detects State B1 and the proximity voltage in the Connected-S3 Closed Range. Depending upon the PEV/DC EVSE sampling frequency of the proximity voltage and how the user connects the connector to the inlet, the PEV/DC EVSE may detect the Connected-S3 Opened proximity state.

(t0')

- The EVSE transitions to State B2 by turning on the oscillator with a 5% duty cycle.
- The Association phase begins with the SECC and EVCC forming a logical network via the Signal Level Attenuation Characterization (SLAC) protocol outlined in SAE J2931/4.
- Once a logical network is created between the SECC and EVCC, the SECC Discovery Protocol (SDP) outlined in SAE J2931/1 is performed. The SDP allows the EVCC to find the IPv6 address and Port of the TCP/IPv6 SECC Server.
- The High Level Communication (HLC) starts with the SupportedAppProtocolReq (0a) application layer message. Appendix G may be used to decipher the MSG ID shown in the yellow stars to the actual application layer message. Details for each of the application layer messages and their requirements are found in SAE J2847/2.

(t0")

- The setup of the communication session, defined as the PEV detecting the DC EVSE turning on the oscillator (State B2) to the reception of the SessionSetupRes message (1b), shall occur within 20 seconds as outlined in SAE J2847/2 (t0" – t0'). Failure to comply shall result in the PEV switching to State B and closing the TCP connection.

(t1)

- The Vehicle sends the ChargeParameterDiscoverReq (3a) which among other signals contains the EVMaximumVoltageLimit and EVMaximumCurrentLimit signals.
- Upon successful reception and parsing of the ChargeParameterDiscoveryRes (3b) message, the Vehicle shall lock the Charge Connector into the Inlet prior to changing the Pilot state and EV Ready signal.
- Vehicle may be performing HV Isolation at any time after it wakes up.
- Prior to t2, the DC EVSE may check internal isolation as long as no voltage is applied to the connector.

(t2)

- After the DC EVSE sends message 3b and receives message 4a from the PEV, the PEV has 1.5 seconds to change the pilot to State C/D as outlined in SAE J2847/2 (t2" – t2'). Failure to comply shall result in a EVSE-initiated emergency shutdown.

- The Pilot signal changes to State C/D when the vehicle is ready to start the precharge of the EVSE output.

- The CableCheckReq (4a) is transmitted from the PEV after the lock is confirmed, and the vehicle has changed its EV Ready status to True.

- After receiving message 4a, the DC EVSE shall start checking HV isolation on its own internal circuits, and along the entire length of the cable up to the opened vehicle's contactors.

(t3)

- Messages 4a and 4b shall be sent cyclically to meet the session and message timing requirements until the EVSE has finished its isolation test. While the isolation test is being performed by the EVSE, the EVSE shall set the EVSEProcessing Signal in the CableCheckRes message (4b) to "Ongoing".

(t4)

- Once the DC EVSE has confirmed that the Isolation is above the limit threshold (as defined by SAE J1772) it will be able to indicate "Valid" in the EVSEIsolationStatus Signal and set the EVSEProcessing Signal in the subsequent CableCheckRes message (4b) to "Finished".

- After the PEV sends the first 4a message the DC EVSE has 40 seconds to finish the Isolation Check as outlined in SAE J2847/2 (t4 – t2). Failure to comply shall result in the PEV switching to State B and closing the TCP connection.

(t5)

- The PEV sends a PreChargeReq (5a) message.

- The PEV may request a small current (as defined in SAE J1772), to allow the charger to PreCharge any capacitance on the bus in the 5a message.

- After the DC EVSE receives the request from the PEV, the charger should (dis)charge bus capacitors while abiding by the maximum current and maximum voltage limits set previously by the PEV.

- The DC EVSE hardware current control must limit inrush current (e.g., by applying precharge resistors) below the requested target current from the PEV. This step is mandatory in order to limit inrush current flow from the DC EVSE into the PEV, even for DC Supplies with a blocking diode.

- As the DC EVSE pre-charges the bus, the PrechargeReq (5a) and PreChargeRes (5b) messages shall be sent cyclically to meet the session and message timing requirements of SAE J2847/2.

- The DC EVSE has 7 seconds from the first 5a message sent by the PEV, until the PEV receives a corresponding 5b message and the bus voltage is adjusted to ± 5V of the vehicle's target voltage request, as outlined in SAE J2847/2 (t6 – t5). Failure to comply shall result in the PEV switching to State B and closing the TCP connection.

- Note the vehicle shall regulate the output voltage request based on its voltage sensor readings to achieve the actual RESS matching voltage.

(t6)

- The DC EVSE has charged the bus to within ± 5V of the vehicle's target voltage request and the PEV has responded with its final 5b message.

(t7)

- Prior to closing the PEV's contactors, the vehicle shall stop any isolation monitoring that interferes with the charger isolation monitoring.

- PEV may close its contactors when deviation of DC output voltage from EV battery voltage is less than 20 V.

- After closing its contactors, the PEV requests the DC EVSE to exit The precharge state (i. e. disable any circuits related to Inrush current limiting and bus pre-charging) and to enable the DC EVSE output with the PowerDeliveryReq message (6a) with the ReadyToChargeState Signal set to True.

- After switching on its main power supply output, the DC EVSE shall inform the PEV that it is ready to start Energy Transfer using the PowerDeliveryRes message (6b) and setting.

(t8)

- The Output of the DC EVSE is enabled.

- The PEV may ramp up its Voltage Request and a Current Request in The CurrentDemandReq message (7a) according the charging algorithm defined by the vehicle manufacturer.

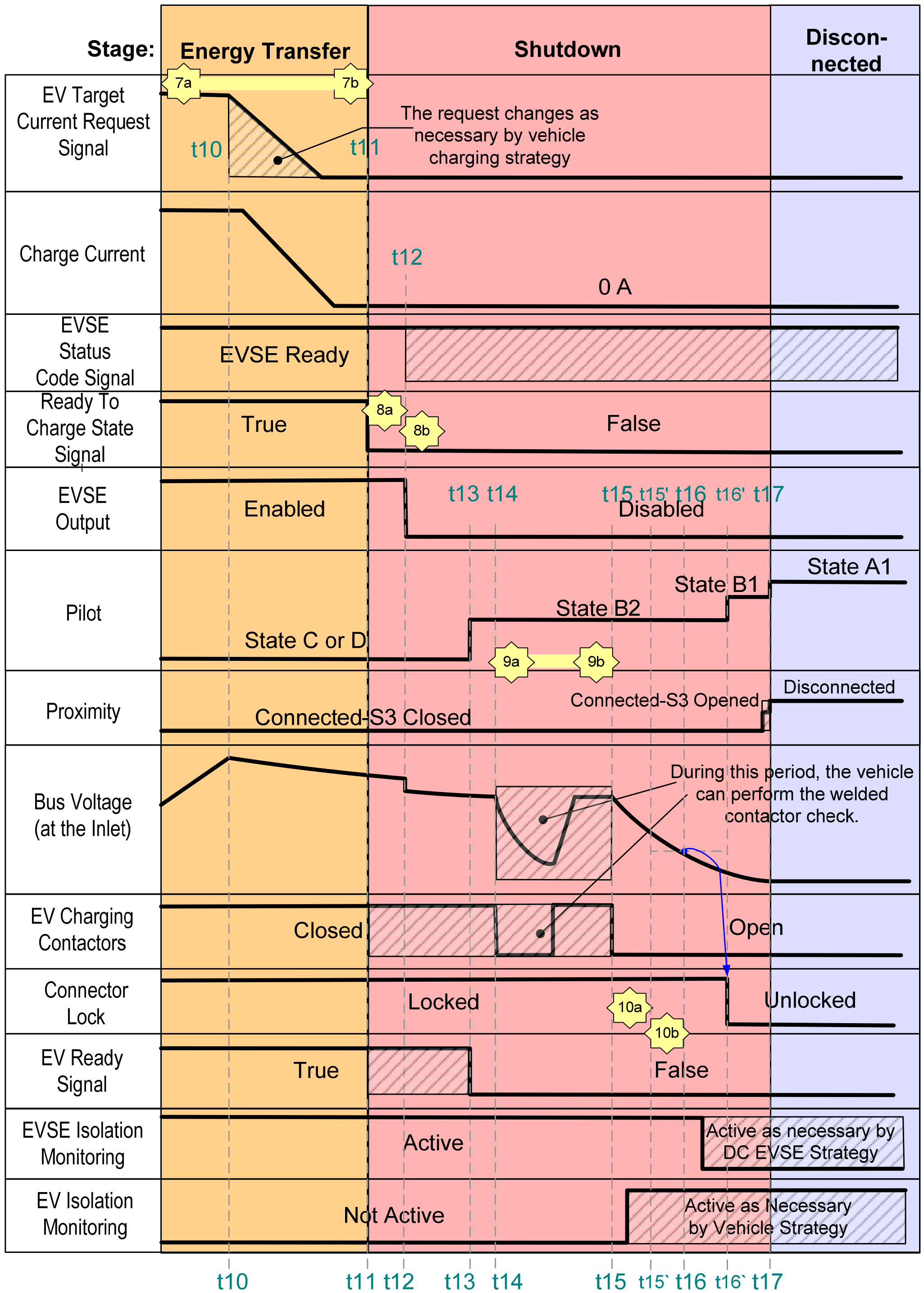
- The DC EVSE should be ready to charge within 150 seconds of the PEV detecting the DC EVSE turning on the oscillator (State B2). The end condition is the PEV receiving the PowerDeliveryRes message (6b) in response to a 6a message with the ReadyToChargeState Signal set to True as outlined in SAE J2847/2 (t8 – t0'). Failure to comply shall result in the PEV switching to State B and closing the TCP connection.

(t9)

- The Vehicle and DC EVSE regulates the energy delivery by managing Voltage Request and Current Request signals with cyclic CurrentDemandReq (7a) and CurrentDemandRes messages (7b).

The DC EVSE reports its present output current and output voltage, its present current limit and voltage limit, and its present status back to the PEV in message (7b).

F.1.9 Normal Shutdown Sequence



Normal Shutdown Sequence

SAE J1772™ Pilot Signal states:

- State A1 (12V), Oscillator Off, EVSE is Disconnected from PEV
- State B1 (9V), Oscillator off, EVSE is Connected to PEV
- State B2 (9V), Oscillator on with 5% duty cycle, EVSE is Connected to PEV
- State C (6V) or D (3V) when Vehicle Ready (S2 switch closed by PEV)

(t10)

- The PEV will reduce the current request as it completes the charging process. The PEV charging strategy determines how to reduce current at t10 (after RESS is full, after fixed time on-plug, etc.).
- Depending on the PEV's charging algorithm, the end of a the energy transfer stage could occur by the PEV sending a final 7a message with a 0 A request, followed by message 8a or the PEV could send message 8a without reducing the current request signal to 0 A in the previous 7a message.

(t11)

- The PEV requests the DC EVSE to disable its output by sending message PowerDeliveryReq (8a) with the ReadyToChargeState Signal set to False.
- Upon receiving message 8a the DC EVSE shall reduce the output current to less than 5 A at a minimum rate of -100 A/s or faster (per SAE J1772) within 2 seconds.
- The DC EVSE shall enable its circuit to actively discharge any internal capacitance on the HV output after receiving message 8a with the ReadToChargeState Signal set to False.
- The DC EVSE shall not cause current to flow into or out of the PEV bus during this discharge.

(t12)

- The DC EVSE disables its output when the charge current is near zero.
- The Supply Bus Voltage should fall toward the RESS voltage until the vehicle contactors open.

(t13)

- The PEV shall change the Pilot to State B2 after receiving message 8b. The PEV has 1.5 seconds to change the pilot to State B as outlined in J2847/2 (t13 – t12). Failure to comply shall result in a EVSE-initiated emergency shutdown.

(t14)

- The PEV may optionally perform a welded contactor check prior to shutting down the communication session. The vehicle may rely only on its own internal voltage sensors for this welded test or the present output voltage of the DC EVSE returned in the WeldingDetectionRes message (9b).
- After the PEV changes the Pilot to state B2, then the WeldingDetectionReq message (9a) is sent. The vehicle may send multiple 9a requests in order to read the DC EVSE voltage in the message 9b response or rely on its own voltage sensors.
- Because the Welded Check is optional, the DC EVSE may not see vehicle message 9a. The welded check test is finished with the PEV sending message 10a.

(t15)

- The PEV completes the optional welded contactor check and leaves its PEV contactors opened.

- The communication session ends when the PEV sends the SessionStopReq (10a) to the DC EVSE and the PEV receives the SessionStopRes (10b) from the DC EVSE.

- Upon the transmission of the SessionStopRes message (10b), the DC EVSE shall keep the oscillator on for 1.5 seconds (State B2). The DC EVSE shall then turn off the oscillator (State B1) per SAE J2847/2 (t16'-t15').

(t16)

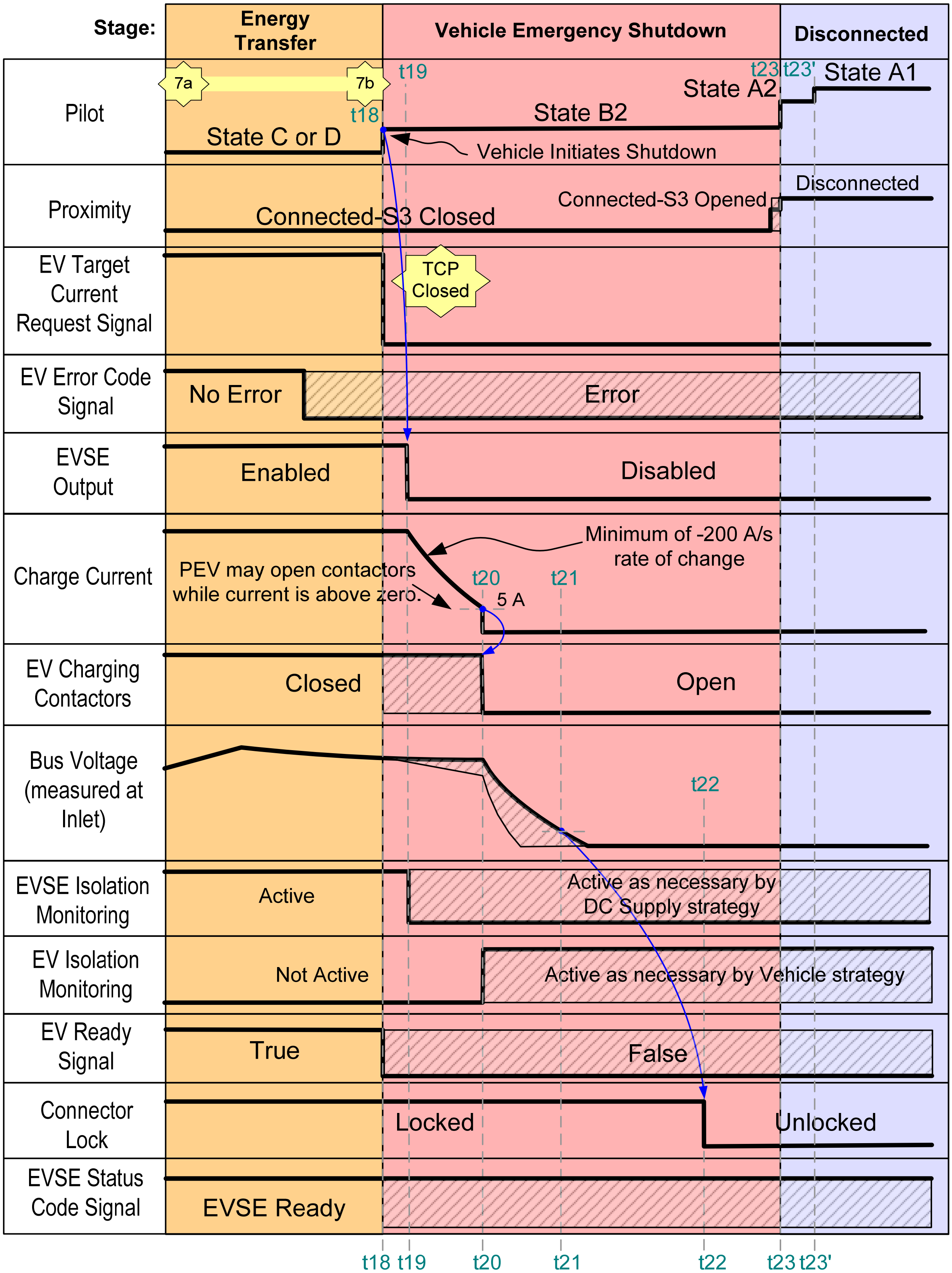
- The PEV may unlock the connector after the bus voltage has dropped below a safe value (60V DC as defined by SAE J2344).

NOTE: There is no defined amount of time that the vehicle shall remain in this state between t16 to t16'. The vehicle may remain in a locked state (t16' – t16), even after the voltage has dropped to safe levels. The PEV may keep the connector locked in the inlet until the customer unlocks the vehicle.

(t17)

The DC EVSE connector is disconnected from the PEV (Pilot State A1).

F.1.9.1 Vehicle Initiated Shutdown Sequence



Vehicle Initiated Shutdown Sequence

SAE J1772™ Pilot Signal states:

- State A1 (12V), Oscillator Off, EVSE is Disconnected from PEV
- State B1 (9V), Oscillator off, EVSE is Connected to PEV
- State B2 (9V), Oscillator on with 5% duty cycle, EVSE is Connected to PEV
- State C (6V) or D (3V) when Vehicle Ready (S2 switch closed by PEV)

(t18)

- The PEV may or may not have sent an EV Error Code in a previous 7a message. Per SAE J2847/2 the EV Error Code Signal is for informational purposes only and shall not influence the charging process.
- The PEV initiates a Vehicle Emergency Shutdown by changing the state of the Control Pilot from State C or D to State B2.

(t19)

- The DC EVSE detects an unexpected State B2, therefore the DC EVSE terminates the communication session by closing the TCP connection per SAE J2847/2.
- The DC EVSE immediately disables its output upon detection of unexpected State B2.
- EVSE shall detect state B2 and begin ramping down output current within 30 ms (t19-t18). Current shall drop to less than 5 A at a minimum rate of -200 A/s or faster.
- The DC EVSE shall discharge bus capacitors.
- Isolation monitoring on the DC supply can start after the DC Supply has disabled its output (and/or opened the DC supply contactor). Cable Isolation check should not be done after the connector is unlocked.

(t20)

- The PEV shall open its contactors after the measured current has fallen below an OEM determined limit.
- The Vehicle shall continue to monitor the HV isolation on the system as per OEM strategy.

(t21)

- The PEV may unlock the connector after the bus voltage has dropped below 60V DC as defined by SAE J2344.

NOTE: The vehicle may keep the connector locked even after the voltage has dropped to safe levels so the PEV can keep the connector locked in the inlet until the customer unlocks the vehicle (t22 – t21).

- If the fault is cleared in the PEV and the connector is still connected to the PEV, the PEV may attempt to reestablish the charging process again from time t0'.

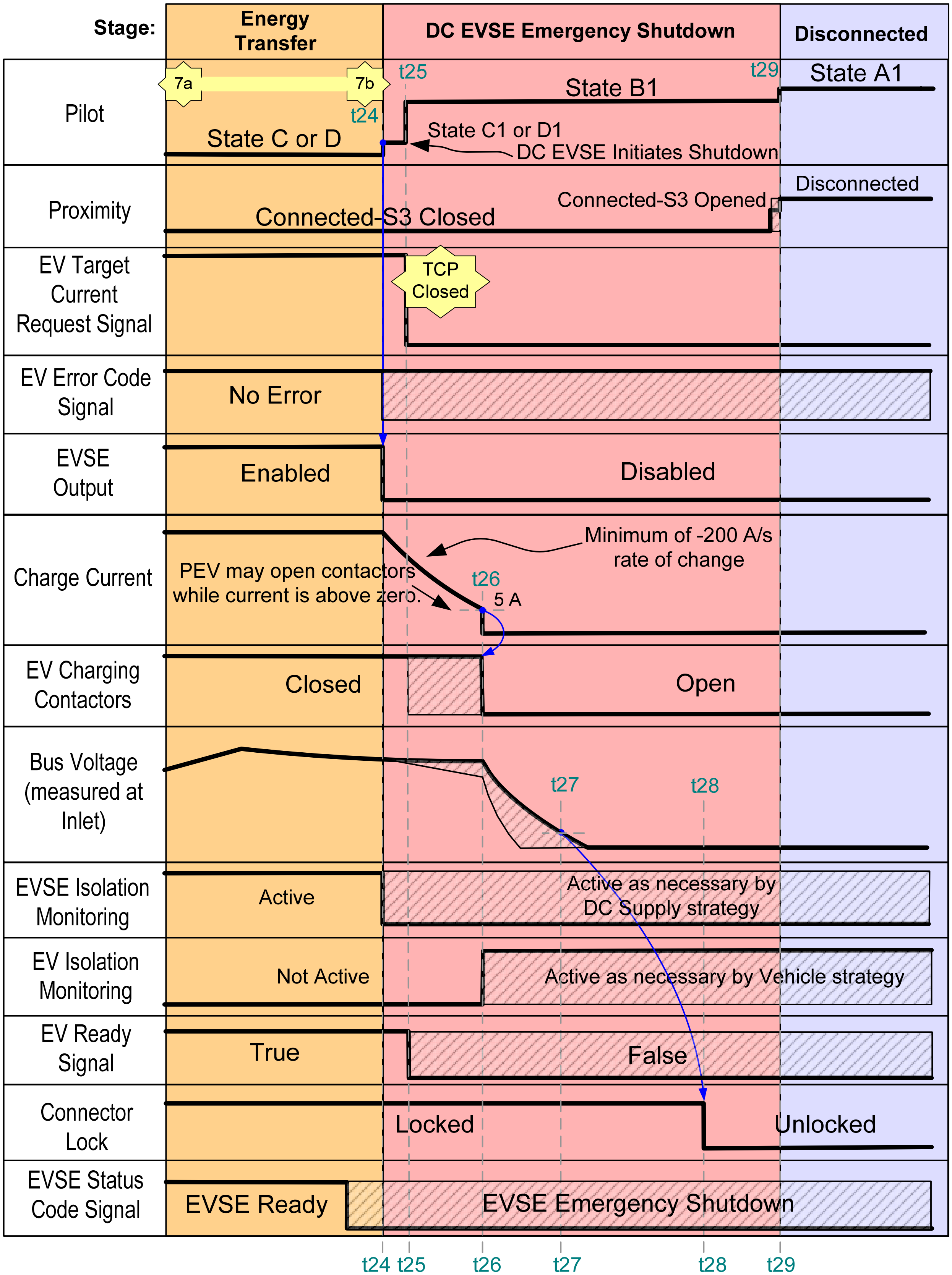
(t22)

- The PEV shall unlock the connector as per OEM strategy.

(t23)

The DC EVSE connector is disconnected from the PEV (Pilot State A2). The DC EVSE has up to 2 seconds to shutoff the oscillator (State A1) per SAE J1772 (t23' – t23).

F.1.10 EVSE Initiated Shutdown Sequence



EVSE Initiated Shutdown Sequence

SAE J1772™ Pilot Signal states:

- State A1 (12V), Oscillator Off, EVSE is Disconnected from PEV
- State B1 (9V), Oscillator off, EVSE is Connected to PEV
- State B2 (9V), Oscillator on with 5% duty cycle, EVSE is Connected to PEV
- State C2 (6V) or D2 (3V) when Vehicle Ready (S2 switch closed by PEV), Oscillator on
- State C1 (6V) or D1 (3V) when Vehicle Ready (S2 switch closed by PEV), Oscillator off

(t24)

- The DC EVSE may or may not have updated the EVSE Status Code Signal to EVSE Emergency Shutdown in previous 7b message. Per SAE J2847/2 the EVSE Status Code Signal is for informational purposes only and shall not influence the charging process.
- The DC EVSE initiates an Emergency Shutdown by turning off the oscillator and disabling its output.
- The DC EVSE could also optionally place the pilot into State F.
- Current output must drop to less than 5 A at a minimum rate of -200 A/s or faster (per SAE J1772) within 1 s of DC EVSE shutting of pilot oscillator (t26-t24).
- The DC EVSE shall discharge bus capacitors.
- Isolation monitoring on the DC supply may start after the DC Supply has disabled its output (and/or opened the DC supply contactor). Cable Isolation check should not be done after the connector is unlocked.

(t25)

- The PEV detects the control pilot oscillator has been turned off, therefore the PEV places the pilot into State B1 and terminates the communication session by closing the TCP connection per SAE J2847/2.

(t26)

- The PEV shall open its contactors after the measured current has fallen below an OEM determined limit.
- The Vehicle shall continue to monitor the HV isolation on the system as per OEM strategy.

(t27)

- The PEV may unlock the connector after the bus voltage has dropped below 60V DC as defined by SAE J2344.

NOTE: The vehicle may keep the connector locked even after the voltage has dropped to safe levels so the PEV may keep the connector locked in the inlet until the customer unlocks the vehicle (t28 – t27).

- If the fault is cleared in the DC EVSE and the connector is still connected to the PEV, the DC EVSE may turn on the oscillator (State B2) and the process may start again from time t0'.

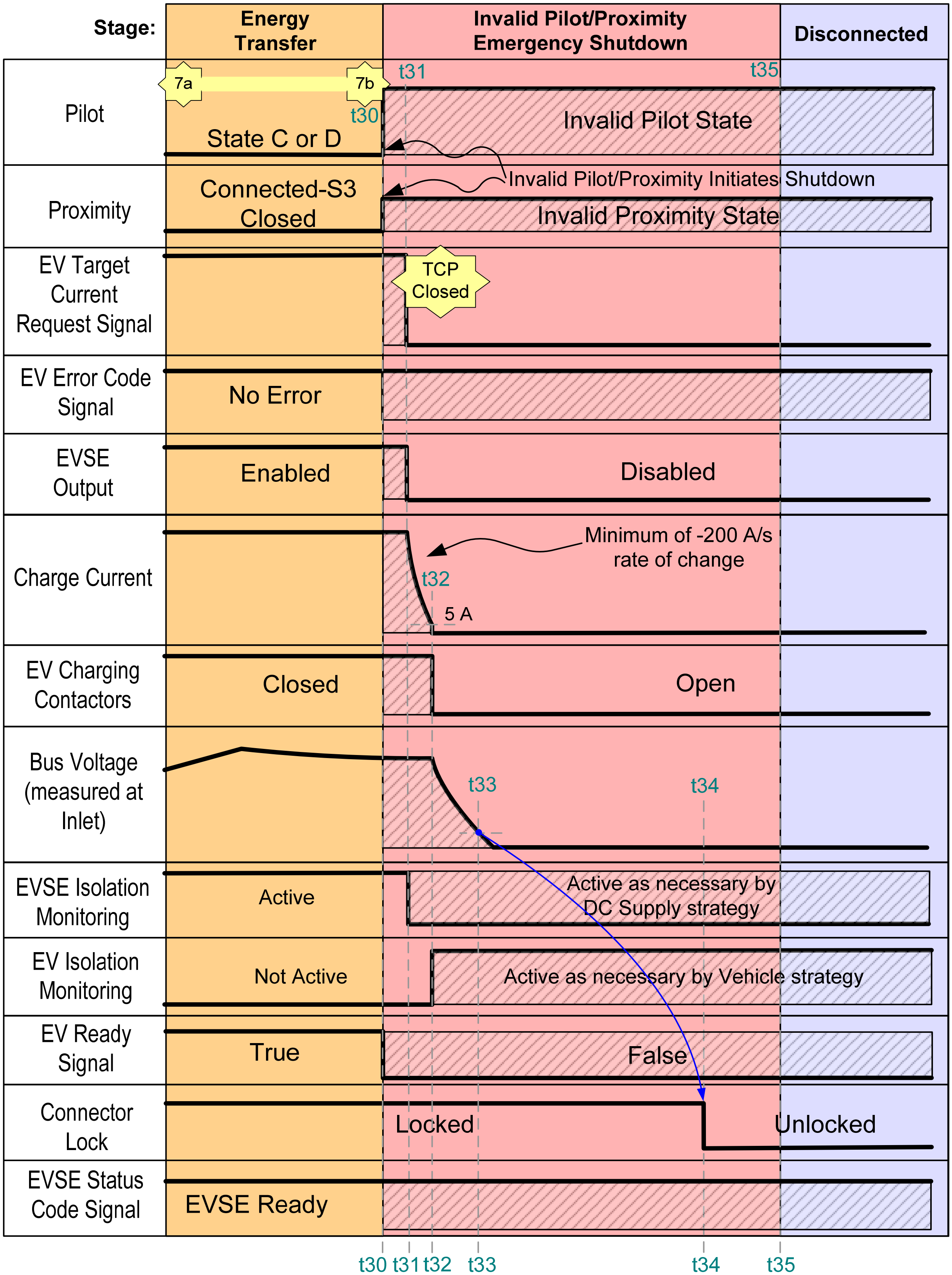
(t28)

- The PEV shall unlock the connector as per OEM strategy.

(t29)

The DC EVSE connector is disconnected from the PEV (Pilot State A1).

F.1.11 Loss of Control Pilot / Proximity Shutdown Sequence



Loss of Control Pilot / Proximity Shutdown Sequence

SAE J1772™ Pilot Signal states:

- State A1 (12V), Oscillator Off, EVSE is Disconnected from PEV
- State B1 (9V), Oscillator off, EVSE is Connected to PEV
- State B2 (9V), Oscillator on with 5% duty cycle, EVSE is Connected to PEV
- State C2 (6V) or D2 (3V) when Vehicle Ready (S2 switch closed by PEV), Oscillator on
- State C1 (6V) or D1 (3V) when Vehicle Ready (S2 switch closed by PEV), Oscillator off

(t30)

- The Pilot State, Proximity State or both Signal States are invalid. The term Invalid Pilot State refers to an invalid voltage (state), duty cycle, or frequency other than the expected values including loss of signal (State E). The term Invalid Proximity state refers to a state other than the expected state including loss of signal. This condition initiates an Emergency Shutdown. Whether the DC EVSE or PEV initiates the Emergency Shutdown is determined by what system detects the Invalid Pilot or Proximity State first.
- The DC EVSE initiates an Emergency Shutdown by turning off the oscillator.
- The DC EVSE could also optionally place the pilot into State F.
- The DC EVSE could also potentially close the TCP connection and disable high level communication at this point.

(t31)

- The DC EVSE disables its output.
- EVSE shall detect the invalid Pilot or Proximity state and begin ramping down output current within 30 ms (t31-t30). Current shall drop to less than 5 A at a minimum rate of -200 A/s or faster.
- The DC EVSE shall discharge bus capacitors.
- Isolation monitoring on the DC supply may start after the DC Supply has disabled its output (and/or opened the DC supply contactor). Cable Isolation check should not be done after the connector is unlocked.
- The PEV detects the EVSE initiated emergency shutdown, therefore the PEV opens switch S2 and terminates the communication session by closing the TCP connection per SAE J2847/2 (if the DC EVSE has not done so already).

(t32)

- The PEV shall open its contactors after the measured current has fallen below an OEM determined limit.
- The Vehicle shall continue to monitor the HV isolation on the system as per OEM strategy.

(t33)

- The PEV may unlock the connector after the bus voltage has dropped below 60V DC as defined by SAE J2344.

NOTE: The vehicle may keep the connector locked even after the voltage has dropped to safe levels so the PEV can keep the connector locked in the inlet until the customer unlocks the vehicle (t28 – t27).

(t34)

- The PEV shall unlock the connector as per OEM strategy.

(t35)

- The DC EVSE connector is disconnected from the PEV.

APPENDIX G - MESSAGE TABLE

The Message ID in the table shown below directly aligns with the Request/Response messages identified by yellow stars in the sequence diagrams in APPENDIX F.

MSG ID	**XML MESSAGE**	**PARAMETERS**
0A	SUPPORTEDAPPPROTOCOLREQ	APPPROTOCOL
0B	SUPPORTEDAPPPROTOCOLRES	RESPONSECODE *SCHEMAID*
1A	SESSIONSETUPREQ	EVCCID
1B	SESSIONSETUPRES	RESPONSECODE EVSEID *DATETIMENOW*
2A	SERVICEDISCOVERYREQ	*SERVICESCOPE* *SERVICECATEGORY*
2B	SERVICEDISCOVERYRES	RESPONSECODE PAYMENTOPTIONS CHARGESERVICE SERVICELIST
XA	SERVICEPAYMENTSELECTIONREQ	
XB	SERVICEPAYMENTSELECTIONRES	
YA	CONTRACTAUTHENTICATIONREQ	
YB	CONTRACTAUTHENTICATIONRES	
3A	CHARGEPARAMETERDISCOVERYREQ	EVREQUESTEDENERGYTRANSFERTYPE DC_EVCHARGEPARAMETER
3B	CHARGEPARAMETERDISCOVERYRES	RESPONSECODE SASCHEDULELIST DC_EVSECHARGEPARAMETER
4A	CABLECHECKREQ	DC_EVSTATUS
4B	CABLECHECKRES	RESPONSECODE DC_EVSESTATUS
5A	PRECHARGEREQ	DC_EVSTATUS EVTARGETVOLTAGE EVTARGETCURRENT
5B	PRECHARGERES	RESPONSECODE DC_EVSESTATUS EVSEPRESENTVOLTAGE
6A	POWERDELIVERYREQ	READYTOCHARGESTATE CHARGINGPROFILE DC_EVPOWERDELIVERYPARAMETER
6B	POWERDELIVERYRES	RESPONSECODE DC_EVSESTATUS
7A	CURRENTDEMANDREQ	DC_EVSTATUS EVTARGETCURRENT EVMAXIMUMVOLTAGELIMIT

MSG ID	**XML MESSAGE**	**PARAMETERS**
		EVMAXIMUMCURRENTLIMIT EVMAXIMUMPOWERLIMIT *BULKCHARGINGCOMPLETE* CHARGINGCOMPLETE REMAININGTIMETOFULLSOC REMAININGTIMETOBULKSOC EVTARGETVOLTAGE
7B	CURRENTDEMANDRES	RESPONSECODE DC_EVSESTATUS EVSEPRESENTVOLTAGE EVSEPRESENTCURRENT EVSECURRENTLIMITACHIEVED EVSEVOLTAGELIMITACHIEVED EVSEPOWERLIMITACHIEVED EVSEMAXIMUMVOLTAGELIMIT EVSEMAXIMUMCURRENTLIMIT EVSEMAXIMUMPOWERLIMIT
8A	POWERDELIVERYREQ	READYTOCHARGESTATE CHARGINGPROFILE DC_EVPOWERDELIVERYPARAMETER
8B	POWERDELIVERYRES	RESPONSECODE DC_EVSESTATUS
9A	WELDINGDETECTIONREQ	DC_EVSTATUS
9B	WELDINGDETECTIONRES	RESPONSECODE DC_EVSESTATUS EVSEPRESENTVOLTAGE
10A	SESSIONSTOPREQ	(NONE)
10B	SESSIONSTOPRES	RESPONSECODE

APPENDIX H - DRAFT COUPLER PERFORMANCE CERTIFICATION TEST PROCEDURE

H.1 INTRODUCTION

A workgroup was formed within the SAE J1772 task force to study coupler field performance. The workgroup has drafted the following test procedure to improve coupler performance in the areas of:

- Connector external mechanical load
- Coupler contact mechanical wear
- Coupler contact corrosion / oxidation
- Terminal crimp performance

These draft procedures require continued evaluation to determine their effectiveness on coupler field performance before they are finalized. These procedures will be finalized using the CANENA (http://www.canena.org/) and/or the CSDS process (http://csds.ul.com/Home/Default.aspx).

The CANENA and/or CSDS processes are used to revise product safety standards. UL2251 (Plugs, Receptacles, and Couplers for Electric Vehicles) is the product safety standard applicable to the SAE J1772 coupler. Revising UL2251 with the finalized test procedures will help improve coupler field performance.

IEC/TC23/SC23H MT8 Ad-hoc Working Group is also working to address coupler field performance. The result of the MT8 work will be included in a subsequent revision to IEC 62196. Harmonization of the MT8 and SAE J1772 workgroup is under consideration.

H.2 DRAFT COUPLER PERFORMANCE CERTIFICATION TEST PROCEDURE

JUDGE

Temperature Rise: Measured at 2 hours (or stable)
Ampacity: 100% of connector maximum rating
Criteria:
- **Max Temperature Rise 50°C**

Connector External Mechanical Load Test

While applying force (4 quadrants):
Ampacity: 100% of connector maximum rating
Criteria:
- **Max Temperature Rise 50°C**
- **Max Temperature Variance 10°C**

POWER PINS:
- **AC L1/L2 Resistance Value < 3mV/A**
- **DC L1/L2 Resistance Value < TBD mV/A**

SIGNAL PINS
- **Resistance Value < 10mV/A**

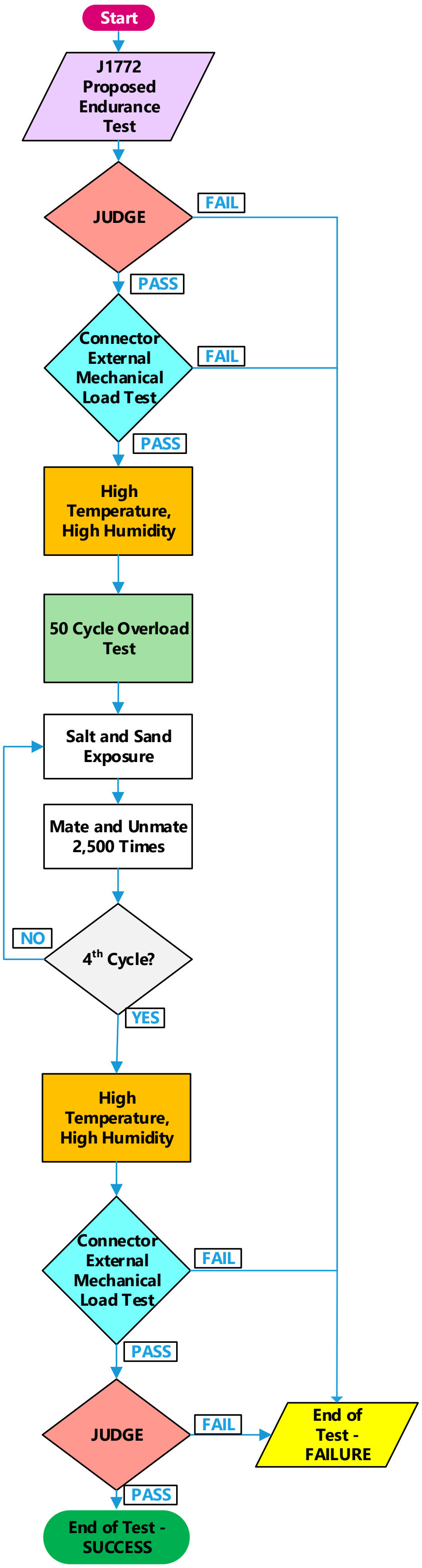
High Temperature, High Humidity Exposure Test

Temperature: 85°C
Humidity: 95% RH
Exposure time: 240 hours

50 Cycle Overload Test

Temperature Cycle: 2 hours (stable) ON; 1 hour OFF
Ampacity: 125% of connector maximum rating
Cycles: 50 times; coupler remains mated
Criteria:
- **Max Temperature Rise 50°C**
- **Max Temperature Variance 10°C**

NOTE:
The JUDGE criteria can be optionally applied at any point in the test process



H.3 DRAFT COUPLER PERFORMANCE CERTIFICATION BASELINE TEMPERATURE RISE MEASUREMENT

H.3.1 Each of ten (10) devices shall be operated in a mated condition under the following conditions as illustrated in Figure 18.

H.3.2 The temperature rise of each device at the points measured (see Figure 19 – or reference UL clause 45.3 – see Note 1 in H.11) shall not exceed 50 °C (122 °F) when the device is carrying a current of 100% of its maximum rated current.

H.3.3 Test is to be conducted at an ambient temperature between 10 – 40 °C (50 – 104 °F). If the tests are conducted at an ambient temperature of other than 25 °C (77 °F), the results are to be adjusted to an ambient temperature of 25 °C (77 °F) by adding or subtracting the appropriate variation between 25 °C (77 °F) and the ambient.

H.3.4 This temperature rise is based on devices intended to be wired with conductors rated 105 °C (221 °F).

H.3.5 The load of H.3.2 shall be applied for 2 hours or until the temperature has stabilized. A temperature is considered to be stabilized when three successive readings taken at intervals of 10 percent of the previously elapsed duration of the test indicate no increase greater than 2 °C (4 °F).

H.3.6 Use text of UL 2251 Clause 45.5 here (see note 2 in H.11).

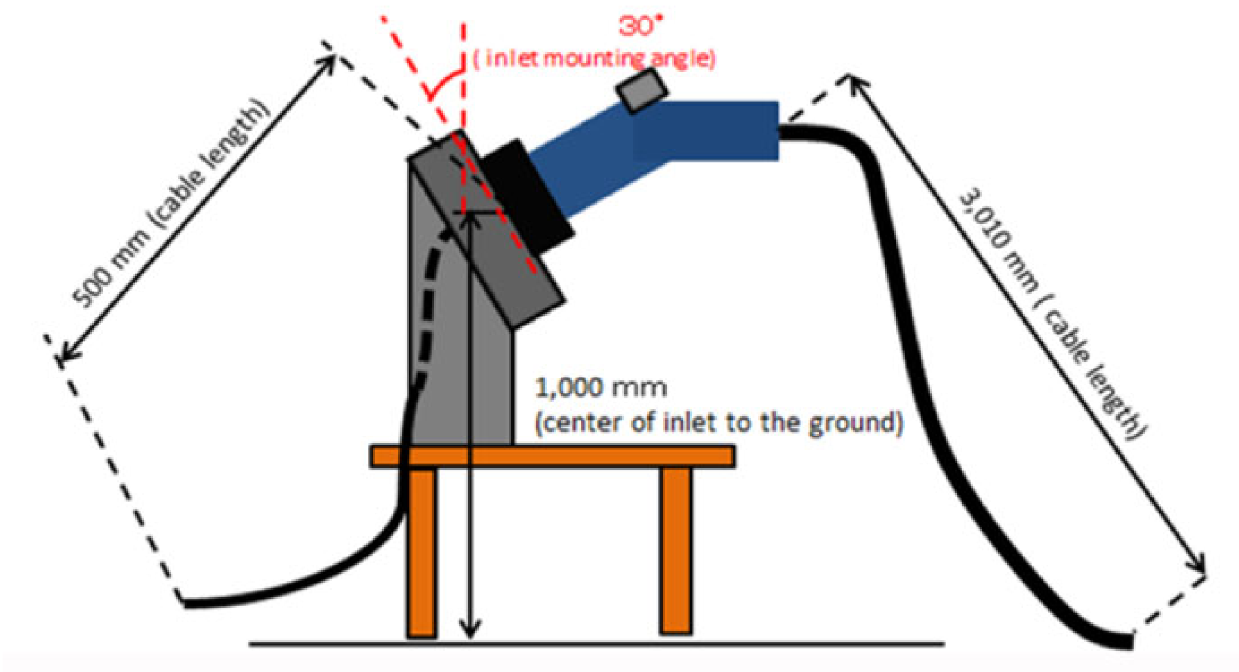


Figure 18 – Charge Coupler Test Setup

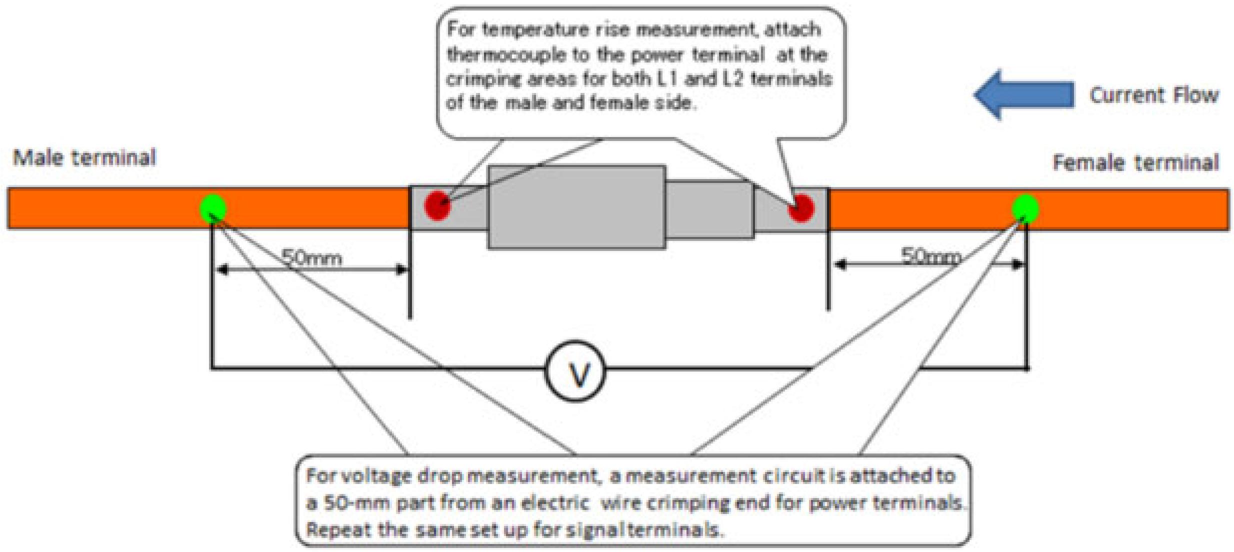


Figure 19 – Temperature rise and resistance measurement set up

H.4 DRAFT CONNECTOR EXTERNAL MECHANICAL LOAD TEST

H.4.1 Each of the devices used in the test described in H.3 shall be evaluated in a mechanical load test as described following.

H.4.2 Apply rated current for 2 hours or until temperature is stable.

H.4.3 Using a hand held force gauge, apply the measuring tip to the end of the connector grip area as illustrated in Figure 20. Move the connector grip with that hand held force gauge within 10 seconds and then apply 100 N for another 10 seconds.

H.4.4 The temperature rise and voltage drop shall be measured at 1 second or less intervals during the test.

H.4.5 Perform H.4.3 – H.4.4 for each direction noted in Figure 20 – Up, Down, Right and Left.

H.4.6 Repeat H.4.5 three (3) times.

H.4.7 During the test, the connector temperature shall not rise more than 50 °C (122 °F) with a maximum temperature variance between tests of less than 10 °C (18 °F). Connector resistance for power pins shall be less than 3mV/A for AC Level 1 and Level 2 operation. Connector resistance for power pins shall be less than TBD mV/A for DC Level 1 and Level 2 operation. Connector resistance for signal pins shall be less than 10mV/A for all tests. See Figure 21 for an illustration of the evaluation criteria.

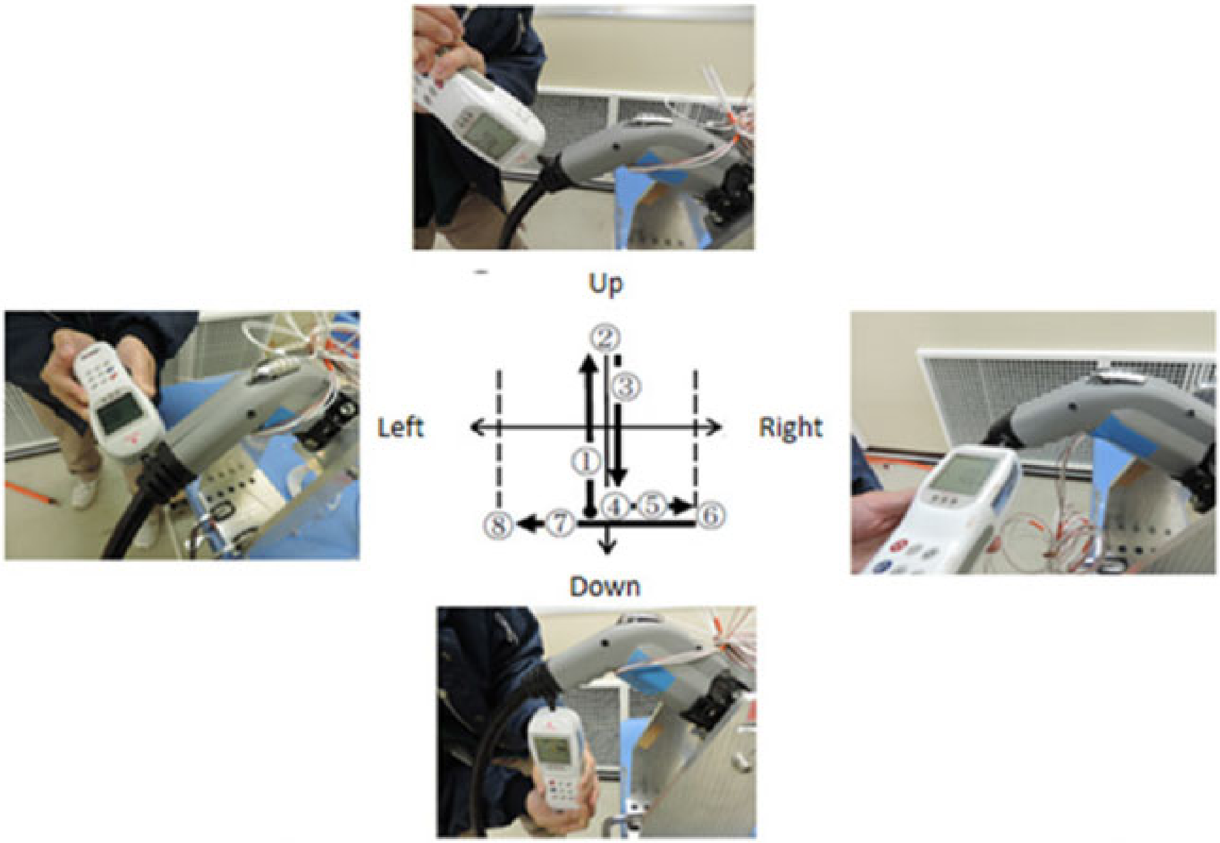


Figure 20 – Applying external load using hand held force gauge

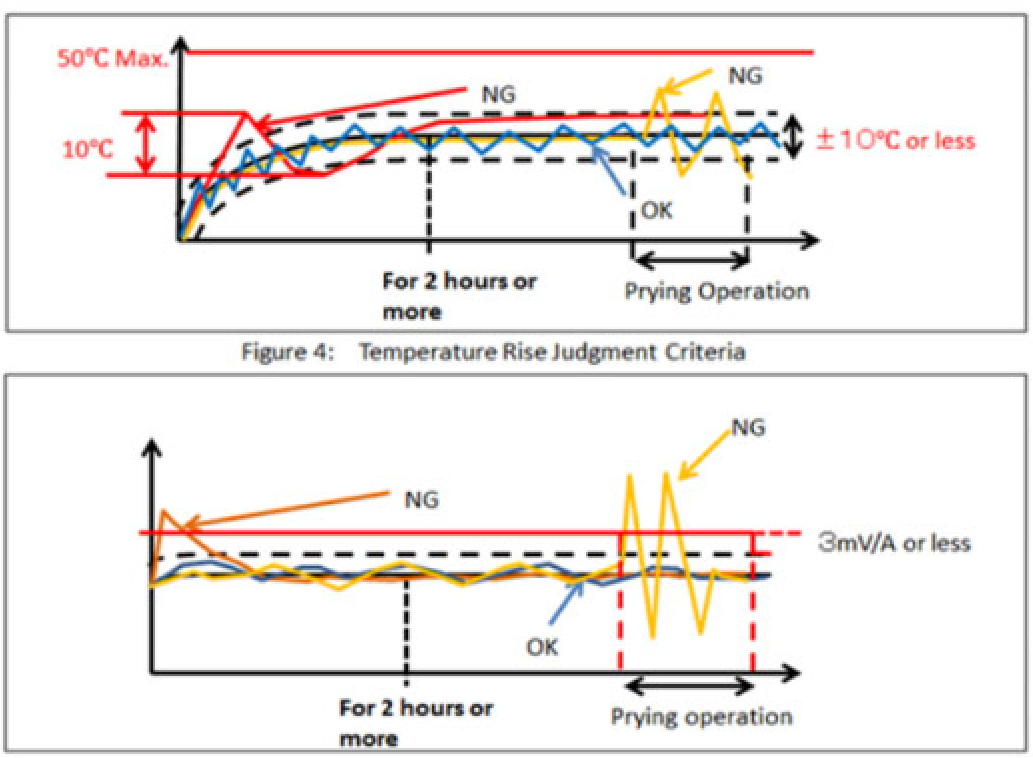


Figure 21 - Voltage drop judgment criteria

H.5 DRAFT COUPLER PERFORMANCE CERTIFICATION HIGH TEMPERATURE, HIGH HUMIDITY EXPOSURE

H.5.1 Each of the devices used in the tests described in H.4 shall be exposed in an un-mated condition to elevated temperature and humidity environment.

H.5.2 The apparatus used for the exposures is to consist of a chamber having a volume of at least 0.08 m3 (3 ft2) with a water jacket and thermostatically controlled heater to maintain a temperature of 85°C, +1.1/-1.7 °C (185 °F, +2, -3°F) at a relative humidity of 95% ± 2%. The devices shall be placed on a platform approximately 50 mm (2 inches) above the bottom of the exposure chamber.

H.5.3 The devices are to be exposed as in H.5.1 – H.5.2 for a period of 240 hours.

H.6 DRAFT COUPLER PERFORMANCE CERTIFICATION OVERLOAD TEMPERATURE CYCLE TEST

H.6.1 Each of the devices used in the test tests described in H.5 shall be operated in a mated condition under the following conditions.

H.6.2 The temperature rise of each device at the points measured (as described in UL 2251 paragraph 45.3 – see note 1 in H.11) shall not exceed 50 °C (122 °F) when the device is carrying a current of 125% of its maximum rated current. The variation of the temperature rise in consecutive tests shall be less than 10 °C (18 °F).

H.6.3 Test is to be conducted at an ambient temperature between 10 – 40 °C (50 – 104 °F). If the tests are conducted at an ambient temperature of other than 25 °C (77 °F), the results are to be adjusted to an ambient temperature of 25 °C (77 °F) by adding or subtracting the appropriate variation between 25 °C (77 °F) and the ambient.

H.6.4 This temperature rise is based on devices intended to be wired with conductors rated 105 °C (221 °F).

H.6.5 The load of H.6.2 shall be applied for 2 hours or until the temperature has stabilized. A temperature is considered to be stabilized when three successive readings taken at intervals of 10 percent of the previously elapsed duration of the test indicate no increase greater than 2 °C (4 °F).

H.6.6 The load is to be removed for a period of 1 hour.

H.6.7 The test of H.6.1 – H.6.6 is to be repeated 50 times.

H.7 DRAFT COUPLER PERFORMANCE CERTIFICATION NO LOAD ENDURANCE TEST

H.7.1 Each of the devices used in the tests described in H.6 shall to be exposed to the test described in UL 2251 clause 41 No-Load Endurance Test as modified in the next paragraph. This is a salt/sand exposure test.

H.7.2 ZUL 2251 Clause 41.1 shall be changed to read “During this test, the devices under test shall be subjected to exposure to contaminants, for a maximum of five seconds after each 2500 cycle of operation and allowed to dry completely before the resuming the cycling test. “

H.8 DRAFT COUPLER PERFORMANCE CERTIFICATION SECOND HIGH TEMPERATURE, HIGH HUMIDITY EXPOSURE TEST

H.8.1 Each of the devices used in the tests described in H.6 shall be exposed to a repeat the high temperature, high humidity test of H.5.

H.9 REPEAT OF CONNECTOR EXTERNAL MECHNICAL LOAD TEST

H.9.1 Each of the devices used in the tests described in H.8 shall be exposed to a repeatof the CEML test of H.4.

H.10 DRAFT COUPLER PERFORMANCE CERTIFICATION FINAL TEMPERATURE RISE MEASUREMENT

H.10.1 Each of the devices used in the tests described in H.9 shall be operated in a mated condition under the following conditions.

H.10.2 The temperature rise of each device at the points measured (described in UL 2251 Clause 45.3 – see note 1 in H.11) shall not exceed 50 °C (122 °F) when the device is carrying a current of 100% of its maximum rated current.

H.10.3 Test is to be conducted at an ambient temperature between 10 – 40 °C (50 – 104 °F). If the tests are conducted at an ambient temperature of other than 25 °C (77 °F), the results are to be adjusted to an ambient temperature of 25 °C (77 °F) by adding or subtracting the appropriate variation between 25 °C (77 °F) and the ambient.

H.10.4 This temperature rise is based on devices intended to be wired with conductors rated 105 °C (221 °F).

H.10.5 The load of H.10.2 shall be applied for 2 hours or until the temperature has stabilized. A temperature is considered to be stabilized when three successive readings taken at intervals of 10 percent of the previously elapsed duration of the test indicate no increase greater than 2 °C (4 °F).

H.10.6 Use text of UL 2251 clause 45.5 here (see note 2 in H.11).

H.10.7 A device that meets the criteria of H.10.1 – H.10..6 after tests H.3 – H.9 have been performed shall be deemed to have passed the SAE proposed connector endurance test.

H.11 REFERENCE NOTES FROM UL 2251

H.11.1 NOTE 1 – Clause 45.3 – Repeated here for reference: “The temperature measurement shall be made on the wiring terminals and at the contacts of the equipment, if they are accessible for mounting thermocouples. If the equipment has no wiring terminals or they or the contacts are inaccessible, temperatures shall be measured as close as possible to the face of the equipment on the male contacts inserted in the mating device. “

H.11.2 NOTE 2 – Clause 45.5 – Repeated here for refercence: “For devices rated less than 200 A, the load shall be applied continuously. For plugs, vehicle connectors, or breakaway couplings rated 200 A or greater, the load shall be applied for 20 minutes followed by a no-load period of 10 minutes. This cycle (20 minutes load, 10 minutes no-load) shall be repeated until temperatures stabilize. The plug, vehicle connector, or breakaway coupling shall be coupled to mating device that employs the same AWG size power conductors that are utilized in the plug, vehicle connector, or breakaway coupling. For receptacles and vehicle inlets rated 200 A or greater, the load shall be applied for a single 20 minute period, with the AWG size of the power conductors sized as normally employed in the receptacle or vehicle inlet.”

APPENDIX I - DC LEVEL 1 AND LEVEL 2 COMBINATIONS FOR PEVS & EVSES - INFORMATIVE

This appendix provides the combinations for DC Level 1 and Level 2 Charging not included in section 6. Section 6 includes the systems for both the PEV and EVSE to include either DC Level 1 or DC Level 2, not combinations that may occur.

I.1 DC LEVEL 1 & LEVEL 2 ALIGNMENTS

If the PEV and EVSE include the system shown in Figure 12 for DC Level 1, or both the PEV and EVSE include the system shown in Figure 13 for DC Level 2, then there are no issues. These are considered alignments and no further action is expected.

I.2 DC LEVEL 1 & LEVEL 2 MISALIGNMENTS

If the two cases described in I.1 above are not used, then we may have power terminals that do not align between vehicles and EVSEs.

The first case is when the EVSE has the DC Level 1 standard connector and the PEV has the DC Level 2 Combo inlet. The issue with this is that the DC charging circuit is not connected between the EVSE connector and the PEV inlet.

The second case is when the EVSE has the DC Level 2 Combo connector and the PEV has the DC Level 1 standard inlet.

Case 1 - EVSE has the DC Level 1 standard connector and the PEV has the DC Level 2 Combo inlet

This case could apply to a PEV that includes the Combo inlet that is connecting to a lower power EVSE (up to 36 kW). DC Level 1 EVSE’s could be more prevalent at homes, multi-family dwellings, businesses (fast food, groceries, etc.) than the 50-100 kW DC Level 2 units.

This is shown in Figure 22 where the PEV and EVSE inlet and connector power circuits do not align. The PEV expects DC energy on terminals 6 & 7 whereas the EVSE expects DC energy on the standard terminals 1 & 2. Since the EVSE connector is the standard connector (not the Combo), the burden of aligning power circuits is on the PEV, that would need to include additional switches (or contactors) that would connect the Combo extended terminals to the standard terminals if DC Level 1 charging is desired.

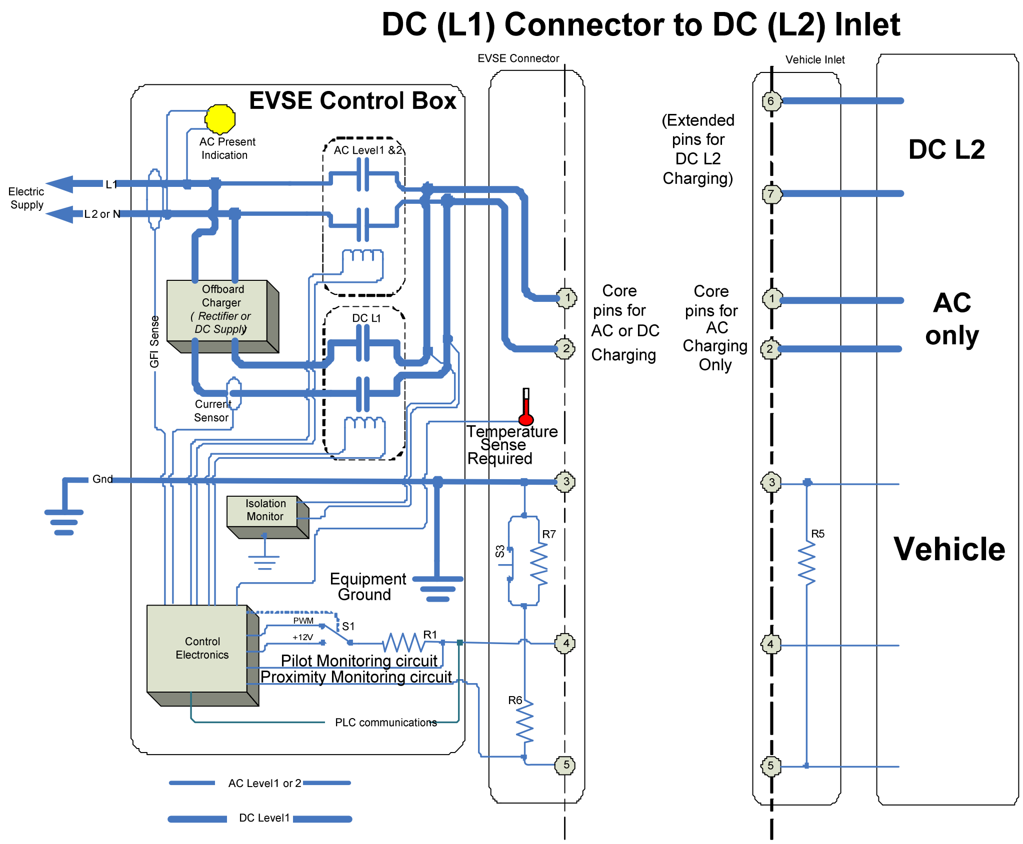


Figure 22 - DC Level 1 connector on EVSE and DC level 2 combo inlet on vehicle

Case 2 - EVSE has the DC Level 2 Combo connector and the PEV has the DC Level 1 standard inlet

Case 2 is shown in Figure 23. The issue with this is that the DC charging circuit is also not connected between the EVSE connector and the PEV inlet terminals. Since the DC Level 2 EVSE connector is the Combo (not the standard), the burden falls on the EVSE to include switches (or contactors) that would transfer DC charging to the standard or core terminals of the PEV inlet.

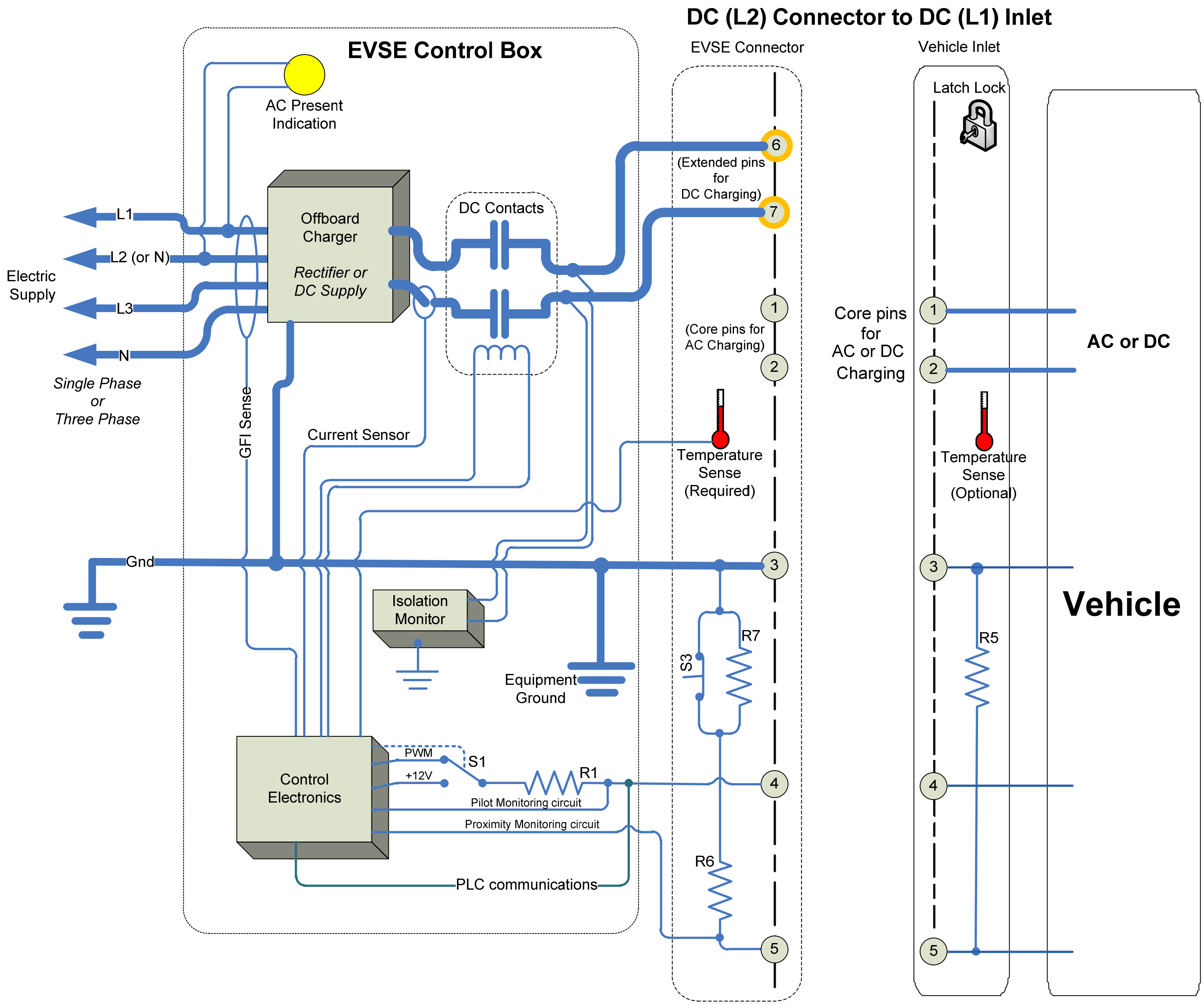


Figure 23 - DC Level 2 combo connector on EVSE and DC level 1 standard inlet on vehicle

Another option for the EVSE is to include both the Standard (for DC Level 1) and Combo connectors (for DC Level 2) with cables to the PEV. This is an approach already used for gasoline pumps where unleaded and diesel have separate nozzles and hoses on the same dispenser unit. This would align the circuits in both connectors and minimize the cable diameter for each, since four circuits are required in the cable from the EVSE to the connector for this combined EVSE. Initial DC Level 2 EVSE's are using 2 AWG cable for up to 174A. The max current for the Combo connector is 400A but above 174A requires 0 AWG which is considerably larger in diameter. 80A for DC Level 1 requires 6 AWG and combining two 2 AWG plus two 6 AWG makes the single cable very heavy and difficult to handle. The two-cable approach would be more customer friendly and easier to handle as shown in Figure 24.

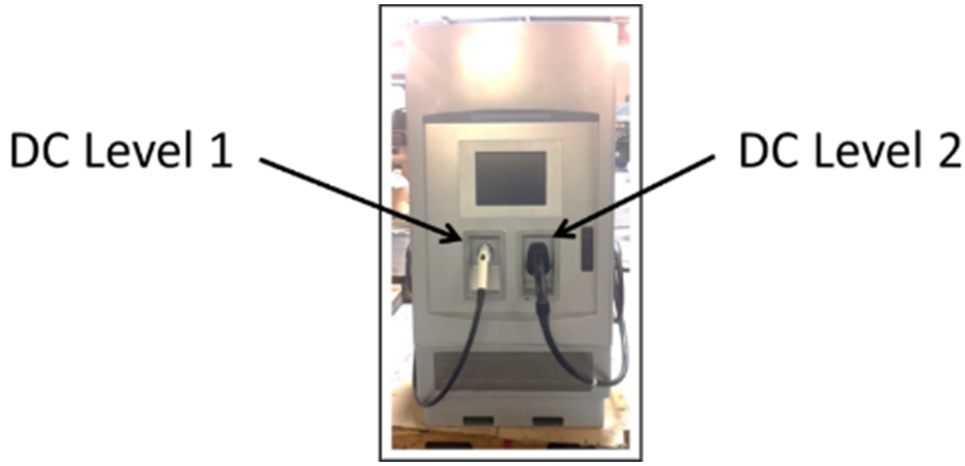


Figure 24 - DC level 1 and level 2 EVSE

I.3 OFFERING OPTIONS TO THE CUSTOMER

Some vehicle manufacturers have DC charging available now, and several DC Level 2 stations are being installed. Most of these are only focused on the SAE Combo. The customer needs to understand that not all DC Level 2 stations will have the same power available and are not at the 100 kW level allowed from DC Level 2. The initial DC EVSEs are being installed at 50 or 60 kW and that makes them slightly more powerful than the 40 kW available for DC Level 1. The charge time for a 25 kWh BEV full charge (20% to 80% SoC) would only be 5 minutes shorter for 50 kW (DC Level 2) vs. 40 kW (DC Level 1). Customers can choose to install a DC Level 1 EVSE at home or merely use public units. These home units may be in the 6-12 kW power level and some public units may only be 15-20 kW.

DC Level 1 therefore, may be the better value to the customer than only offering DC Level 2. Offering DC Charging and maintaining a smaller on-board charger allows the customer to choose their vehicle options, similar to what they do today with powertrains and other vehicle options. They will eventually choose on-board charger size and if they want DC Charging as an option or not.

This appendix therefore is intended to show some of the combinations not identified in the main document and describes how to include these in PEV and EVSE designs.

APPENDIX J – DC Y CAPACITANCE REQUIREMENT DERIVATION - INFORMATIVE

J.1 INTRODUCTION

This appendix describes the derivation of Y capacitance limits, as a function of voltage, from the limits given in IEC 60479-2. The IEC standard references quantities called specific fibrillating energy and specific fibrillating charge:

$$F_e = \int_0^\infty i^2 dt \qquad \text{(in W s / }\Omega\text{ or A}^2\text{s)}$$

$$F_q = \int_0^\infty i\, dt \qquad \text{(in A s or C)}$$

These are minimum values for unidirectional impulses of short duration, which under given conditions (current path, heart phase) cause ventricular fibrillation with a certain probability.

NOTE: The upper limits of integration in the definitions above are taken from the detailed derivations within IEC 60479-2, as opposed to the definitions, where the upper limits are given as t_i.

J.2 IEC LIMITS BASED ON SPECIFIC FIBRILLATING ENERGY

For capacitor discharge (exponentially decaying) pulses, the IEC F_e limit is specified indirectly via the impulse duration t_i and equivalent RMS impulse current $I_{C\,rms}$:

$$F_e = t_i\, I_{C\,rms}$$
$$t_i = 3RC$$
$$I_{C\,rms} = I_{C\,(peak)} \big/ \sqrt{6}$$

In Figure 20 of the IEC standard, values of t_i are given as a function of $I_{C\,rms}$ for 0%, 5%, and 50% probability of fibrillation. It can be seen that the functional form of t_i is:

$$t_i = A\, I_{C\,rms}{}^{P} \quad \text{for } t_i \le .004$$

In paragraph 11.4.1 of the IEC standard, values of F_e and t_i are given at two points on the 50% probability curve C3. The corresponding $I_{C\,rms}$ values can be calculated:

$$I_{C\,rms}(t_i = .004) = \sqrt{\frac{F_e}{t_i}} = \sqrt{\frac{.01}{.004}} = 1.581$$

$$I_{C\,rms}(t_i = .001) = \sqrt{\frac{F_e}{t_i}} = \sqrt{\frac{.02}{.001}} = 4.472$$

Solving for the exponent P and the scaling constant A_3 for curve C3:

$$P = \frac{\log\left(\dfrac{t_{i,1}}{t_{i,2}}\right)}{\log\left(\dfrac{I_{B\_rms,1}}{I_{B\_rms,2}}\right)} = \frac{\log\left(\dfrac{.004}{.001}\right)}{\log\left(\dfrac{1.581}{4.472}\right)} = -1.333$$

$$A_{C3} = \frac{t_i}{I_{C\,rms}{}^{P}} = \frac{.004}{1.581^{-1.333}} = .007367$$

For the 0% probability of fibrillation curve C1, the exponent P is unchanged, and the constant A_{C1} is:

$$A_{C1} = \frac{t_i}{I_{C\,rms}{}^{P}} = \frac{.004}{0.5^{-1.333}} = .001587$$

The impulse duration for the 0% probability of fibrillation curve C1 is thus determined to be:

$$t_i = \begin{cases} 0.001587 \;\; I_{C\,rms}{}^{-4/3} & \text{for } I_{C\,rms} > 0.5 \text{ A} \\ .004 \text{ to } .01 & \text{for } I_{C\,rms} = 0.5 \text{ A} \end{cases}$$

The limit on capacitor energy for 0% probability of fibrillation is calculated, assuming a body resistance of 500 Ω. The F_e – based capacitor energy limit is included in Figure J-1:

$$E_C = \int_0^{\infty} i^2 R\, dt = F_e R = I_{C\,rms}{}^2 t_i R$$
$$= \begin{cases} R\, A_{C1}\, I_{C\,rms}{}^{2/3} = 0.7937\, I_{C\,rms}{}^{2/3} & \text{for } I_{C\,rms} > 0.5 \text{ A} \\ 0.5^2 t_i R = 0.500 \text{ to } 1.25 & \text{for } I_{C\,rms} = 0.5 \text{ A} \end{cases}$$

The corresponding voltage-dependent capacitance limit is calculated and included in Figure 26:

$$C = \frac{t_i}{3R}$$
$$= \begin{cases} \dfrac{A_{C1}}{3R} I_{C\_rms}{}^{P} = \dfrac{A_{C1}}{3R}\left(\dfrac{V_C}{\sqrt{6}R}\right)^{P} = 0.01387 \cdot V_C{}^{-4/3} & \text{for } \;\; V_C \geq 612 \\ \dfrac{t_i}{1500} = 2.67 \cdot 10^{-6} \text{ to } 6.67 \cdot 10^{-6} & \text{for } \;\; V_C = 612 \end{cases}$$

The boundary of applicability of the F_e limit comes from the curve C_1 condition:

$$I_{C\,rms} = \frac{V_C}{\sqrt{6}R} \geq 0.5$$
$$V_C \geq 612$$

J.3 IEC LIMITS BASED ON SPECIFIC FIBRILLATING CHARGE

The F_q limit is given for 50% probability of fibrillation in IEC 60479-2 paragraph 11.4.1, in units of A s:

$$F_q \Big|_{50\%} = .005$$

Assuming that F_q scales with probability the same as $I_{C\,rms}$:

$$F_q \Big|_{0\%} = F_q \Big|_{50\%} \frac{I_{C\,rms}\big|_{0\%}}{I_{C\,rms}\big|_{50\%}} = .005 \frac{.5}{1.58} = .0016$$

The corresponding F_q –based capacitance limit is easily obtained, and is included in Figure 25:

$$F_q = \int_0^\infty i\,dt = Q_C = C\,V$$

$$C = \frac{F_q}{V} = \frac{0.0016}{V}$$

The F_q –based capacitor energy limit is calculated and is included in Figure J-2:

$$E_C = \frac{Q_C\,V}{2} = \frac{F_q\,V}{2} = \frac{F_q\,I_{C\,peak}R}{2} = \frac{F_q\,\sqrt{6}I_{C\,rms}R}{2}$$

$$= 0.98\,I_{C\,rms}$$

J.4 RANGE OF APPLICABILITY OF IEC 60479-2 LIMITS

The IEC 60479-2 limits for unidirectional impulse currents are defined for shocks of up to 10 ms duration. Assuming R=500 Ohms:

$$t_i = 3RC \le 0.01$$

$$C \le \frac{0.01}{3R} = 6.67 \cdot 10^{-6}$$

Substitution of the derived F_q = 0.0016 limit yields the ranges of applicability for capacitance, voltage, and equivalent RMS impulse current, for 0% probability of fibrillation:

$$C = \frac{F_q}{V} \le \frac{0.01}{3R} = 6.67 \cdot 10^{-6}$$

$$V \ge \frac{3\,R\,F_q}{.01} = 240$$

$$I_{C\,rms} = \frac{I_{C\,(peak)}}{\sqrt{6}} = \frac{V}{R\sqrt{6}} \ge \frac{3\,F_q}{.01\sqrt{6}} = 0.196$$

J.5 GRAPHS

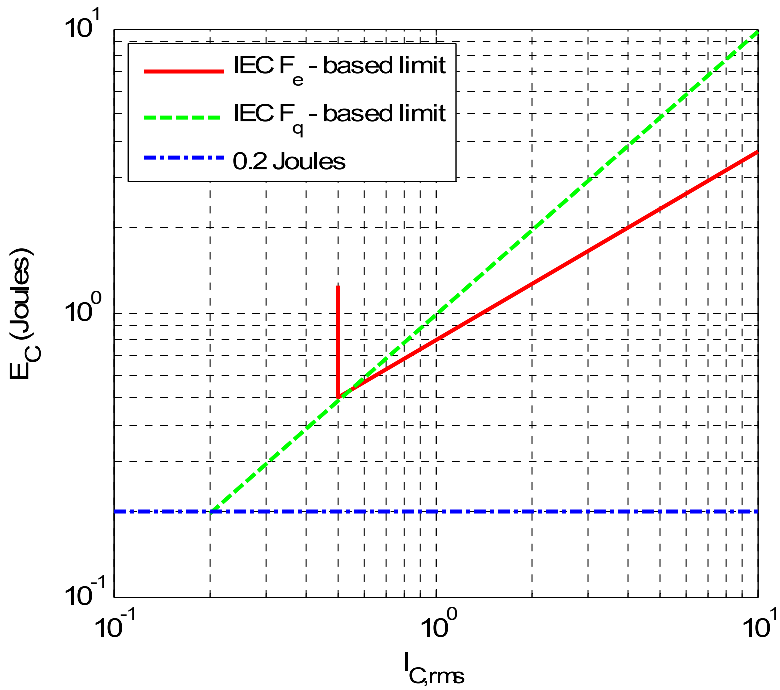


Figure 25 - Energy limit vs. equivalent RMS discharge current

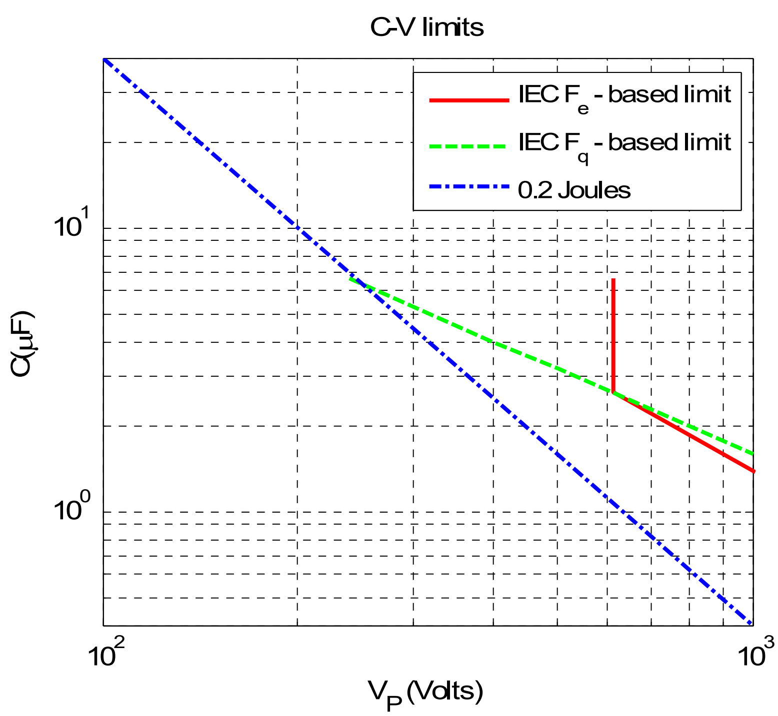


Figure 26 - Capacitance limit vs. voltage

APPENDIX K – WAKEUP OF CERTAIN LEGACY VEHICLES (INFORMATIVE)

This informative appendix describes an optional transition that may be implemented by EVSE manufacturers. This optional transition is intended to wakeup certain legacy vehicles that cannot wakeup upon a Control Pilot state transition once the legacy vehicle enters a sleep state.

Vehicles that comply with this standard and detect transition 14 in Table 14 do not require this optional transition.

Transition	Initial Condition	New Condition	EVSE Response Time	EV/PHEV Response Time	Specification or Condition
optional	State = B1 OSC = off	State = E	4 s		EVSE attempts to wake up vehicle

This optional transition may also be used by the EVSE when changing from a 5% duty cycle to a duty cycle between 10% and 96%, or vice versa.

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APPENDIX L - HISTORY EVSE/VEHICLE INTERFACE

NOTE: THE FOLLOWING IS HISTORICAL INFORMATION FOR REFERENCE ONLY.

The specifications for the Control Pilot system shown in 4.2 of SAE J1772™ are purposely written to convey the most basic information needed to precisely define the system. However, the initial version of this system has been in use since 1997, and the experience gained by the industry may be of help to new manufacturers attempting to design equipment conforming to the SAE J1772™ Recommended Practice. This Appendix is a compilation of that experience, focused on the interface circuitry between the EVSE and the Vehicle.

Typical circuitry presently in use by Charging Station and Vehicle Manufacturers, is shown in basic form in Figure 27. Actual schematics cannot be shown due to proprietary considerations.

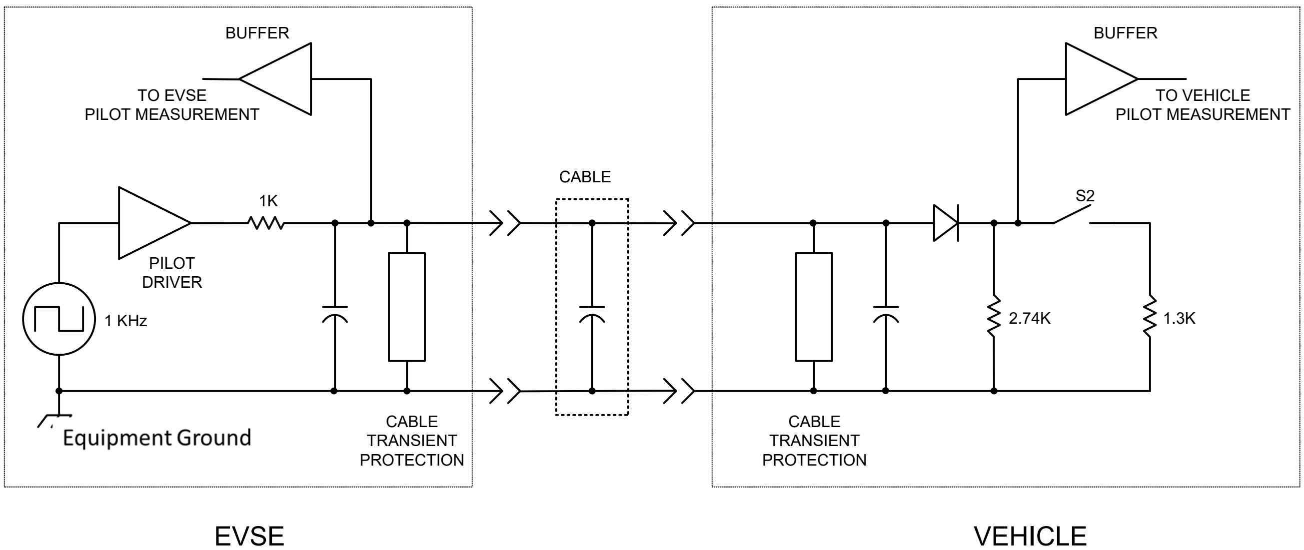


Figure 27 - Typical pilot line circuitry

L.1.1 Pilot Circuit Components

a. The op-amp shown as a driver is only indicative of the function, and is not intended to imply that this is a standard method of driving the Pilot line. The low output impedance of a typical op-amp makes the source resistance essentially the resistor itself. Although this may simplify the design, it does not mean that this is the only valid architecture. Other factors, such as susceptibility to cable transients, should also be considered in the design effort.

b. The two op-amps shown as buffers are meant to show a method of tapping off the Pilot line, for measurement purposes, in a manner that will not significantly affect the line waveform.

c. Switch S2 need not be a mechanical switch or relay. At least one vehicle manufacturer is successfully using an FET for this purpose.

d. The diode shown on the vehicle side is intended to be a common small signal silicon diode. Reverse voltage ratings of at least 100V are readily available and are recommended since this diode is exposed directly to cable transients.

e. The cable capacitance from the Pilot wire to the Ground wire will probably be around 25 pF per foot, and many cables are 15 to 20 feet long. If the EVSE’s contactor closes when the line voltage is near a positive or negative peak, then the voltage on the contactor output can rise from 0 to 170 V in just a few nanoseconds. This fast, high-voltage transition can easily be coupled through the capacitance of the cable. In addition, with the contactor closed during charging, any transients such as might be generated by nearby industrial equipment or lightning strikes can be coupled through. It is highly recommended that transient protection be installed on both the EVSE output and the vehicle input.

L.1.2 Basic Communication Sequence

The most basic communication sequence between the EVSE and the Vehicle is presented below in terms of the nominal voltage levels involved.

a. The EVSE generates a static +12 V, waiting for connection to the Vehicle.

b. Upon connection, assuming that switch S2 is open, the 2.74K Ω resistor on the vehicle will pull the +12V down to +9V, as measured at the EVSE output. The EVSE will sense this and begin generating a +9V, –12V, 1KHz square wave. Because of the diode on the Vehicle, the negative portion will be at –12V. Note that, for standard AC Level I and AC Level 2 charging, the negative portion will always remain at –12V. This purpose of this feature is safety, to allow the EVSE to distinguish between a vehicle and the straight resistance of a curious child's fingers.

c. If the Vehicle requires AC energy transfer, it will close switch S2. Most often, this will switch a 1.3K Ω resistor in parallel with the 2.74K Ω resistor, for an effective total resistance of 882 Ω. This value will pull the positive portion of the square wave down to +6V. The EVSE will interpret this as a request for AC power and close the contactor.

   If a 270 Ω resistor is switched in, the positive portion of the square wave will be pulled down to +3V, informing the EVSE that the vehicle's battery is a type that emits hazardous gasses during charging, and requires an exhaust fan in enclosed areas. Unless the EVSE is equipped to verify that such a fan is running, it must not close the contactor. In practice, very few auto manufacturers have put such batteries in their vehicles due to liability issues, and virtually all are using the 1.3K Ω resistor value.

d. When the Vehicle no longer requires AC energy transfer, it will open S2 and the positive portion of the signal will go back up to +9V. The EVSE will open the contactor, removing power. The +9V, –12V square wave will remain until the cable is disconnected from the Vehicle, when it will again go back to the static +12V state.

L.1.3 Pilot Line Voltage Ranges

Table 15 is not intended to imply that the Control Pilot voltages must remain within the minimum and maximum voltages shown. Rather, given the voltages and component values, and their tolerances as specified in Section 5 of SAE J1772™, it shows the range of voltages that will be obtained on the Pilot line output, over a –40 °C to 85 °C temperature range. This includes a tolerance of 3% for resistors on both the EVSE and the vehicle, and includes temperature effects on the small signal silicon diode. The table also assumes low-resistance Pilot line and Ground connections through the cable and connections.

EVSE manufacturers must decide for themselves what voltage tolerances will be acceptable for each Pilot line state, keeping in mind that vehicle tolerances are also involved.

Table 15 - Pilot line voltage ranges

	Min	Nominal	Max
Positive Voltage, State A	11.40	12.00	12.60
Positive Voltage, State B	8.36	9.00	9.56
Positive Voltage, State C	5.48	6.00	6.49
Positive Voltage, State D	2.62	3.00	3.25
Negative Voltage - States B, C, D, and F	-11.40	-12.00	-12.60

In the States B, C, and D, where a 1 KHz square wave is present with capacitance on the line, the voltages shown represent the fully-settled values (> 8RC) after a transition.

The +12V and –12V voltages will most likely be generated using generic 3-terminal regulators. The minimum and maximum voltages shown in Table 15 both indicate a 5% tolerance. However, in recent years the +12V regulators have become commonly and inexpensively available with tolerances of ±2% over line, load, and temperature variations. The -12V regulators are commonly available with ±4% tolerance. Use of these, or others that may have even tighter tolerance specifications, will give greater tolerance to other components, increasing the probability that system voltages will stay within the specifications over the life of the equipment.

Previously, SAE J1772™ specified the voltage range for each state, as shown in Table 16. Each state had a ±1V range, with 1V gaps between each range that were considered invalid voltages. This was intended to give each state a large tolerance leeway, and provide gaps between states for noise immunity.

Table 16 - Original pilot voltage specification (reference)

Vehicle State	Measured Voltage
	13.0 V
State A	12.0 V - nominal
	11.0V
	Invalid
	10.0 V
State B	9.0 V - nominal
	8.0 V
	Invalid
	7.0 V
State C	6.0 V - nominal
	5.0 V
	Invalid
	4.0 V
State D	3.0 V - nominal
	2.0 V
	Invalid

These voltage ranges are no longer part of the SAE 1772™ Specification. EVSE manufacturers may still use these ranges, at their discretion, but they are no longer constrained to do so by the Recommend Practice. As shown in Table 15, in a properly functioning system where the voltages and component tolerances are within the Specification, the voltages obtained will be well within those in Table 16.

However, staying within the Specifications for the EVSE in Section 5 of SAE J1772™, it will be left to the EVSE designer to decide the general architecture they will use and what voltage tolerances they will allow in their equipment for each state. At the other end of the cable, the Vehicle Manufacturers must be sure the equivalent resistances for each state fall within the specifications.

The specifications for the EVSE in Table 3 of SAE J1772™ can be used by the Vehicle Manufacturers to fully test their end of the system by simulating the EVSE part of the interface. The same is true for EVSE manufacturers, who can simulate the vehicle part of the interface. Values of all parameters can be adjusted over their specified range, and the robustness of the system can be determined before committing to the manufacture of a particular design.

APPENDIX M - AC LEVEL 3 CHARGING

NOTE: AC LEVEL 3 CHARGING HAS NEVER BEEN IMPLEMENTED. THE FOLLOWING IS HISTORICAL INFORMATION FOR REFERENCE ONLY.

M.1 SCOPE

This appendix is included for historical reference and illustrates a charging system capable of accepting current in excess of 48 A AC.

M.1.1 System Description

The SAE J1772™ recommended conductive coupler provides for two sets of current-carrying conductors. Contacts 1 and 2 are designated for AC charging at 6 to 48 A line current; contacts 3 and 4 are designated for high-current charging at up to 400 A. DC Charging uses the high-current contacts exclusively while AC Level 2 and AC Level 1 charging use the low-current contacts exclusively. Improvements in onboard charging technology enable more powerful charging, but require more current than can be supplied by contacts 1 and 2. The high-power coupler contacts 3 and 4 may be used to supply AC Level 3 to compatible vehicles following the guidelines in this appendix.

Definition: AC Level 3 – A charging method that uses dedicated electric vehicle supply equipment in either private or public locations. The vehicle shall be fitted with an on-board charger capable of accepting energy from an AC supply network at a nominal voltage of 208 and 240 V AC and a maximum current of 400 A.

Table 17 compares the characteristics of electric vehicle charging modes. Note that AC Level 3 charging shares most characteristics with AC Level 2 charging because the charger is located in the vehicle.

Table 17 - Charging mode characteristics

EVSE Type	EVSE Input	EVSE Output	EVSE Vehicle Control Method	Charger Location	Charger Location	Power Max.
AC Level 2	208-240 V AC	208-240 V AC	SAE J1772™ Pilot	Vehicle	Vehicle	11.5 kW
AC Level 3	208-240 V AC	208-240 V AC	SAE J1772™ Pilot	Vehicle	Vehicle	96 kW
DC Charging	208-600 V	0-1000 V DC	SAE J1772™ and SAE J2293	EVSE	EVSE	400 kW

M.2 PILOT CIRCUIT

AC Level 3 charging interface is controlled by a pilot signal output from the Electric Vehicle Supply Equipment, similar to AC Level 2 charging. Characteristics of the EVSE are conveyed by the output (open circuit) voltage combination of the pilot signal. When plugged into an EVSE, a vehicle connects the pilot output to the supply ground through a resistor/diode combination, bringing the pilot test point voltages into the range of a valid response. If the EVSE detects a valid charge request, it adjusts the pilot duty cycle to convey the available a.c. line current, and then closes the appropriate contactor.

M.2.1 Electric Vehicle Supply Equipment Output Parameters

Table 18 defines pilot signal characteristics for AC Level 2, AC Level 3, and DC Charging EVSE. Note that an AC Level 3 EVSE can operate as an AC Level 2 EVSE if AC Level 3 charging is not requested. The AC Level 3 pilot signal duty cycle range corresponds to the duty cycle range for AC Level 2 charging but not DC Charging. Permissible supply resistance (on pilot oscillator output) is the same for all EVSE.

Table 18 - EVSE control pilot parameters

EVSE Type	Output OCV (-)	Output OCV (+)	Duty Cycle Min.	Duty Cycle Max.	Oscillator Hz	Supply Resistance
AC Level 2	-12 V DC	+12 V DC	10%	80%	1000	1000 Ω
DC Charging	-12 V DC	+12 V DC	90%	90%	1000	1000 Ω
AC Level 3	-9 V DC(1)	+12 V DC	10%	80%	1000	1000 Ω

1. EVSE supporting Level 2 and High-power AC may transition to –12 V for Level 2 mode.

M.2.2 Vehicle Response Parameters

Electric vehicles respond to the pilot signal by applying a resistor/diode combination to complete the pilot circuit. The necessary equivalent resistance (diode plus resistor) values for valid responses are indicated in Table 19.

Table 19 - Vehicle charge request parameters

Charge Request	Pilot Voltage Test Point (–)	Pilot Voltage Test Point (+)	Vehicle Equiv. Resistance (–)	Vehicle Equiv. Resistance (+)
AC Level 2	–12 V DC	+6 V DC(1)	∞	1000 Ω(1)
DC Charging	–12 V DC	+9 V DC	N/A	3000 Ω
AC Level 3	–3 V DC	+9 V DC	500 Ω	3000 Ω

1. Confirmation is +3 V if ventilation is required, Req. = 333 Ω.

M.2.3 EVSE Response Parameters

The EVSE continuously monitors the filtered test point voltages. Test point voltages specified in Table 20 constitute valid responses. While the power contactor is being opened or closed, the EVSE may be configured to lower pilot duty cycle (current limit) to reduce wear on the power contacts.

Table 20 - EVSE response parameters

EVSE Type	Vehicle Present Test Point (–)	Vehicle Present Test Point (+)	Charge Request Test Point (–)	Charge Request Test Point (+)
AC Level 2	–12 V DC	+9 V DC	–12 V DC	+6 V DC(1)
DC Charging	–12 V DC	+9 V DC	–12 V DC	+9 V DC
AC Level 3	–9 V DC	+9 V DC	–3 V DC	+9 V DC

1. Test point is +3 V if ventilation is required.

M.2.4 EVSE Current Limit Function

AC Level 2 and AC Level 3 EVSE use the pilot signal duty cycle to communicate available line current to the vehicle charger. The equations for these scales are indicated Table 21. The AC Level 3 charging scale enables the EVSE to limit current between 0 and 400 A, while the AC Level 2 scale enables control between 6 and 48 A. Examples of duty-cycle to line-limit correspondence are shown in Table 22.

Table 21 - Current limit equation

Charging Mode	Duty Cycle Range	Current Limit, AC amperes
AC Level 2	5% < duty cycle <80%	I = 60 X (DUTY CYCLE)
AC Level 3	13% < duty cycle <80%	I = 600 X (DUTY CYCLE) – 80
AC Level 3	If duty cycle < 13%	I = 0

Table 22 - Current limit scale

Control Pilot Duty Cycle	Current Limit AC Level 2 (AC amps, cont.)	Current Limit ACLevel3 (AC amps, cont.)
10%	6	0
20%	12	40
30%	18	100
40%	24	160
50%	30	220
60%	36	280
70%	42	340
80%	48	400
90%	0—DC Charging Only	0—DC Charging Only

M.2.5 AC Charging Implementation

Vehicles and EVSE configured for AC Level 3 charging may also support AC Level 2 for greater compatibility. Figure 28 shows an EVSE/vehicle implementation of AC Level 3 charging. Note that the EVSE and EV are both configured to support AC Level 2 charging. The vehicle's low and high current charge port contacts are wired together to permit the on-board charger to operate from either low or high-power sources. The EVSE uses 2 separate contactors to preclude parallel current paths while charging AC Level 3 vehicles. Vehicles could also be configured for DC Charging with the addition of a serial data interface and contactors between the high-power contacts and the on-board charger and battery pack.

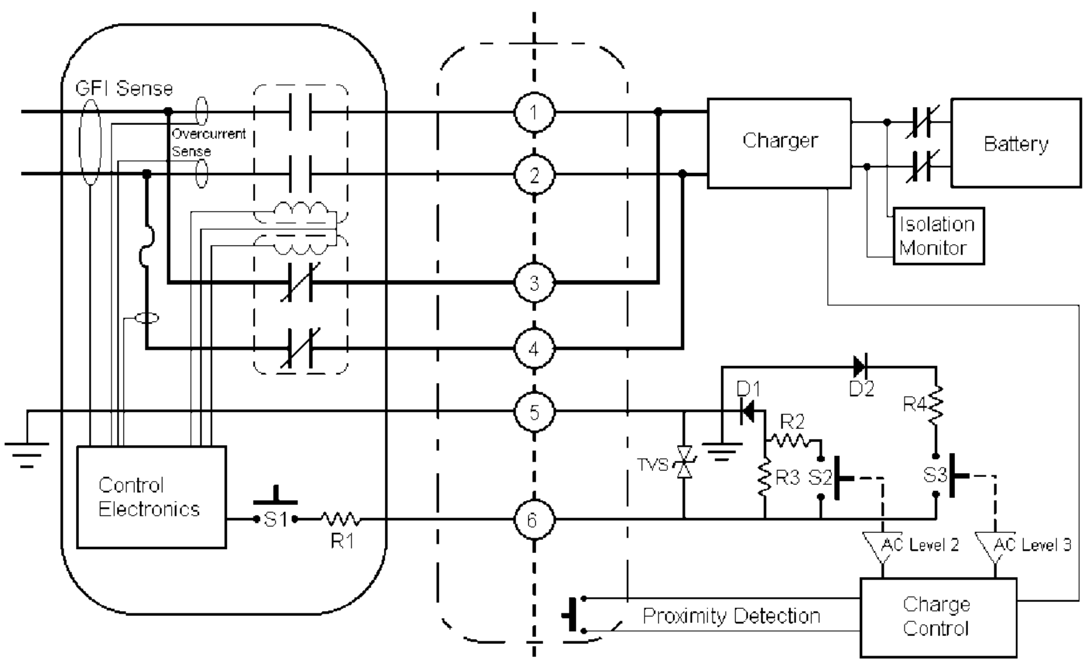


Figure 28 - AC level 3 and AC level 2 system configuration

APPENDIX N - PREVIOUS CHARGE COUPLER DESIGNS

NOTE: THE FOLLOWING IS HISTORICAL INFORMATION FOR REFERENCE ONLY.

This appendix provides information on the previous SAE J1772™ charge coupler.

N.1 GENERAL COUPLER PHYSICAL DESCRIPTION

The coupler interface shall be a single common configuration using pressure type contacts and shall be designed for interchangeability with devices of identical ratings and function.

Vehicle Inlet General requirements

There shall be a single vehicle inlet design with two configurations. The standard configuration shall be capable of AC Level 1 and AC Level 2 charging. The optional configuration shall be capable of AC Level 1, AC level 2, and DC Charging. The contact requirements shall be as specified in Table 23. The standard configuration shall not function with a connector suitable for DC Charging. The optional configuration shall function with all connector configurations.

Table 23 - Vehicle inlet contact requirements

Contact #	Function	Standard – AC Level 1 and 2(1)	Optional – AC Level 1 and 2 , DC Charging(1)
1	Charger 1	X	X
2	Charger 2	X	X
3	Battery positive		X
4	Battery negative		X
5	Chassis ground	X	X
6	Control pilot	X	X
7	Data negative	O	X
8	Data positive	O	X
9	Data ground	O	X

1. Note: X = required, O = optional.

N.1.1 Connector General Requirements

There shall be a single connector design with two configurations. The standard configuration shall be capable of AC Level 1 and AC Level 2 charging. The optional configuration shall be capable of DC Charging. The minimum contact requirements shall be as specified in Table 24. The connector shall be fitted with a cord corresponding to its intended usage and shall meet the requirements specified in the National Electrical Code, NFPA 70 – Article 625.

Table 24 - Connector contact requirements

Contact #	Function	Standard – AC Level 1 and 2(1)	Optional – DC Charging
1	AC Power	X	O
2	AC Power	X	O
3	DC Power		X
4	DC Power		X
5	Equipment ground	X	X
6	Control pilot	X	X
7	Data negative	O	X
8	Data positive	O	X
9	Data ground	O	X

1. Note: X = required, O = optional.

N.2 DIMENSIONAL REQUIREMENTS

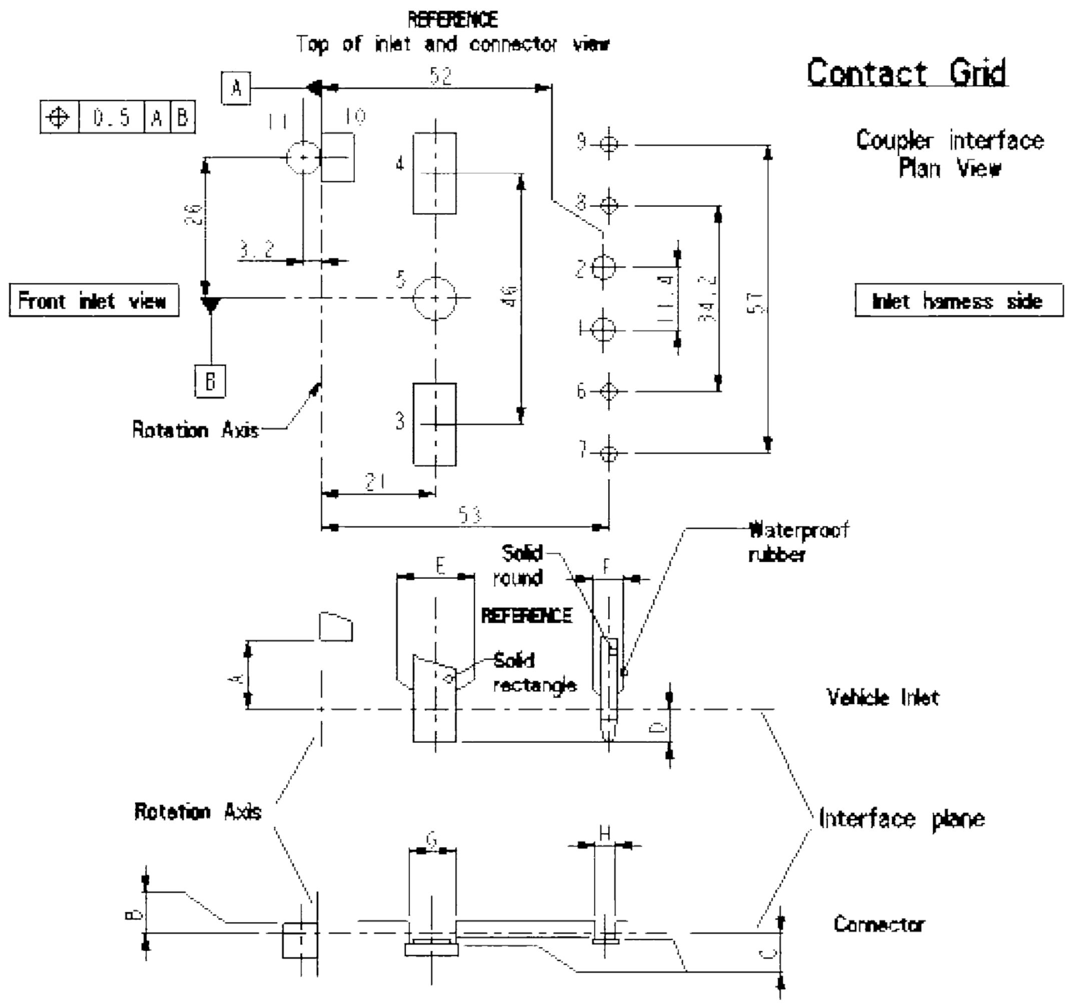
The coupler shall be designed to comply with the key dimensional requirements as specified in this section.

N.2.1.1 Interface Contact Spacing

The general contact sizes and spacing at the coupler interface shall comply with the dimensions as specified in Table 25 and shown in Figure 29.

Table 25 - Contact size and current rating

Contact #	Function	Size (mm)	Current Rating (Amps)	Voltage Rating	Dimension A (mm)	Dimension B (mm)
1	AC Power	4.6 diameter	40 A	300 vac	1.0	6.0
2	AC Power	4.6 diameter	40 A	300 vac	1.0	6.0
3	DC Power	15.0 x 8.0	400 A	600 vdc	2.0	6.0
4	DC Power	15.0 x 8.0	400 A	600 vdc	2.0	6.0
5	Equipment/chassis ground	8.0 diameter	Fault rated		1.0	6.0
6	Control pilot	3.1 diameter	15 A	60 vdc	1.0	5.0
7	Data negative	3.1 diameter	15 A	60 vdc	1.0	6.0
8	Data positive	3.1 diameter	15 A	60 vdc	1.0	6.0
9	Data ground	3.1 diameter	15 A	60 vdc	1.0	6.0



Pin Number	Designation	Size (mm)	Ampacity (A)	A±02 (mm)	B±02 (mm)	C±02 (mm)	D±02 (mm)	E±02 (mm)	F±02 (mm)	G±02 (mm)	H±02 (mm)
1	Low power AC (L,N)	Ø 4.6	40	-	-	1	6	-	8.5	-	6.5
2	Low power AC (L)	Ø 4.6	40	-	-	1	6	-	8.5	-	6.5
3	High Power	15 x 8	400	-	-	2	6	13	-	11	-
4	High Power	15 x 8	400	-	-	2	6	13	-	11	-
5	Equipt/Chassis ground	Ø 8	-	-	-	1	6	13	-	11	-
6	Control pilot	Ø 3.1	15	-	-	1	5	-	6.8	-	5.2
7	Communication (-)	Ø 3.1	15	-	-	1	6	-	6.8	-	5.2
8	Communication (+)	Ø 3.1	15	-	-	1	6	-	6.8	-	5.2
9	Communication (GRD)	Ø 3.1	15	-	-	1	6	-	6.8	-	5.2
10	Reed Switch *	9 x 6 x20	-	12.9	-	-	-	-	-	-	-
11	Magnetic Sensor *	Ø 6 x 6.3	Surf 5000 Gauss @ 3 413 Gauss	-	1.8	-	-	-	-	-	-

* Reed minimum attractive distance to magnet : 17mm

Figure 29 - Contact interface spacing and control dimensions

N.2.1.2 Connector Physical Dimensions

The connector shall comply with the key physical dimensions as shown in Figure 30.

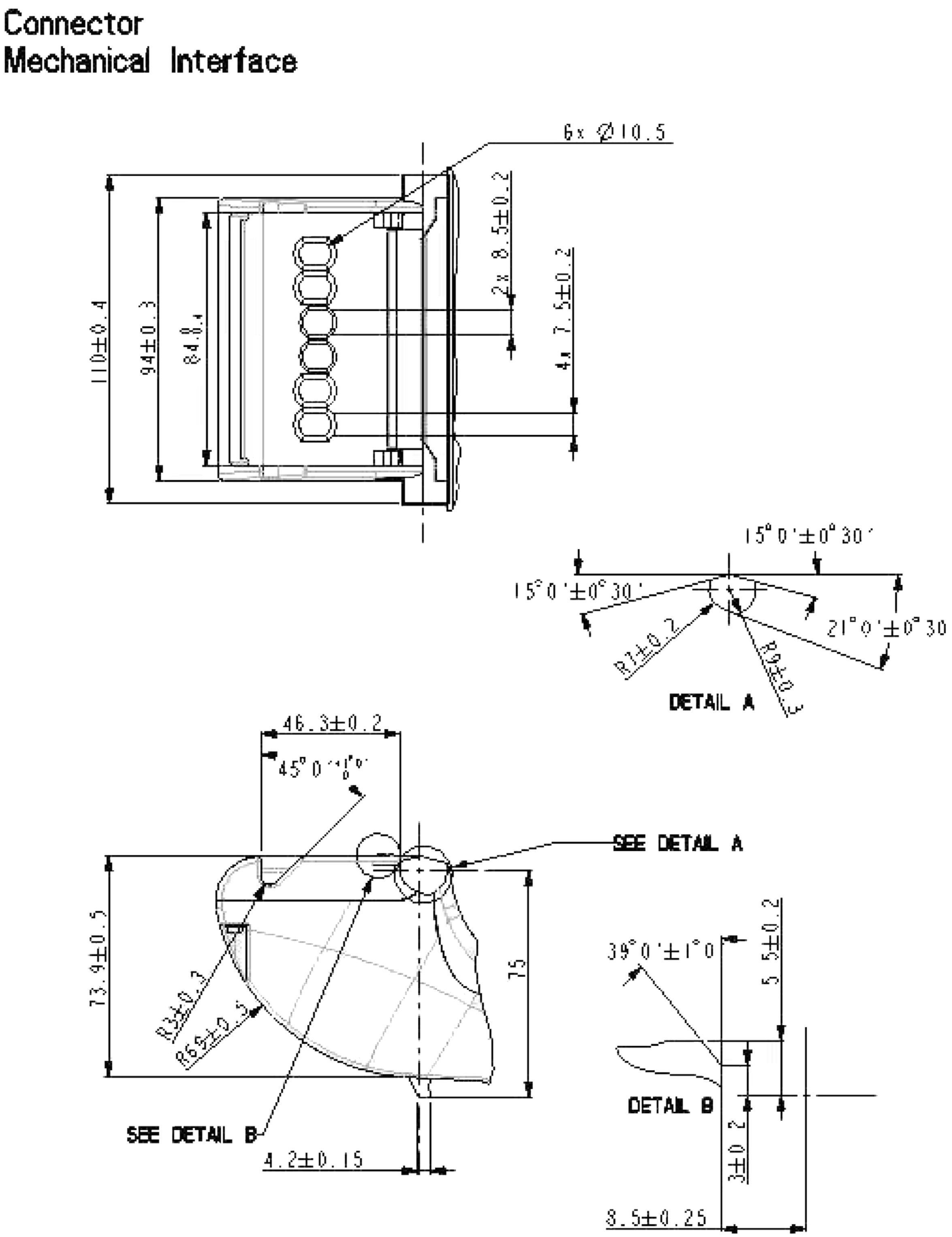


Figure 30 - Connector physical control dimensions

N.2.1.3 Vehicle Inlet Physical Dimensions

The vehicle inlet shall comply with the key physical dimensions as shown in Figure 31.

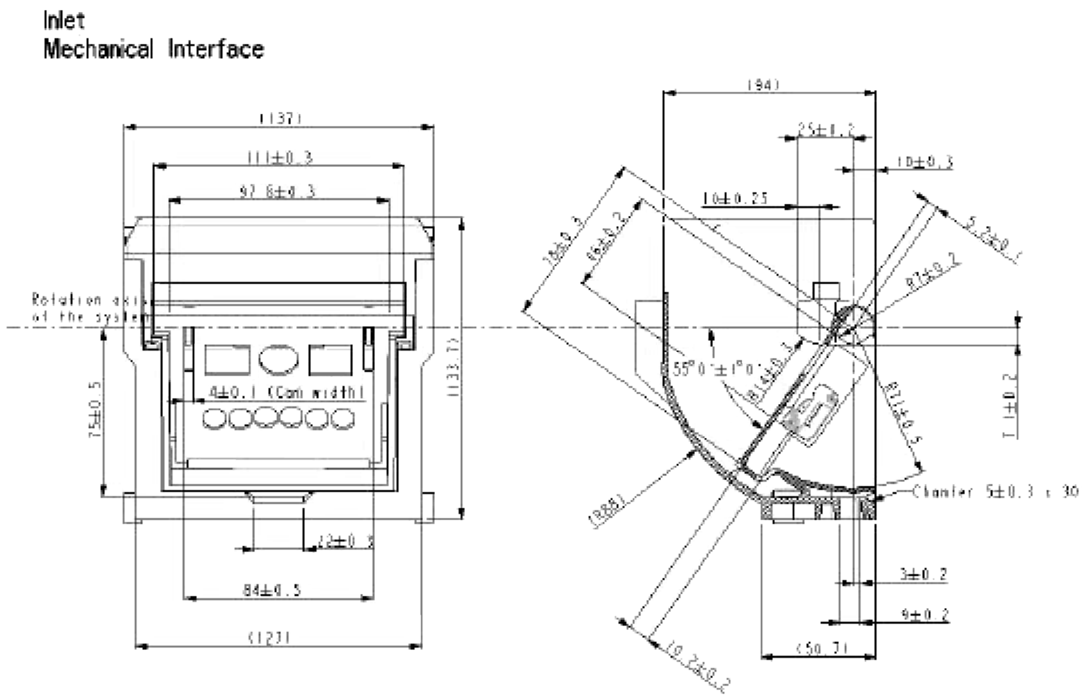


Figure 31 - Vehicle inlet physical control dimensions

N.2.1.4 Vehicle Inlet Access Zone

The vehicle inlet shall be installed in the vehicle to allow connector access when the cover door is opened as shown in Figure 32.

N.2.1.5 Contact Sequencing

During connection, the connector and vehicle inlet shall comply with the contact sequencing and events shown in Figure 33 and specified in Table 26. It should be noted that the equipment/chassis ground contact is first make/last break and the control pilot contact is last make/first break.

Table 26 - Coupler interface contact sequencing events

Sequencing Event	AC Level 1 and 2 Angle A (degrees)	DC Charging Angle A (degrees)
Insertion zone	0 to –12	0 to –12
Line-to-line connector/inlet	0	0
Equipment-chassis ground	44.5	34.5
Power	49.5	43.0
Data	51.0	51.0
Control pilot	52.0	52.0
Latch point	55.0	55.0
Over travel	58.0	58.0

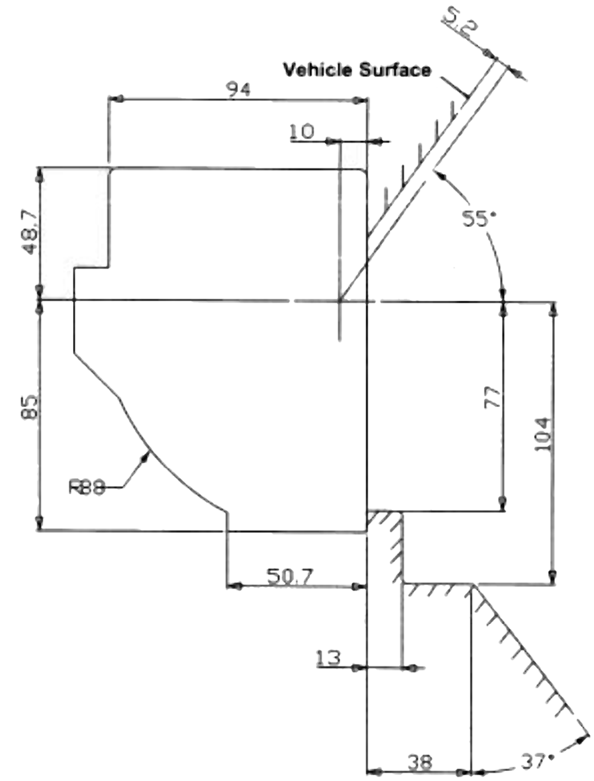


Figure 32 - Vehicle inlet interface access zone

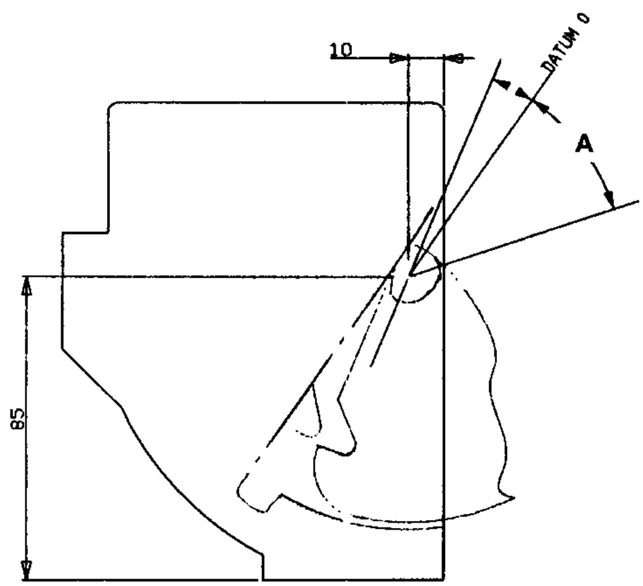


Figure 33 - Coupler interface contact sequencing

APPENDIX O - COMPATIBILITY BETWEEN HIGH CAPACITY EVSES AND CERTAIN LEGACY VEHICLES (INFORMATIVE)

This informative appendix describes an optional transition that may be implemented by EVSE manufacturers. This optional transition, consisting of two phases, is intended to ensure the backward compatibility of high capacity EVSEs with certain legacy vehicles that are unable to recognize control pilot duty cycles above 80%. Vehicles that fully comply with this standard and are capable of detecting the control pilot duty cycles defined in Table 5 do not require this optional transition.

Table 27 - Optional transition descriptions

Transition	Initial Condition	New Condition	EVSE Response Time	EV/PHEV Response Time	Specification or Condition
Optional phase 1	State = B2 Duty cycle > 80%	State = E	10s min, 60s max	-	EVSE changes control pilot state from B2 to E when vehicle does not close S2 after changing the control pilot state from B1 to B2 during the start-up sequence.
Optional phase 2	State = E	State = B2 Duty cycle ≤ 80%	4s min	-	(Continued from phase 1.) EVSE attempts to wake up vehicle and charge at duty cycle < 80%.

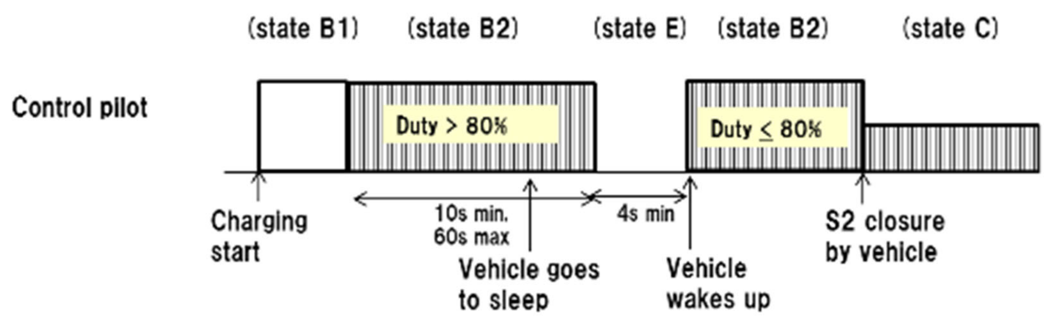


Figure 34 - Timing diagram of optional transitions