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INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

SURFACE VEHICLE RECOMMENDED PRACTICE

SAE J1772

REV. NOV2001

Issued 1996-10
Revised 2001-11

Superseding J1772 OCT1996

(R) SAE Electric Vehicle Conductive Charge Coupler

Foreword**—**Since the energy stored in a battery provides the power for an electric vehicle (EV), an EV requires a method of charging the battery on a regular basis. Conductive charging is a method for connecting the electric power supply network to the EV 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 and the supply equipment. This document describes the functional and performance requirements for proper operation and the physical interface for a conductive charging system. This document contains 31 pages, including this page, and should not be used as a design tool if any of the pages are missing.

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

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1. Scope—This SAE Recommended Practice covers the general physical, electrical, and performance requirements for the electric vehicle conductive charge system and coupler for use in North America. The intent of this document is to define a common electric vehicle conductive charging system architecture including operational requirements and the functional and dimensional requirements for the vehicle inlet and mating connector.

2. References

2.1 Applicable Publications—The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE and other applicable publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAEJ551-5—Performance Levels and Methods of Measurement of Electromagnetic Radiation from Vehicles and Devices (30 Hz to 1000 MHz)
SAE J551-11—Vehicle Electromagnetic Immunity—Off-Vehicle Source
SAE J551-15—Vehicle Electromagnetic Immunity—Electrostatic Discharge (ESD)
SAE J1211—Recommended Environmental Practices for Electronic Equipment Design
SAE J1850—Class B Data Communication Network Messages
SAE J2178—Class B Data communication Network Messages – Network Management Strategies
SAE J2293—Energy Transfer System for Electric Vehicle

2.1.2 CANADIAN STANDARDS ASSOCIATION—Available from Canadian Standards Association, 170 Rexdale Boulevard, Rexdale, Ontario, Canada M9W 1R3.

Canadian Electrical Code—Part 1, Section 86

2.1.3 FEDERAL COMMUNICATION COMMISSION PUBLICATIONS—Available from The Superintendent of Documents, U. S. Government Printing Office, Mail Stop SSOP, Washington, D.C. 20402-9320.

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 the International Electrotechnical Commission, 3, Rue de Varembe / CH-1211, Geneva 20, Switzerland.

NOTE— IEC Publications are also available from The American National Standards Institute, 25 West 43rd Street, New York, NY 10036-8002.

IEC 61851-2.1—Electric Vehicle Conductive Charging System—Part 2.1: Electric Vehicle Requirements for Connection to an AC / DC supply

2.1.5 NATIONAL FIRE PROTECTION ASSOCIATION PUBLICATION—Available from The National Fire Protection Association, Batterymarch Park, Quincy, MA 02269.

National Electrical Code, NFPA 70—Article 625

2.1.6 UNDERWRITERS LABORATORIES, INC. PUBLICATIONS—Available from Underwriters Laboratories, Inc., Corporate offices, 333 Pfingsten Road, Northbrook, IL 60062-2096. Phone (708)272-8800.

UL 50—Standard for Enclosures for Electrical Equipment
UL 1439—Determination of Sharpness of Edges on Equipment
UL 2202—EV Charging System Equipment
UL 2231—Personnel Protection Systems for EV Charging Circuits
UL 2251—Plugs, Receptacles, and Couplers for Electric Vehicles

2.2 Related Publications—The following publications are provide for information purposes only and are not a required part of this document

2.2.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096

SAE J1742—Connections for High Voltage On-board Vehicle Electrical Wiring Harness
SAE J1773—SAE Electric Vehicle Inductively Coupled Charging

2.2.2 INTERNATIONAL ELECTROTECHNICAL COMMISSION PUBLICATIONS—Available from the International Electrotechnical Commission, 3, Rue de Varembe / CH-1211, Geneva 20, Switzerland

NOTE— IEC Publications are also available from The American National Standards Institute, 25 West 43rd Street, New York, NY 10036-8002

IEC 61851-1—Electric Vehicle Conductive Charging System—Part 1: General Requirements
IEC 61851-2.2—Electric Vehicle Conductive Charging System—Part 2.2: AC electric vehicle charging station
IEC 61851-2.3—Electric Vehicle Conductive Charging System—Part 2.3: DC electric vehicle charging station

2.2.3 UNDERWRITERS LABORATORIES, INC. PUBLICATIONS—Available from Underwriters Laboratories, Inc., Corporate offices, 333 Pfingsten Road, Northbrook, IL 60062-2096. Phone (708)272-8800

UL 94—Tests for Flammability of Plastic Materials for Parts in Devices and Appliances
UL 746A—Standard for Polymeric Materials – Short Term Property Evaluations
UL 840—Insulation Coordination including Clearance and Creepage Distances for Electrical Equipment

3. Definitions

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

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

3.3 Connector—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.

3.4 Coupler—A mating vehicle inlet and connector set.

3.5 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 that 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).

3.6 Enclosure—The case or housing into which the contacts and insulators are assembled.

3.7 Insulator—The portion of a coupler that provides for the separation, support, sealing, and protection of the contacts.

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

3.9 AC Level 1 Charging—A method that allows an EV to be connected to the most common grounded electrical receptacle (NEMA 5-15R). The vehicle shall be fitted with an on-board charger capable of accepting energy from the existing alternating current (AC) supply network. The maximum power supplied for AC Level 1 charging shall conform to the values in Table 1.

3.10 AC Level 2 Charging—A method that utilizes dedicated AC. EV supply equipment in either private or public locations. The vehicle shall be fitted with an on-board charger capable of accepting energy from alternating current electric vehicle supply equipment. The maximum power supplied for AC Level 2 charging shall conform to the values in Table 1.

3.11 DC Charging—A method that utilizes dedicated direct current (DC) EV supply equipment to provide energy from an appropriate off-board charger to the EV in either private or public locations. The range of charger ratings encompassed shall conform to the values shown in Table 1.

3.12 Off-Board Charger—A charger located off of the vehicle.

3.13 On-Board Charger—A charger located on the vehicle.

3.14 Equipment Ground (Grounding Conductor)—A conductor used to connect the non-current carrying metal parts of the EV supply equipment to the system grounding conductor, the grounding electrode conductor, or both at the service equipment.

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

3.16 Control Pilot—The primary control conductor that 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

3.17 **Vehicle Inlet—**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.

3.18 **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.

3.19 **3.19 EV 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 traction battery bus for the purpose of charging the battery and/or operating vehicle electrical systems while connected.

4. ***General Conductive Charging System Description—***In the most fundamental sense, there are 3 functions, 2 electrical and 1 mechanical, that must be performed to allow charging of the EV battery from the electric supply network. The electric supply network transmits alternating current electrical energy at various nominal voltages(rms) and a frequency of 60 Hz. The EV battery is a direct current 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 alternating current to direct current and is commonly referred to as rectification. The second electrical function is the supply voltage must be controlled or regulated at a voltage 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 to the EVSE and is performed by the user. The conductive charging system consists of a charger and a coupler. The conductive system architecture is suitable for use with both on-board and off-board chargers with electrical ratings as specified in Table 1 and as shown in Figure 1.

TABLE 1—CHARGE METHOD ELECTRICAL RATINGS (NORTH AMERICA)

Charge Method	Nominal Supply Voltage(Volts)	Maximum Current (Amps-continuous)	Branch Circuit Breaker rating (Amps)
AC Level 1	120 V AC, 1-phase	12 A	15 A (minimum)
AC Level 2	208 to 240 V AC, 1-phase	32 A	40 A
DC Charging	600 V DC maximum	400 A maximum	As required

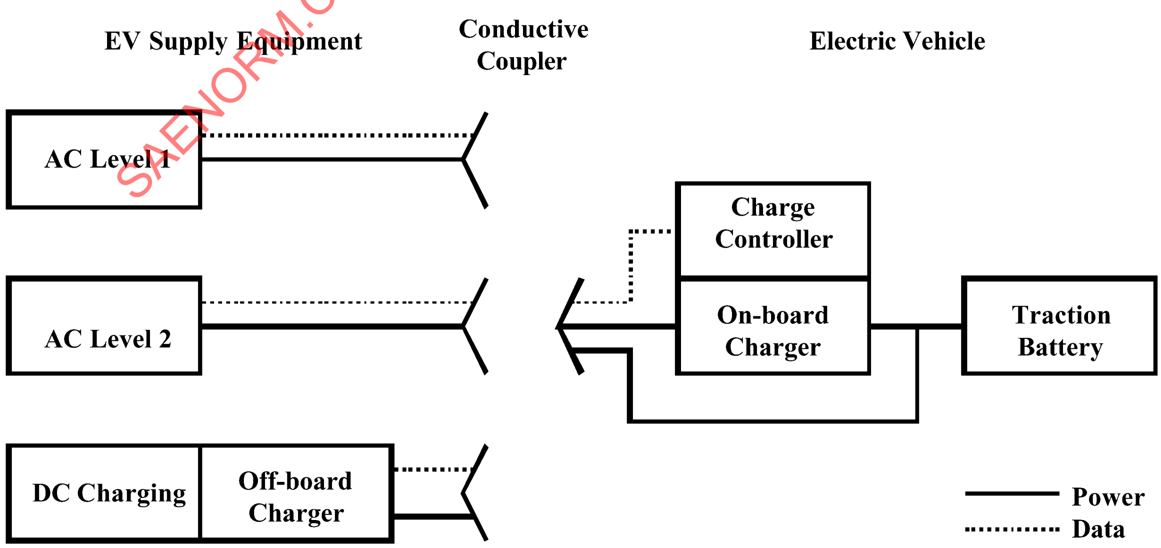


FIGURE 1—CONDUCTIVE EV CHARGING SYSTEM ARCHITECTURE

4.1 Interface Functions—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, control pilot conductor, and under certain conditions serial data conductors between the EV and EVSE. The interface consists of 9 possible contacts that perform the interface functions as shown in Figure 2 and specified in Table 2.

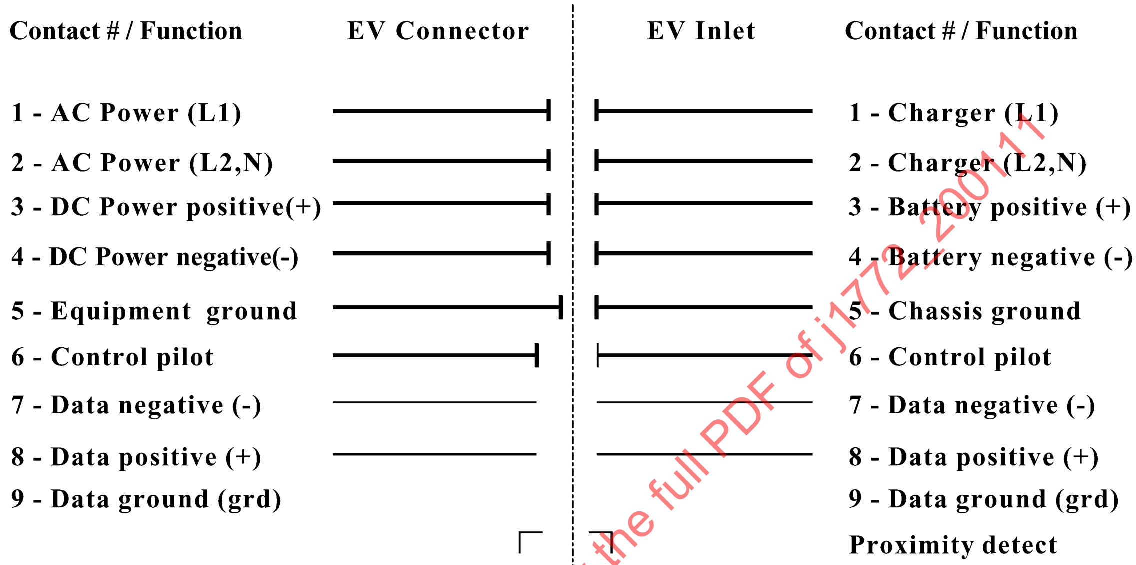


FIGURE 2—CONDUCTIVE COUPLER CONTACT INTERFACE FUNCTIONS

TABLE 2—CONDUCTIVE COUPLER CONTACT FUNCTIONS

Contact #	Connector Function	Vehicle Inlet Function	Description
1	AC Power (L1)	Charger 1	Power for AC Level 1 and 2
2	AC Power (L2,N)	Charger 2	Power for AC Level 1 and 2
3	DC Power positive(+)	Battery positive(+)	Power for DC charging
4	DC Power negative(–)	Battery negative (–)	Power for DC charging
5	Equipment ground	Chassis ground	Connect EVSE equipment grounding conductor to EV chassis ground during charging
6	Control pilot	Control pilot	Primary control conductor (operation described in Section 5)
7	Data negative(–)	Data negative(–)	Negative serial data conductor (SAE J1850 Type 2 only)
8	Data positive(+)	Data positive(+)	Positive serial data conductor (SAE J1850 Type 1 and 2)
9	Data ground	Data ground	Serial data ground conductor (SAE J1850 Type 1 and 2)

4.2 AC Level 2 Charging—The primary method of EV charging that extends AC power from the electric supply to an on-board charger from dedicated EVSE as shown in Figure 3. The electrical ratings are similar to large household appliances and specified in Table 1. AC Level 2 may be utilized at home, workplace, and public charging facilities.

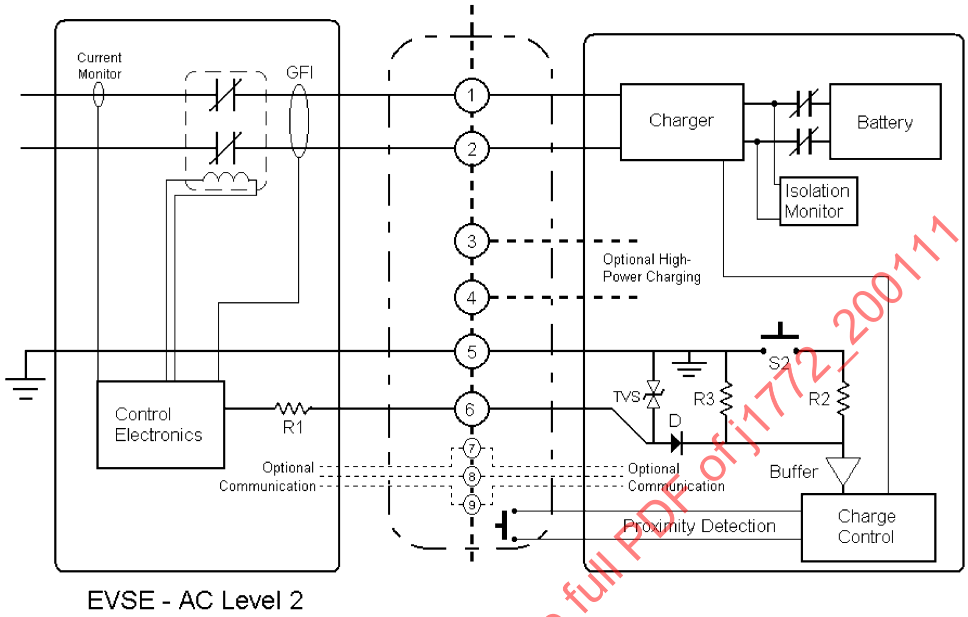


FIGURE 3—AC LEVEL 2 SYSTEM CONFIGURATION

4.3 AC Level 1 Charging—A method of EV charging that extends a.c. power from the electric supply to an on-board charger from the most common grounded electrical receptacle using an appropriate cord set as shown in Figure 4 at the electrical ratings specified in Table 1. AC level 1 allows connection to existing electrical receptacles in compliance with the National Electrical Code.

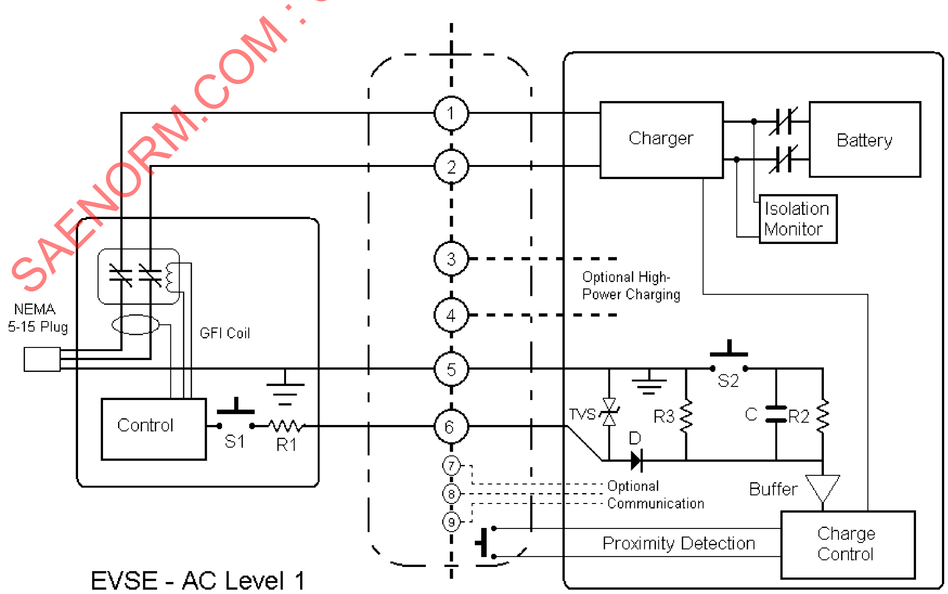


FIGURE 4—AC LEVEL 1 SYSTEM CONFIGURATION

4.4 DC Charging—The conductive charging system architecture provides a method to provide energy from an appropriate off-board charger as shown in Figure 5 to the EV in either private or public locations. The power available for DC Charging can vary from power levels similar to AC Level 1 and 2 to very high power levels that may be capable of replenishing more than 1/2 of the capacity of the EV battery in as few as 10 min. The electrical ratings for DC Charging are specified in Table 1.

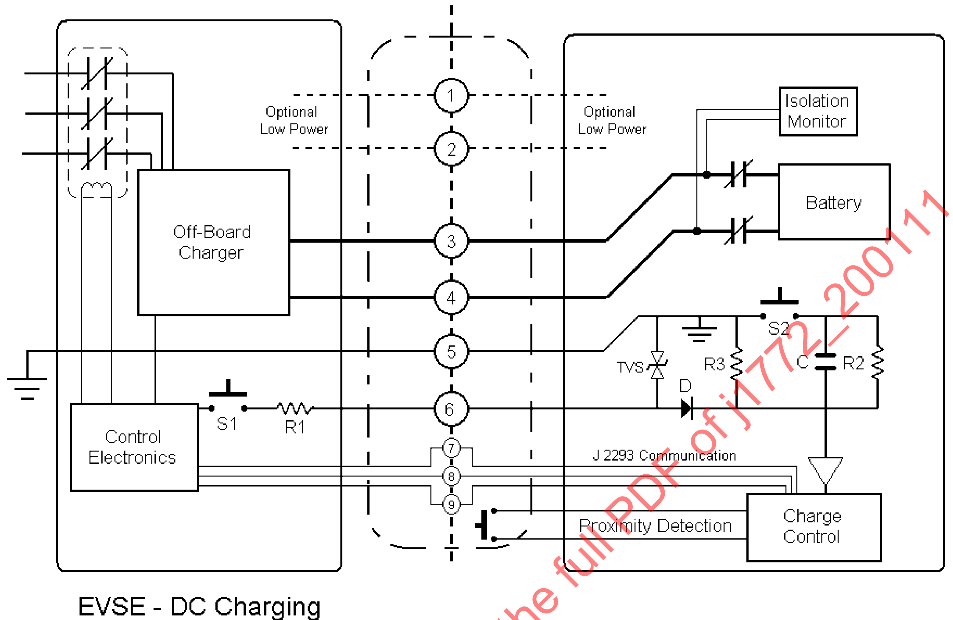


FIGURE 5—DC CHARGING SYSTEM CONFIGURATION

5. Control and Data—The control pilot circuit is the primary control means to ensure proper operation when connecting an EV 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. Additional data exchange between the EV and EVSE, using SAE J1850, is mandatory for DC Charging control.

5.1 Control Pilot Circuit—A typical control pilot circuit is shown in Figure 6.

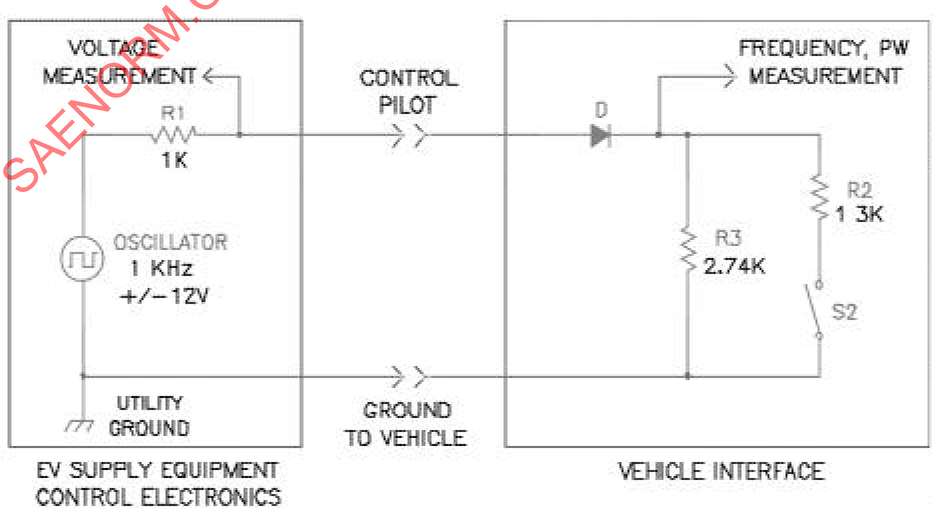


FIGURE 6—TYPICAL CONTROL PILOT CIRCUIT

5.2 **Control Pilot Circuit—**The equivalent control pilot circuit and vehicle states are shown in Figure 7 and defined in Table 3, Table 4, and Table 5.

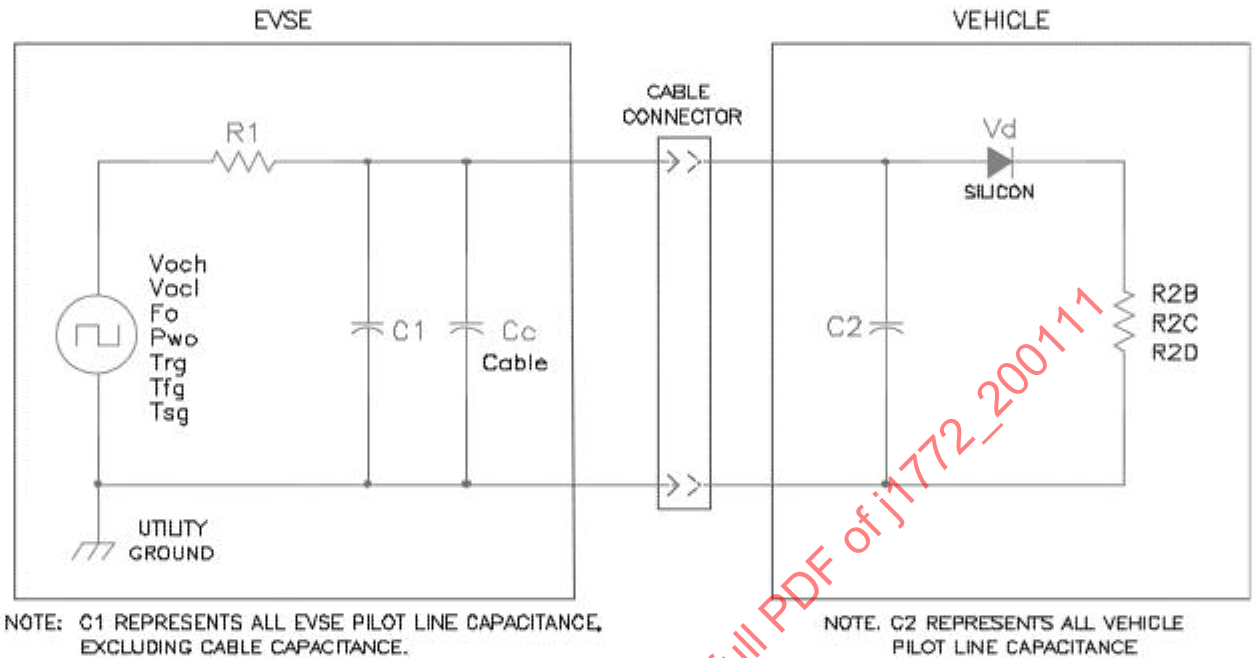


FIGURE 7—CONTROL PILOT EQUIVALENT CIRCUIT

TABLE 3—DEFINITION OF VEHICLE STATES

Vehicle state designation	Voltage (vdc nominal)	Description of vehicle state
State A	12.0 (1)	Vehicle not connected
State B	9.0(2)	Vehicle connected / not ready to accept energy
State C	6.0(2)	Vehicle connected / ready to accept energy / indoor charging area ventilation not required
State D	3.0(2)	Vehicle connected / ready to accept energy / indoor charging area ventilation required
State E	0	EVSE disconnected, utility power not available, or other EVSE problem
State F	–12.0(1)	EVSE not available, or other EVSE problem

1. Static voltage
2. Positive portion of 1 KHz square wave, measured after transition has fully settled.

TABLE 4—EVSE CONTROL PILOT CIRCUIT PARAMETERS (SEE FIGURE 7)

Parameter[1]	Symbol	Units	Nominal value	Maximum value	Minimum value
Generator					
voltage high, open circuit	Voch	Volts	12.00	12.60	11.40
voltage low, open circuit	Vocl	Volts	–12.00	–12.60	–11.40
Frequency	Fo	Hertz	1000	1050	950
pulse width[2]	Pwo	Microsec	Per Figure 8	Nom, + 25 µs	Nom, - 25 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	Ohms	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 condiitions 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. Generator rise/fall times longer than 2 µs may affect Pilot Line rise/fall times defined by source resistance and line capacitance.
4. To 95% of steady-state value, measured from start of transition.
5. Maximum and minimum resistor values are ±3% about nominal.
6. Guarantees rise time slow enough to remove transmission line effects from cable.

TABLE 5—EV CONTROL PILOT CIRCUIT PARAMETERS (SEE FIGURE 7)

Parameter[1]	Symbol	Units	Nominal value	Maximum value	Minimum value
Equivalent load resistance – State B	R2B	Ohms	2740	2822 [2]	2658[2]
Equivalent load resistance – State C[3]	R2C	Ohms	882	908 [2]	856[2]
Equivalent load resistance – State D[4]	R2D	Ohms	246	253 [2]	239[2]
Total equivalent capacitance	C2	picofarads	n.a.	2400	n.a.
Equivalent diode voltage drop[5]	Vd	Volts	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. Vehicle requiring ventilation for indoor charing areas.
5. Silicon small signal diode, –40 °C to 85 °C, forward current 2.75 to 10.0 ma.

5.3 Control Pilot Functions—The control pilot performs the following functions.

5.3.1 VERIFICATION OF VEHICLE CONNECTION—The EVSE is able to determine that the connector is fully inserted into the vehicle inlet and properly connected to the EV by sensing resistance R3 as shown in Figures 3, 4, 5, and 6. The diode, D1, insures that an EV is actually connected and can be discriminated from other potential low impedance loads.

5.3.2 EVSE Ready to Supply Energy—The EVSE is able to indicate to the EV that it is ready to supply energy by turning on the oscillator and providing the square wave signal specified in Figure 8. In each of the states specified in Table 3, 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 B, State C, or State D. Oscillation in other states should only be transitory as specified in Table 6.

5.3.3 EV Ready to Accept Energy—The EV indicates that it is ready to accept energy from the EVSE by closing switch S2, as shown in Figures 3, 4, 5, and 6, when the current profile on the control pilot oscillator is sensed. The EV may de-energize the EVSE at any time by opening switch S2.

5.3.4 Determination of Indoor Ventilation—The EVSE is able to determine if the EV requires indoor charging ventilation by sensing the voltage as specified in Table 3. If required, the EVSE will provide a signal to turn on the indoor charging area ventilation system according to NFPA 70 / NEC – Article 625.

5.3.5 EVSE Current Capacity—The EVSE provides the maximum available continuous current capacity, and by inference the rating of the protective circuit breaker, to the EV by modulating the pulse width as described in Table 4 and shown in Figure 8. The available line current is linearly proportional to the pulse width by the following equation:

$$\text{Ampacity} = (0.6\ \text{A}\ \times \text{pulse width, in}\ \mu\text{s})/10\ \mu\text{s, from 100 to 800}\ \mu\text{s} \qquad \text{(Eq. 1)}$$

As an example, a 200 µs pulse width would be (0.6 x 200)/10 = 12 A. In this case, the vehicle must adjust its current draw to a maximum of 12 A.

A pulse width of 900 µs, represents an off-board DC charger and requires that serial data communication be established with the EV before proceeding. The EVSE may accept an external signal to vary the pulse width for supply or premises power limitations. The EV shall use the pulse width to control the on-board charger input/output.

5.3.6 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 chassis ground during charging. Loss of this signal shall result in the automatic de-energization at the EVSE.

5.4 Proximity Detection—Upon initial insertion of the connector into the vehicle inlet and before any electrical contact is established, the coupler shall provide a means to detect the presence of the connector in the vehicle inlet at a point where damage to coupler, EV, or EVSE could occur if the EV were to be moved. The means shall provide a signal to activate the EV charge controller and engage the EV drive interlock system. One method to accomplish this is a permanent magnet in the connector and a corresponding hall effect switch in the vehicle inlet as specified in Section 8. Other functionally equivalent means to measure the presence of the connector's magnet shall be permitted at the discretion of the EV manufacturer.

5.5 Serial Data Transfer—Coupler contact numbers 7, 8, and 9 are provided to allow an exchange of serial data information between the EV and the EVSE based on SAE J1850, SAE J2178, and SAE J2293. The serial data link is mandatory for DC Charging to allow the vehicle to control the charge process. The serial data link is optional for AC Level 2 and AC Level 1 – i.e., for displaying charge related or other information to the user.

TABLE 6—EVSE AND EV RESPONSE TIME SPECIFICATIONS

	Initial Condition [1][2][3]	New Condition	EVSE Response Time	EV Response Time	Specification or Condition
1	State = x OSC = off	State = x OSC = on	no maximum		delay until pilot oscillator will be turned on by EVSE
2	State = x OSC = x	State = A OSC = x	100 ms maximum		delay from disconnect until the contactor opens and terminates AC energy transfer
3	State = x OSC = x	State = E or State = F OSC = x		5 seconds maximum	delay until EV opens battery isolation contactor
4	State = x OSC = on	State = A OSC = off	2 seconds maximum		delay until oscillator turned off after EV is disconnected
5	State = B OSC = on	State = C or State = D OSC = on	3 seconds maximum		delay until contactor closes and initiates AC energy transfer in response to S2 closed
6	State = C or State = D OSC = on	State = B OSC = on	3 seconds maximum		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		3 seconds maximum	in response to an invalid pilot the EV enters a safe mode and if necessary opens S2 and terminates the AC energy transfer
8	State = x OSC = x	State = E or State = F OSC = x	3 seconds maximum		delay from EVSE setting invalid pilot until termination of AC energy transfer
9	State = B or State = C or State = D OSC = on	invalid pilot frequency		3 seconds maximum	in response to an invalid pilot frequency the EV enters a safe mode and if necessary opens S2 and terminates the AC energy transfer
10	State = x OSC = x	external signal to EVSE	10 seconds maximum		delay from external load management signal until EVSE modifies pilot signal state or other required response
11	State = C or State = D OSC = on	change in pilot duty cycle		5 seconds maximum	EV modifies maximum current draw for on-board battery charger in response to pilot signal duty cycle modification

1. Current State from Table 3 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:

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 guarantee de-energization of 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. For safety reasons, it is important to guarantee the vehicle goes into a safe state.
4. After a transition from any State to State A, the EVSE should turn off the oscillator. For the purpose of filtering and reasonable control response time, the EVSE will not respond immediately. The connector may be immediately reinserted into the vehicle, and the EV could see State C or State D with the oscillator turned on and no AC energy transfer for this 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 must respond to the pilot signal voltages. In this case, the EVSE may be experiencing a power outage, ground fault, or other condition that requires termination of the AC energy transfer mode. The vehicle should respond by opening the S2 and entering a safe mode.
8. If the EVSE is experiencing a condition that requires termination of the AC energy transfer mode, the EVSE must open the contactor in less than 3 seconds from setting the pilot signal to a non AC energy transfer state.
9. The vehicle must 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 should respond by opening the S2 and entering a safe mode. The recommended tolerance is ±10%, 1100Hz to 900Hz.
10. It is common for EVSE equipment to support an input signal for the purpose of external load control. This input is used for various purposes including off peak charging support, utility load shedding, and building load management controllers. A maximum response time must be specified to guarantee universal compatibility with the external controlling equipment.
11. The EVSE may modify the pilot signal pulse width at any time, commanding the EV to increase or decrease the maximum AC current draw. The vehicle must adhere to the maximum response time in order guarantee universal compatibility with the external controlling equipment. (see Table 6, specification 10)

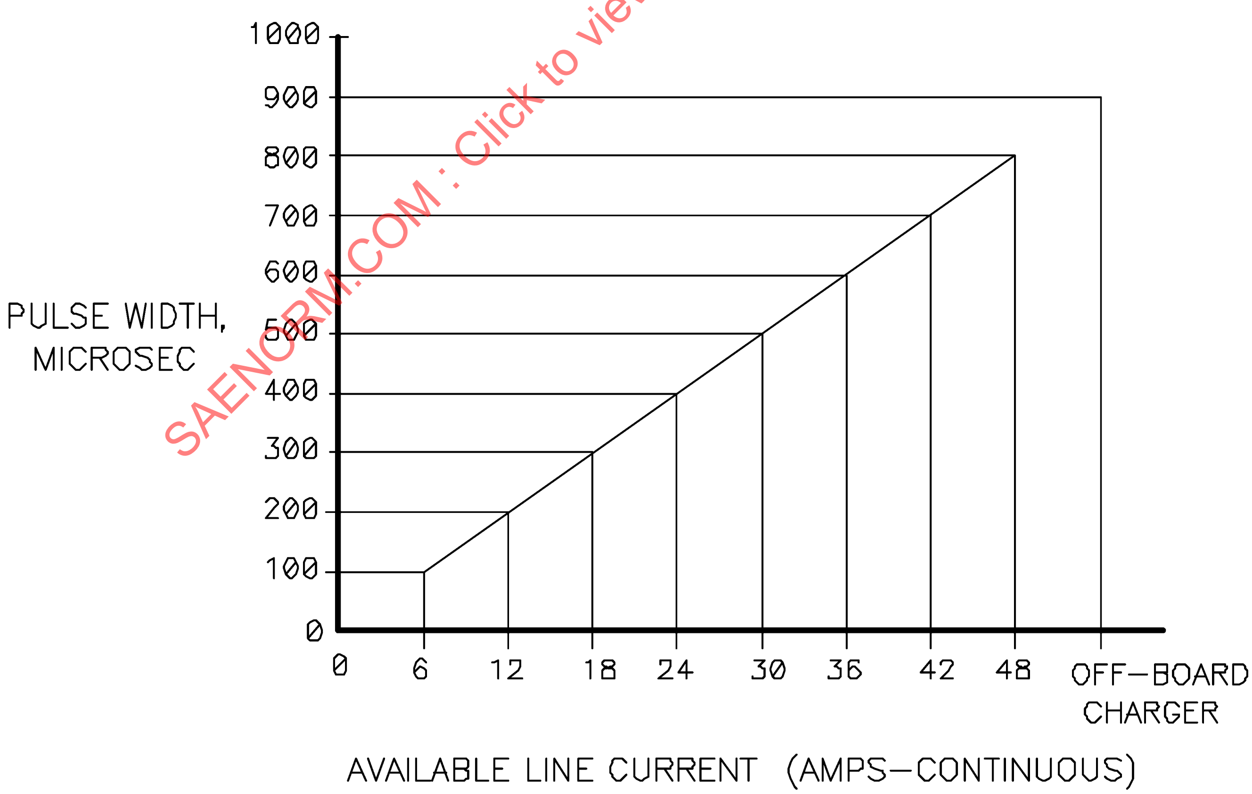


FIGURE 8—EVSE CURRENT CAPACITY VERSUS CONTROL PILOT PULSE WIDTH

5.6 Typical 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 proximity detection means activates EV charge controller and drive interlock
b. Verification of EV connection is detected by EVSE, State B, the oscillator is turned off.
c. EVSE indicates that it is ready to supply energy by turning on the oscillator and supplying square wave pilot signal to the EV, State B.
d. EV 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.
e. The EVSE determines that the equipment grounding conductor to the EV chassis ground is in place.
f. The EVSE determines that the EV pilot control circuitry is correctly configured by verifying the presence of the diode. The negative side of the pilot pulse must be within the range specified in Table 4.
g. 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. Condition1–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. Condition2–If the EVSE is listed for outdoor charging of all vehicles, proceed to the next step
   c. Condition3–If the EVSE is listed for vehicles not requiring indoor charging area ventilation, terminate the process and do not allow energization

h. The EV determines the nature of and available current from the EVSE according to 1 of the following 3 conditions by measuring the pulse width of the signal and proceeding as follows:

   a. If the pulse width is between 100 and 800 µs, establish the serial data link, if required, and proceed to the next step
   b. In the pulse width is 900 µs, indicating DC charging, the serial data link must be established before proceeding to the next step.
   c. If the serial data link cannot be established under the above circumstances, the process must be terminated and the fault condition displayed by the EVSE

i. The EVSE may now energize the system by closing the main power contactor and charging may commence at power levels up to 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 serial data link. A continuous load is defined as operating at a given level for more than 3 h.
j. The above conditions shall be monitored continuously during the charge process. If any of the above conditions do not satisfy the specified requirements, the EVSE must terminate the charge process by opening the main contactor and turning off the pilot oscillator. The EVSE should also display the 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.

6. General EV Requirements

6.1 Electromagnetic Compatibility—During charging, the EV shall meet the requirements of CFR 47- Code of Federal Regulations - Title 47, Parts 15A, 15B, and 18C

6.2 Electromagnetic Emissions—During charging, the EV shall meet the requirements specified in SAE J551-5.

6.3 Electromagnetic Immunity—The charging system shall be tested in accordance with SAE J511-11 over the frequency range of 530 kHz to 1000 MHz. The test level shall be 50 V/m. As a minimum, the test shall be conducted at 90% of the maximum rated power and at the lowest power rating used during normal operation.

6.4 Electrostatic Discharge—During charging, the EV shall be tested in accordance with and meet the requirements of SAE J511-15. The EV may also consider the requirements of IEC 61851-2.1.

6.5 Environmental— The on-board EV charging system electronic components shall meet the requirements specified in SAE J1211.

7. General EVSE Requirements

7.1 Installation Requirements—The EVSE shall meet the requirements specified in the National Electrical Code, NFPA 70 – Article 625 and Canadian Electrical Code – Part 1, Section 86.

7.2 General Product Standards—The EVSE shall meet and be listed to the general product requirements specified in UL 2202.

7.3 Personnel Protection System—The EVSE shall incorporate a listed system of personnel protection as specified in UL 2231.

7.4 Conductor Cord Requirements—The conductor cord shall meet the requirements specified in the National Electrical Code, NFPA 70 – Articles 625 and Article 400 – Table 400-4, and UL 2202.

7.5 Coupler Requirements—The EV coupler shall meet the requirements specified in the National Electrical Code, NFPA 70 – Articles 625, UL 2251, and Section 8 of this document

7.6 Electromagnetic Compatibility—During charging, the EVSE shall meet the requirements of CFR 47- Code of Federal Regulations - Title 47, Parts 15A, 15B, and 18C. See 6.1.

8. Coupler Requirements

8.1 Vehicle Inlet/ Connector Compatibility—The vehicle inlet designs shall be of a common physical configuration that is capable of accepting common connector physical configurations for AC Level 1, AC Level 2, and DC charging. 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.

8.2 Ergonomic Requirements—The coupler shall comply with the following ergonomic requirements.

8.2.1 EASE OF USE—During connection and disconnection, the human efforts required shall be within the physical capabilities of the general adult population and persons with limited or restricted capabilities

8.2.2 INDEXING—During connection and disconnection, the insertion/removal of the connector and inlet shall be intuitively obvious and free of multiple orientations for AC Level 1, AC Level 2, and DC charging configurations.

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

8.2.4 TACTILE FEEL—The coupler shall incorporate a means to provide tactile and/or audible feedback to the user when fully engaged

8.2.5 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 control pilot conductor when disengaging from the vehicle inlet.

8.2.6 CONTACT VISIBILITY—The coupler contacts shall not be directly visible when decoupled per 8.5.8.

8.3 Safety Requirements—The coupler shall comply with the following safety requirements.

8.3.1 ISOLATION—The power contacts shall be electrically isolated from the electric supply and battery voltages when decoupled

8.3.2 EXPOSURE OF CONTACTS—When not connected the vehicle inlet and connector shall be designed to prevent direct contact with live parts according to UL 2251.

8.3.3 SHARP EDGES—The vehicle inlet and connector shall be free of sharp edges and potentially injurious protrusions per UL 1439.

8.3.4 TOUCH TEMPERATURE—the maximum external touch temperature of the coupler shall not be greater than 60°C when the ambient temperature is 40 °C. the design process shall take into consideration material types as specified in UL 2251.

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

8.3.6 UNAUTHORIZED ACCESS—For unattended public access charging, the coupler should provide a means to engage a locking or latching mechanism to reduce the likelihood of tampering or unauthorized removal.

8.4 Performance Requirements—The coupler shall comply with the following performance requirements

8.4.1 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 8.5 of this document.

8.4.2 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.

8.4.3 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.

8.5 Environmental Requirements—The coupler shall comply with the following environmental requirements:

8.5.1 GENERAL ENVIRONMENTAL CONSIDERATIONS—The vehicle inlet should meet the performance requirements specified in 8.4 under weather and environmental conditions specified by the individual automobile manufacturers.

8.5.2 TEMPERATURE RANGE—The coupler shall be designed to withstand continuous ambient temperatures in the range of –30 °C to +50 °C during operation when supplied with the EVSE or installed in the EV and continuous ambient temperatures in the range of –50 °C and +80 °C during shipping or storage when the components parts are assembled, supplied with the EVSE, or installed in the EV.

8.5.3 TEMPERATURE RISE—The electrical contacts shall be designed for a maximum temperature rise of 50°C above ambient at rated load. The wiring insulation shall be rated for 105 °C. For couplers rated less than 200A, the load is to be applied continuously. For connectors rated 200 A or greater, the load is to be applied for 20 min followed by a no-load period of 10 min and repeated until peak temperatures stabilize.

8.5.4 INSULATION RESISTANCE—The insulation resistance of the coupler between the power conductors and the EV chassis ground shall be a minimum of 10M Ω at 500 V DC.

8.5.5 FLUID RESISTANCE—The coupler shall be unaffected by automotive lubricants, solvents, and fuels as specified in Section 4.4 Immersion and Splash of SAE J1211.

8.5.6 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:
b. Frequency—Varied from 10 to 55 Hz and return to 10 Hz at a linear sweep period of 2 min/complete sweep cycle.
c. Excursion—1.0 + 0.1/–0.0 mm peak to peak over the specified frequency range.
d. Direction of Vibration—Vertical axis of the vehicle inlet as it is mounted on the vehicle.
e. Test Duration—60 + 1/–0 min.
f. 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 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.

8.5.7 SEALING REQUIREMENTS—The vehicle inlet and connector 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.

8.5.8 SHIELDING REQUIREMENTS—The coupler shall meet the following shielding requirements:

a. In addition to an external door, the contacts of the vehicle inlet shall be shielded, physically and visually, when decoupled.
b. The contacts of the connector shall be shielded, physically and visually, when decoupled.
c. The shielding mechanism(s), shall operate automatically during decoupling.
d. When decoupled, the shielding mechanism(s) should be designed to avoid or mitigate direct contact with conductive parts by reducing the likelihood of accidental or inadvertent touching.
e. When decoupled, the shielding mechanism(s) should prevent the ingress of small particles, dirt, leaves, and other small objects from degrading the performance of the sealing system, obstructing electrical current flow, or diminishing coupler performance.

8.6 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.

8.6.1 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 7. The standard configuration shall not function with a connector suitable for DC Charging. The optional configuration shall function with all connector configurations.

TABLE 7—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

8.6.2 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 8. 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 – Articles 625 and Article 400 – Table 400-4.

TABLE 8—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

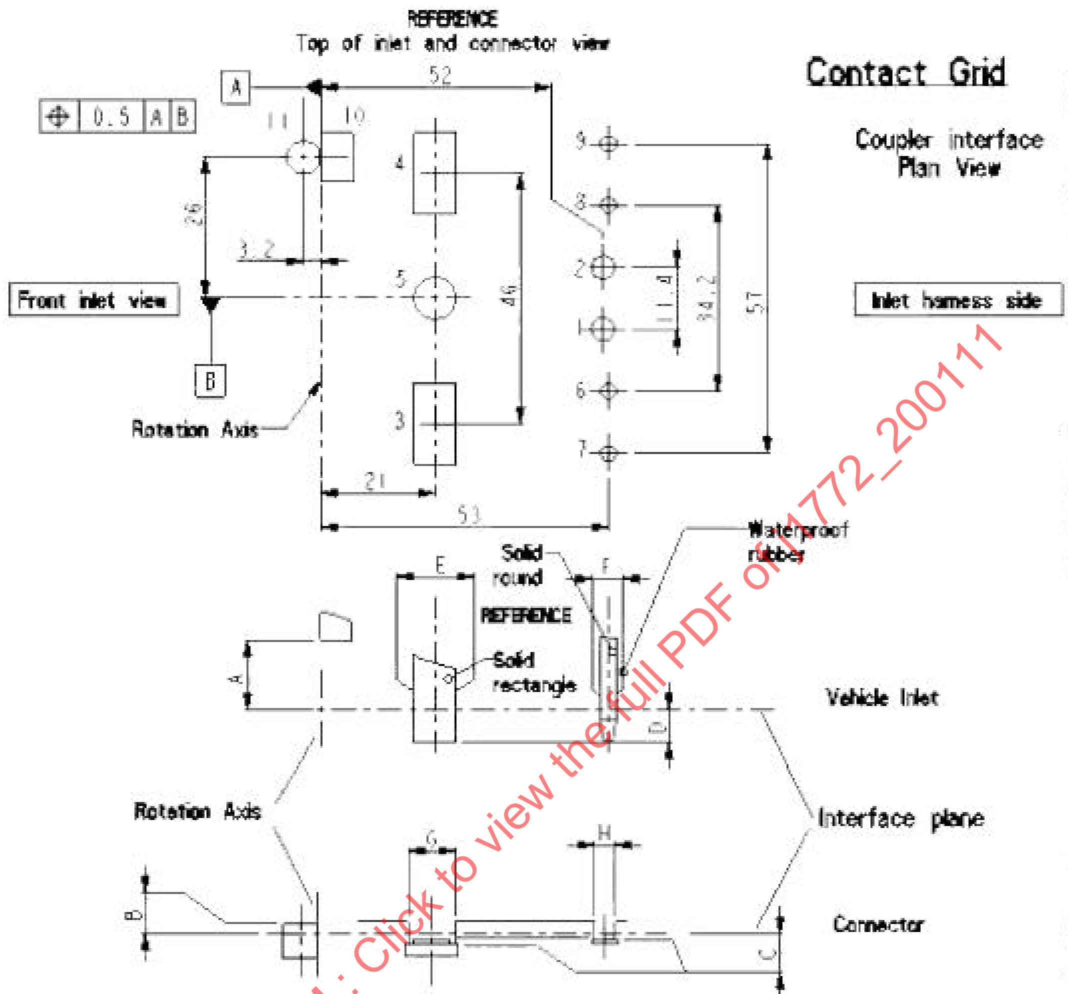
1. Note: X = required, O = optional

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

8.7.1 INTERFACE CONTACT SPACING—The general contact sizes and spacing at the coupler interface shall comply with the dimensions as specified in Table 9 and shown in Figure 9.

TABLE 9—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	Sat 5000 Gauss Φ 3 415 Gauss	-	1.8	-	-	-	-	-	-

* Reed minimum attractive distance to magnet : 17mm

FIGURE 9—CONTACT INTERFACE SPACING AND CONTROL DIMENSIONS

8.7.2 CONNECTOR PHYSICAL DIMENSIONS—The connector shall comply with the key physical dimensions as shown in Figure 10.

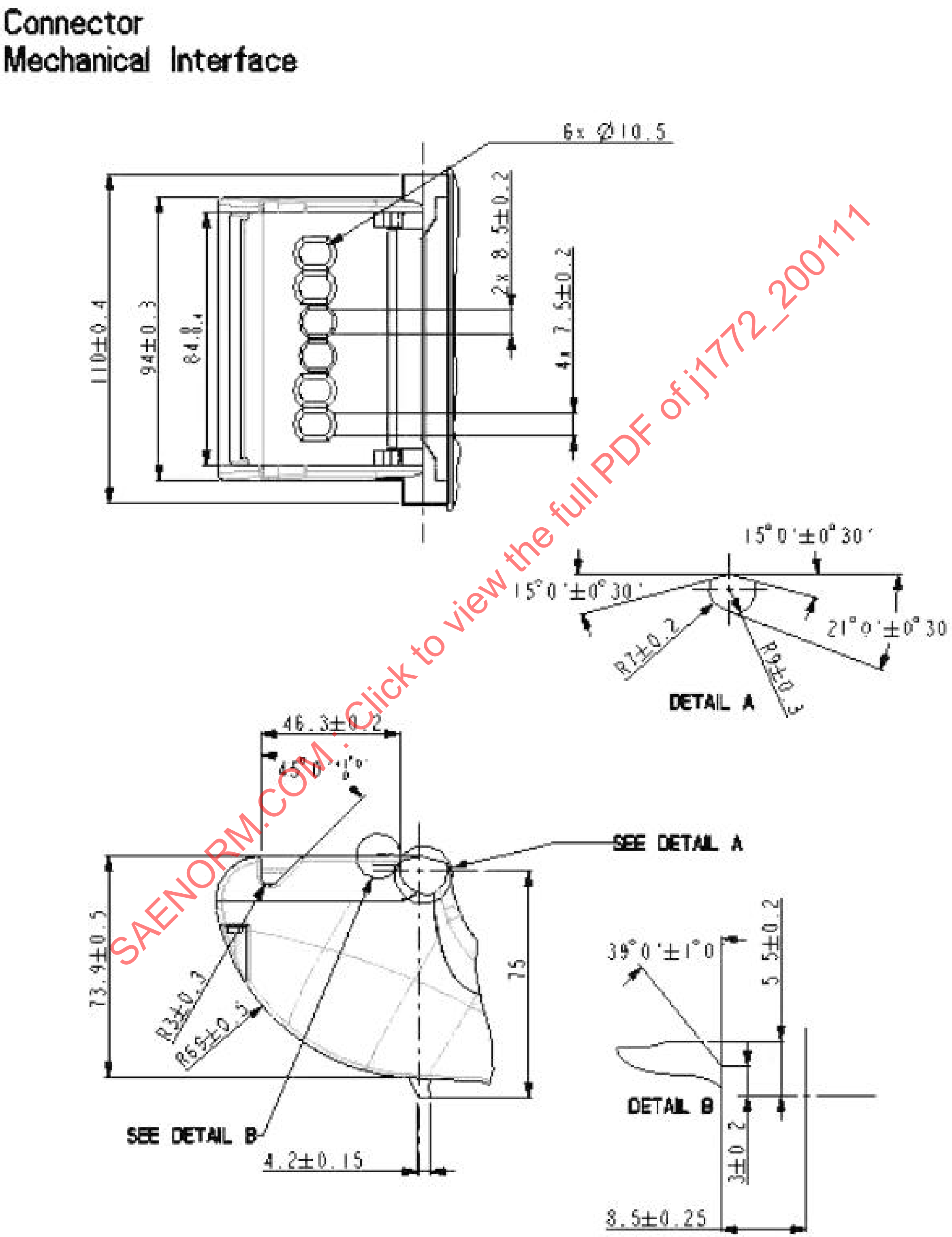


FIGURE 10—CONNECTOR PHYSICAL CONTROL DIMENSIONS

8.7.3 VEHICLE INLET PHYSICAL DIMENSIONS—The vehicle inlet shall comply with the key physical dimensions as shown in Figure 11.

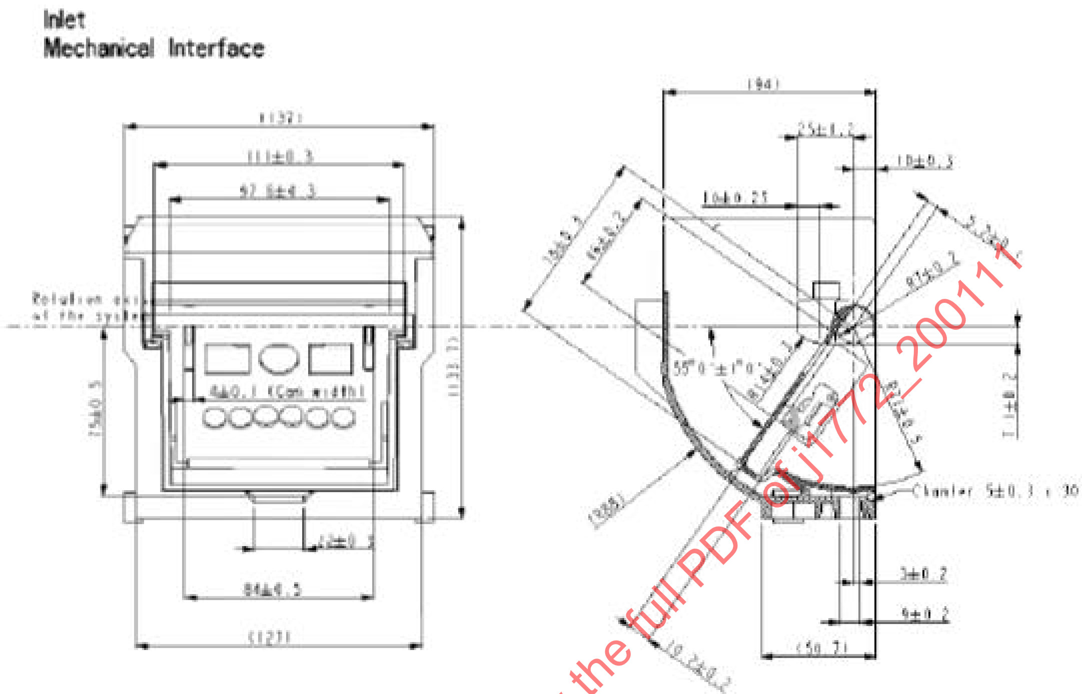


FIGURE 11—VEHICLE INLET PHYSICAL CONTROL DIMENSIONS

8.7.4 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 12.

8.7.5 CONTACT SEQUENCING—During connection, the connector and vehicle inlet shall comply with the contact sequencing and events shown in Figure 13 and specified in Table 10. 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 10—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

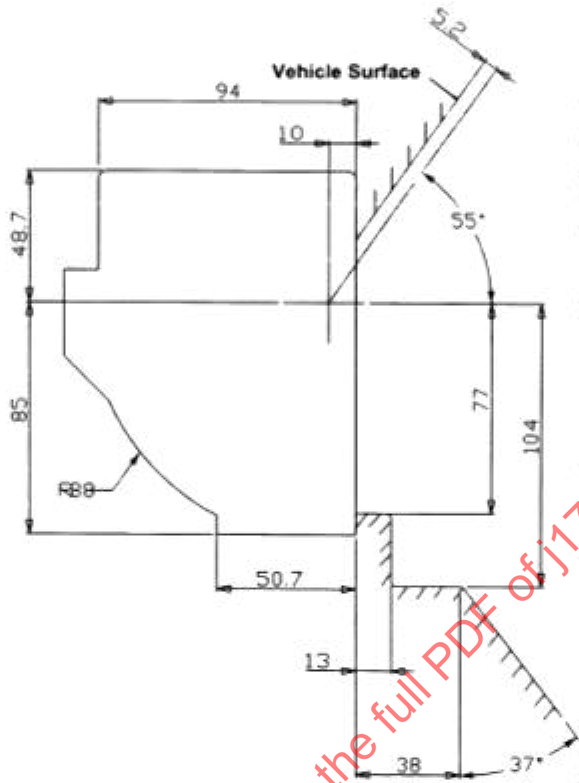


FIGURE 12—VEHICLE INLET INTERFACE ACCESS ZONE

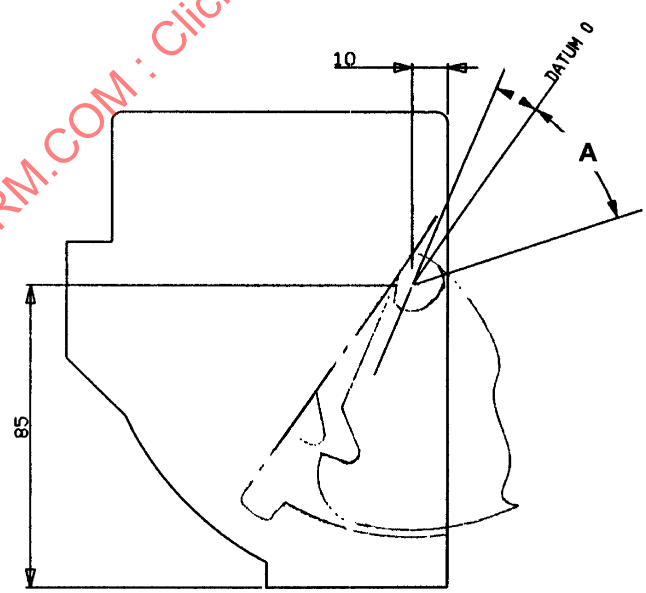


FIGURE 13—COUPLER INTERFACE CONTACT SEQUENCING

9. Notes

9.1 Marginal Indicia—The change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. An (R) symbol to the left of the document title indicates a complete revision of the report.

PREPARED BY THE SAE ELECTRIC VEHICLE CHARGING SYSTEMS OF THE
SAE ELECTRIC VEHICLE FORUM

APPENDIX A

HISTORY EVSE/VEHICLE INTERFACE

A.1 The specifications for the Control Pilot system shown in Section 5 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 Standard. 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 A1. Actual schematics cannot be shown due to proprietary considerations.

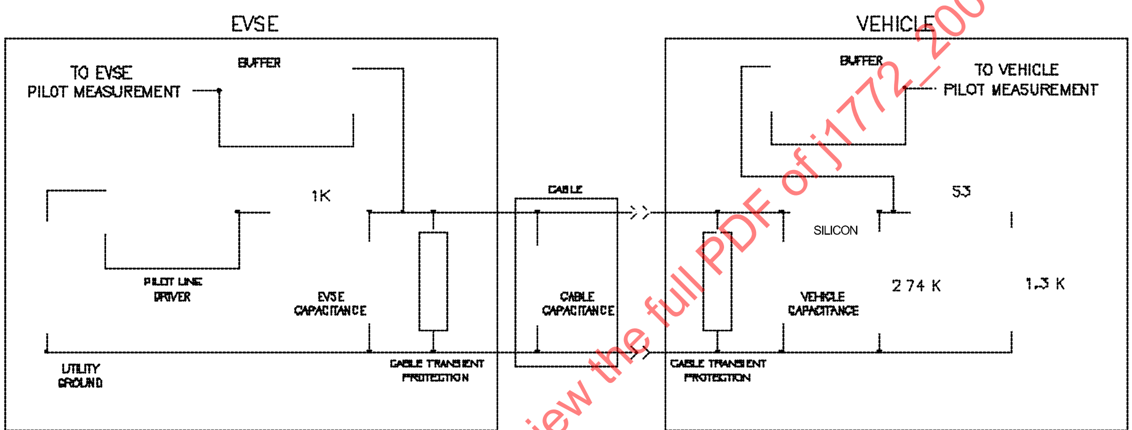


FIGURE A1—TYPICAL PILOT LINE CIRCUITRY

A.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 effect 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.