SURFACE VEHICLE RECOMMENDED PRACTICE

J2953™/1 MAY2023

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Superseding J2953/1 OCT2013

Plug-in Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE)

RATIONALE

This document supports the digital communication requirements within SAE J2836™ that includes the use cases and general information for several communication approaches and SAE J2847 includes the corresponding detail messages and state diagrams. SAE J2931 identifies the requirements and protocols, as various options are available to the consumer and utility. Battery Electric Vehicles (BEV) were developed several years ago and the connector, EVSE and analogue interface was described in SAE J1772™ and has been updated to better match Plug-In Hybrid Vehicle (PHEV) criteria. Utility companies are developing the smart grid communication and control system to balance this additional load with available distribution and several options will be available to the consumer. Plug-In Vehicle (PEV) and EVSE digital communication is required to insure the customer is able to roam and connector any PEV to any EVSE for these additional features. Considerably more manufacturers have entered the market PEVs and EVSEs with more BEV and PHEV combinations, and also offer a wide variety of EVSEs from 120V and 240V AC, plus DC charging where the EVSE includes an off-board charger for faster rates. This market will continue to expand and change, and the customers need to connect and charge any PEV with any EVSE using their preferred communication medium and still interface with the local utility.

SAE J2953/1 has been reaffirmed to comply with the SAE Five-Year Review policy.

FOREWORD

The recent inception of the PEV (Plug-In Electric Vehicle) and its related charging standards has brought a high level of concern regarding the interoperability between PEVs and related grid equipment. Because of the variation of charging standard implementation it is currently difficult to ensure that any PEV will be able to interface and communicate successfully with supply equipment or other grid devices available to consumers.

To meet the needs of PEV operators, the PEV charging process must have "plug and play" interoperability, meaning that any specific PEV and any related supply equipment must interface and communicate properly without special effort by the operator. The acceptance of the PEV as a supplement to fossil fuel vehicles is dependent on the interoperability, reliability and convenience of the charge process. In order to meet these criteria PEV charging standards must be sufficiently robust and must have a significant focus on achieving interoperability.

NOTE: This SAE Recommended Practice is intended as a 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 J2953/1 establishes requirements and specification by which a specific Plug-In Electric Vehicle (PEV) and Electric Vehicle Supply Equipment (EVSE) pair can be considered interoperable. The test procedures are further described in J2953/2.

1.1 Purpose

This document assembles and clarifies the requirements for multiple levels of interoperability as defined in related PEV charging standards (listed below). It provides support for charging systems which are developed according to SAE J1772 and may also implement the digital communication requirements within SAE J2836 and SAE J2847 standards. There is also support for SAE J2931 which identifies the vehicle to grid requirements and protocols as various options are available to the consumer and utility.

This document also functions as a tool for documenting interoperability issues and standards gaps that can be communicated to standards committees, ultimately leading to refining vehicle charging related SAE standards.

1.2 Rational

Analyzing the number of real world PEV – EVSE combinations that show interoperability will give insight on the effectiveness of the vehicle charging related SAE standards in terms of interoperability. Using single component testing one can already see that there are inconsistencies between manufacture supply equipment and inconsistencies between manufacture Plug-In Electric Vehicles. Combining both components into a system allows one to discover how these inconsistencies can interact to affect the system's ability to perform correctly.

1.3 Revision Information:

This first revision addresses interoperability testing for AC Level 1 und AC Level 2 charging systems.

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 724-776-4970 (outside USA), www.sae.org.

2.2 Related Publications

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

SAE J1772™ SAE Electric Vehicle Conductive Charge Coupler (Surface Vehicle Recommended Practice).

SAE J2836/1™ Use Cases for Communication between Plug-in Vehicles and the Utility Grid (Surface Vehicle Information Report).

SAE J2836/2™ Use Cases for Communication between Plug-in Vehicles and the Supply Equipment (EVSE) (Surface Vehicle Information Report).

SAE J2836/3™ Use Cases for Communication between Plug-in Vehicles and the Utility Grid for Reverse Power Flow (Surface Vehicle Information Report).

SAE J2836/4™ Use Cases for Diagnostic Communication for Plug-in Vehicles (Surface Vehicle Information Report).

SAE J2836/5™ Use Cases for Communication between Plug-in Vehicles and their customers (Surface Vehicle Information Report).

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

SAE J2931/1 Requirements for digital communication between the PHEV and a EVSE or a DC off board charger

SAE J2847/1 Communication between Plug-in Vehicles and the Utility Grid (Surface Vehicle Recommended Practice).

SAE J2847/2 Communication between Plug-in Vehicles and the Supply Equipment (EVSE) (Surface Vehicle Recommended Practice).

SAE J2847/3 Communication between Plug-in Vehicles and the Utility Grid for Reverse Power Flow (Surface Vehicle Recommended Practice).

SAE J2894/1 Power Quality Requirements for Plug-In Electric Vehicle Chargers (Surface Vehicle Recommended Practice).

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

2.3 Other Publications

ReleaseCandidate2 DIN SPEC 70121: Electromobility - Digital communication between a D.C EV charging station and an electric vehicle for control of D.C. charging in the Combined Charging System

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 5.2 of SAE J1772. 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.

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 COMPATIBILITY

A statement of design and implementation of a device to standards specifications.

3.5 CONDUCTIVE

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

3.6 CONFORMANCE

A statement of successful measureable verification that a device has implemented a standard as written. A compatible device may claim it conforms to a standard only after comprehensive conformance testing.

3.7 CONNECTOR (Charge)

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

3.8 CONTACT (Charge)

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

3.9 CONTROL PILOT

An electrical signal that is sourced by the Electric Vehicle Supply Equipment (EVSE). Control Pilot is the primary control conductor and is connected to the equipment ground through control circuitry on the vehicle and performs the following functions:

a. Verifies that the vehicle is present and connected

b. Permits energization/de-energization of the supply

c. Transmits supply equipment current rating to the vehicle

d. Monitors the presence of the equipment ground

e. Establishes vehicle ventilation requirements

f. Serves as medium for Power-Line-Communication (PLC), as per SAE J2931

3.10 COUPLER (Charge)

A mating vehicle inlet and connector set.

3.11 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.

3.12 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).

3.13 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.

3.14 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.

3.15 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.

3.16 INTEROPERABILITY

Capability of a standards conforming device to function as intended with other standards conforming devices without special effort by the user.

3.17 ON-BOARD CHARGER

A charger located on the vehicle.

3.18 OFF-BOARD CHARGER

A charger located off-board 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 PROXIMITY CIRCUIT

A circuit that defines the state of the charge connector in reference to the vehicle inlet. For AC charging the PEV and coupler contain a proximity circuit that the PEV uses to detect connection of the EVSE connector to the PEV inlet. The proximity circuit is modified for DC charging so that the EVSE can also sense that the cord is plugged into the PEV inlet.

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. TECHNICAL REQUIREMENTS FOR AC LEVEL 1 AND LEVEL 2

In the most fundamental sense, there are 3 functions, 2 electrical and 1 mechanical, which 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 is 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.

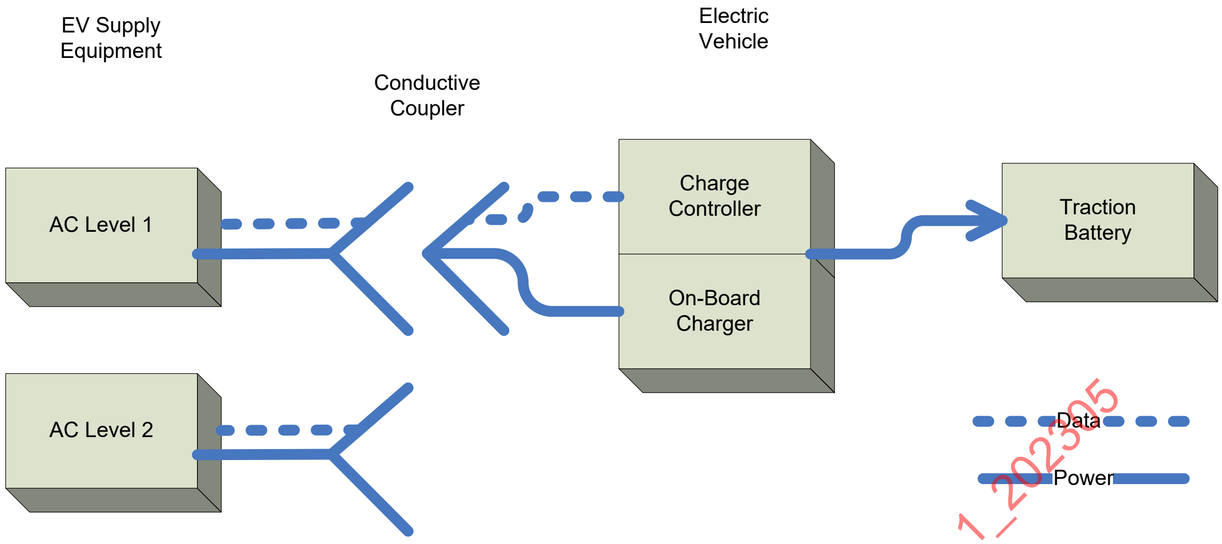

FIGURE 4.1 - AC CONDUCTIVE EV/PHEV CHARGING SYSTEM ARCHITECTURE

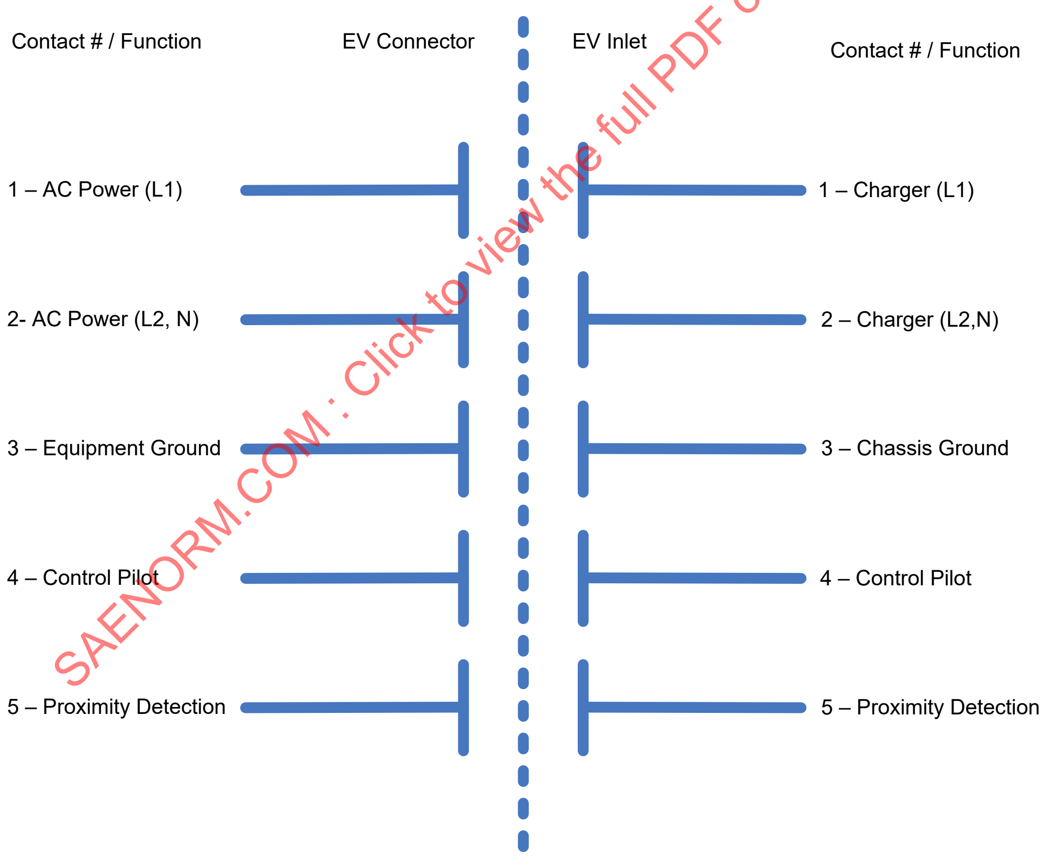

FIGURE 4.2 - AC LEVEL 1 AND AC LEVEL 2 CONDUCTIVE COUPLER CONTACT INTERFACE FUNCTIONS

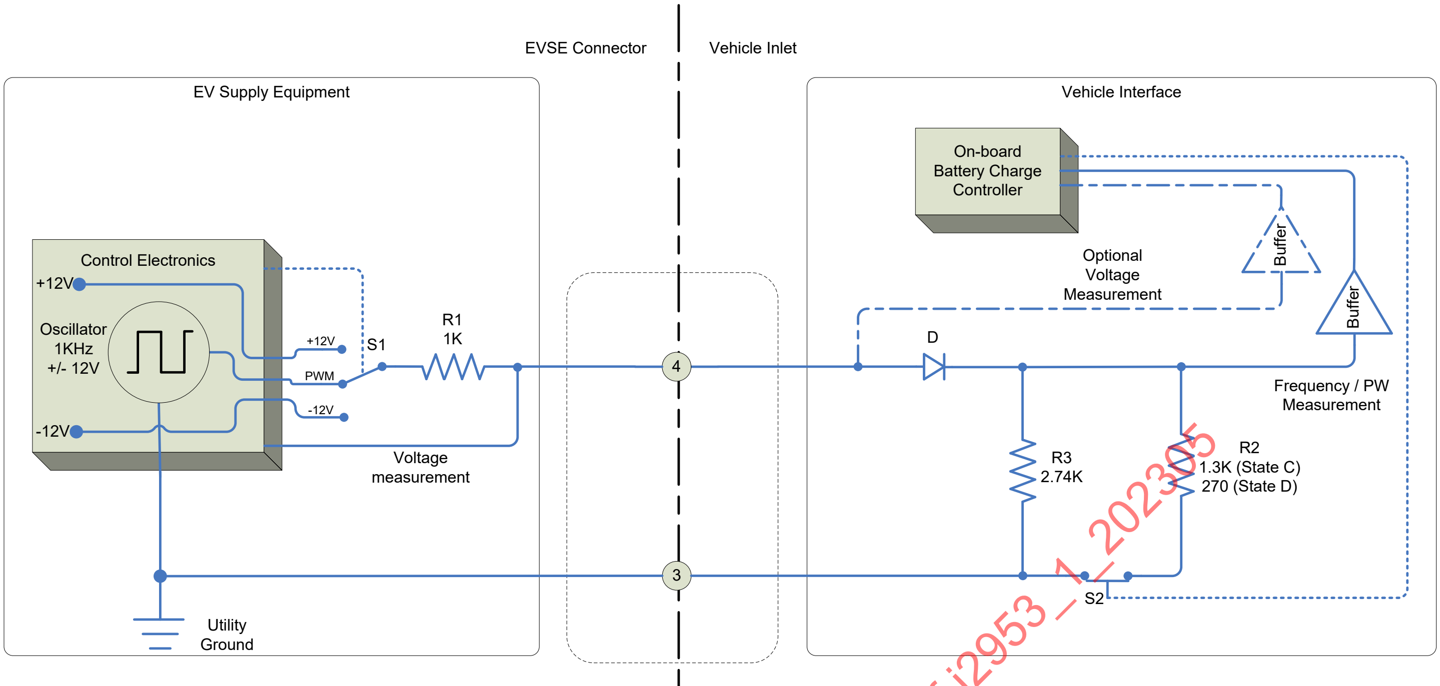

FIGURE 4.3 - AC LEVEL 1 AND AC LEVEL 2 CONTROL PILOT CIRCUIT

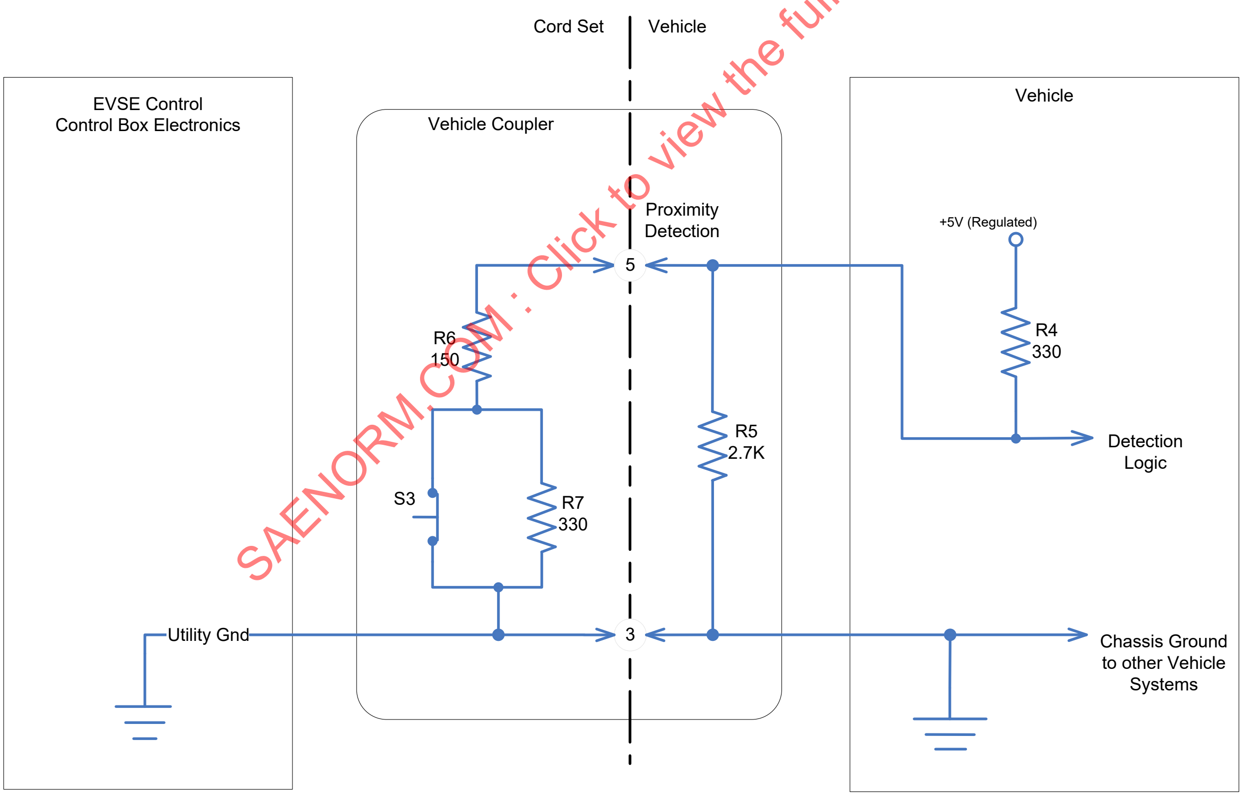

FIGURE 4.4 - AC LEVEL 1 AND AC LEVEL 2 PROXIMITY CIRCUIT

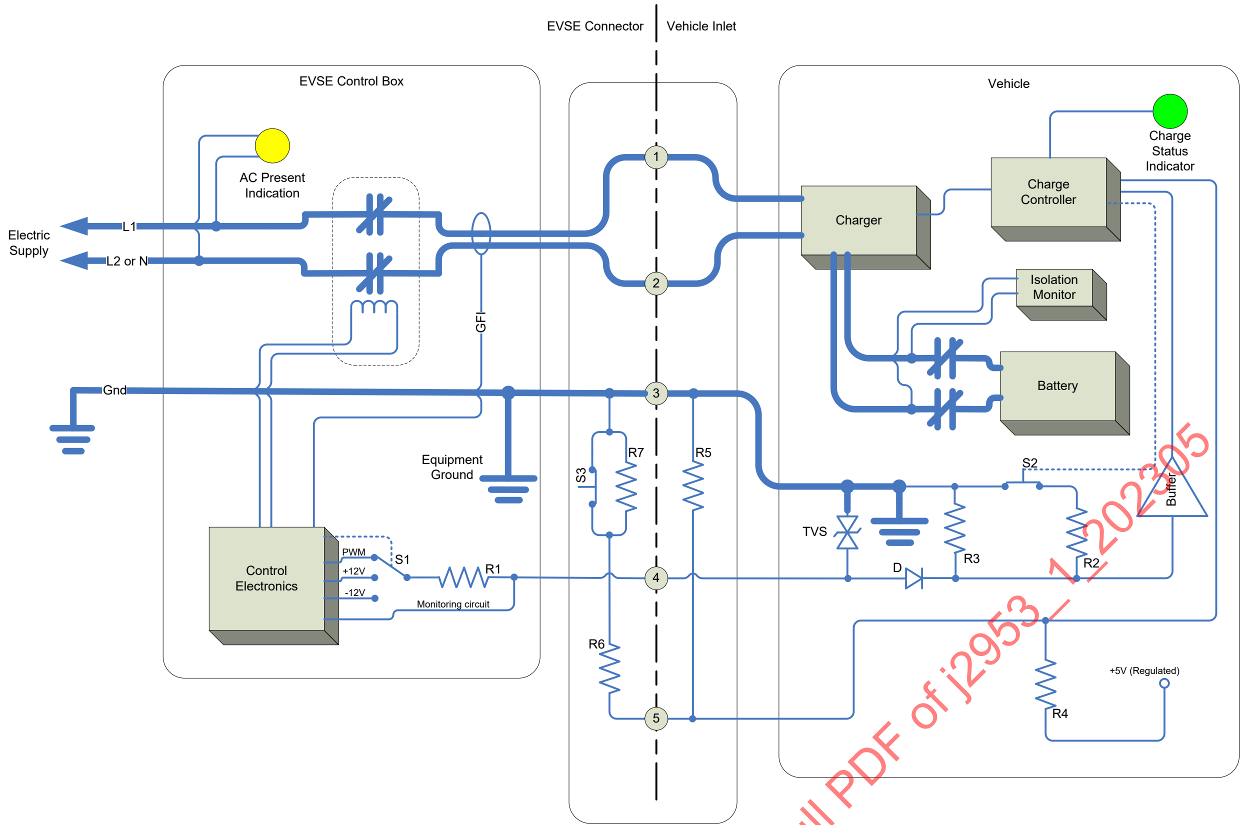

FIGURE 4.5 - AC LEVEL 2 SYSTEM CONFIGURATION

4.1 Interoperability Requirements for AC Level 1 and AC Level 2 Charging Standards

This section addresses the interoperability requirements of a charge system consisting of a SAE J1772 conforming PEV and SAE J1772 conforming EVSE. The EVSE and PEV are not measured or characterized as components rather as a whole system. Below are the system requirements. This section does not address EVSE/PEV conformance requirements or testing.

NOTE: All requirements are based upon SAE J1772 and are intended to be measured at the charge coupler nodes.

This section of the document assumes that the reader has comprehensive understanding of SAE J1772 Recommended Practice.

4.1.1 Start-up Timing

When the EVSE connector is initially plugged into a PEV inlet the EVSE and PEV begin a startup sequence to establish a charge session. An unplugged EVSE is assumed to have a positive 12 volt potential on the pilot (State A). Once the EVSE is plugged into the PEV it enters State B and has a 9 volt potential.

The EVSE is able to indicate to the PEV 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 is able to indicate to the PEV that it is ready to supply energy by turning on the oscillator and providing the square wave signal; entering State B2. There is no timing requirement for transition from State B1 to B2.

The PEV interprets the current limit based upon the square wave duty cycle signaled by the EVSE. The PEV then indicates that it is ready to accept energy from the EVSE by closing switch S2. There is no timing requirement for transition from EVSE entering State B2 to PEV S2 switch being closed. Once the PEV closes switch S2 to accept energy the EVSE must close the AC contactors and supply energy to the PEV within a maximum of 3.0 seconds.

TABLE 4.1 - START-UP SEQUENCE REQUIREMENTS (SAE J1772 APPENDIX E)

Start-up Sequence Requirements			
#	**Specification**	**Acceptance Criteria**	**Action**
4.1.1.1	State B1 to State B2 transition	None	Timing from plug-in to EVSE PWM oscillator on
4.1.1.2	State B2 to State C or D timing	None	Timing from PWM on to PEV S2 closed
4.1.1.3	State C or D to mains voltage present	≤ 3.0 seconds	Timing from PEV S2 closed to EVSE AC contactors close

4.1.2 Pilot Voltage

Pilot Line Voltage defines charge system states. Those states are used for: both the PEV and EVSE to realize system connection, PEV to communicate charge readiness, and for the EVSE to communicate availability of charge energy.

Refer to SAE J1772 "Definition of Vehicle / EVSE States" Table for state designations and description.

Table 4.2 contains acceptance criteria for each state voltage as measured at the mated coupler.

TABLE 4.2 - PILOT VOLTAGE REQUIREMENTS (SAE J1772 GENERAL CONDUCTIVE CHARGING)

Pilot Voltage Requirements			
#	**Specification**	**Acceptance Criteria**	**Comment**
4.1.2.1	State A Voltage	11.40V ≤ V ≤ 12.60V	Static Voltage
4.1.2.2	State B Voltage	8.36V ≤ V ≤ 9.56V	May be static voltage or positive portion of PWM signal after transition has fully settled
4.1.2.3	State C Voltage	5.48V ≤ V ≤ 6.49V	Positive portion of PWM after transition has fully settled
4.1.2.4	State D Voltage	2.62V ≤ V ≤ 3.25V	Positive portion of PWM after transition has fully settled
4.1.2.5	State E Voltage	---	Passive fault mode due to short or loss of power; 0.0 Volts nominal
4.1.2.6	State F Voltage	-11.40V ≤ V ≤ -12.60V	Active fault mode
4.1.2.7	State A-D, F Low-Side Voltage	-11.40V ≤ V ≤ -12.60V	Negative portion of PWM signal in all states when pilot in oscillation

4.1.3 Control Pilot Waveform and Interpretation

Pilot Waveform requirements per SAE J1772 are limited to the EVSE. A set of pilot waveform requirements for the EVSE – PEV system can be found by extending EVSE waveform requirements and pilot circuit requirements. SAE J1772 specifies state voltage ranges, PWM generator rise /fall time and settling time requirements, and pilot circuit capacitance requirements. The resulting circuits are simulated in worst case scenario; rise/fall times and settling time measurements are made and are considered the acceptance criteria for control pilot waveform requirements; detailed analysis can be found in Section A.2; table 4.3 shows these requirements.

TABLE 4.3 - CONTROL PILOT WAVEFORM REQUIREMENTS

Control Pilot Waveform Requirements			
#	**Specification**	**Acceptance Criteria**	**Comment**
4.1.3.1	PWM Duty Cycle	8% < Duty Cycle ≤ 97%	Communicates maximum continuous current capacity
4.1.3.2	PWM Frequency	980 Hz ≤ Freq. ≤ 1020 Hz	Continuously monitored when oscillating
4.1.3.3	State B Rise Time	≤ 9.624µs	10% to 90% transition
4.1.3.4	State B Fall Time	≤ 12.479 µs	90% to 10% transition
4.1.3.5	State C Rise Time	≤ 6.937 µs	10% to 90% transition
4.1.3.6	State C Fall Time	≤ 12.508 µs	90% to 10% transition
4.1.3.7	State D Rise Time	≤ 4.689 µs	10% to 90% transition
4.1.3.8	State D Fall Time	≤ 12.655 µs	90% to 10% transition
4.1.3.9	State B Settling Time	≤ 17.660 µs	0% to 95% transition
4.1.3.10	State C Settling Time	≤ 13.191 µs	0% to 95% transition
4.1.3.11	State D Settling Time	≤ 8.625 µs	0% to 95% transition
4.1.3.12	PEV AC Current Draw	≤ maximum current capacity communicated by EVSE	See SAE J1772 Table 4.6 for available current equations Exception: Change in PWM duty cycle during charge session allows for appropriate current draw change within 5 seconds.

4.1.4 Shutdown Transition

During the charge cycle the PEV has the ability to transition from State C or D (ready to accept charge) to State B (not ready to accept charge) by opening the S2 switch. This transition can occur for a number of reasons including the PEV being completely charged. Per J1772 it is required that the timing from switch of S2 to the EVSE opening the AC contacts shall be 3 seconds or less.

TABLE 4.4 - SHUTDOWN SEQUENCE REQUIREMENTS

Shutdown Sequence Requirements			
#	**Specification**	**Acceptance Criteria**	**Comment**
4.1.4.1	State C or D to State B2 transition	≤ 3 seconds	Timing from AC contactors open in response to S2 open

4.1.5 Proximity Circuit Voltage

For AC charging the proximity circuit is utilized by the PEV in order to recognize when a J1772 connector is coupled with the PEV inlet. The circuit is driven by the PEV and is only monitored by the PEV. The circuit is only complete once the EVSE coupler is plugged into the PEV. Safe AC charge cycles are dependent on the proximity circuit. Without proper implementation of the proximity circuit charging may be impossible or unsafe. Table 4.5 contains voltage requirements for the three possible proximity circuit stages.

TABLE 4.5 - PROXIMITY CIRCUIT REQUIREMENTS

Proximity Circuit Requirements			
#	**Specification**	**Acceptance Criteria**	**Comment**
4.1.5.1	EVSE Unplugged	4.35V≤ Voltage ≤ 4.55V	Based on PEV regulating 5.0V
4.1.5.2	EVSE plugged in with S3 open	2.51V≤ Voltage ≤ 3.01V	Based on PEV regulating 5.0V
4.1.5.3	EVSE plugged in with S3 closed	1.30V≤ Voltage ≤ 1.72V	Based on PEV regulating 5.0V

4.1.6 Error Handling and Timing

Error handling is important to facilitate a safe system state during human error or component error situations. Table 4.6 includes system error handling requirements for AC charging. It is implicit that the acceptance criteria include the timing requirements as well as the system responses.

TABLE 4.6 - ERROR HANDLING REQUIREMENTS

Error Handling and Timing Requirements			
#	**Specification**	**Acceptance Criteria**	**Delay from Action / Reaction**
4.1.6.1	State X to State A	≤ 100 milliseconds	Delay from operator connector disconnect to EVSE opening AC contactors
4.1.6.2	State X to State A	≤ 2 seconds	Delay from operator connector disconnect to EVSE oscillator shut-off
4.1.6.3	State E or F to No Line Voltage	≤ 3 seconds	Delay from EVSE passive/ active fault state to EVSE AC contactors opening
4.1.6.4	Invalid Pilot to State B2	≤ 3 seconds	Delay from EVSE invalid pilot frequency to PEV opening S2
4.1.6.5	State E or F to Zero Charge Current	≤ 5 seconds	Delay from EVSE fault state to PEV terminating charge(PEV zero charge current)
4.1.6.6	Duty Cycle change response	≤ 5 seconds	Delay from EVSE PWM modification to PEV current draw adjustment
4.1.6.7	State C or D S3 Open to Zero Charge Current	≤ 100 milliseconds	Delay from operator S3 open to PEV terminating charge(PEV zero charge current)
4.1.6.8	External Load Management Signal	≤ 10 seconds	Delay from external load management signal to EVSE modification of PWM duty cycle
4.1.6.9	State C or D to State D or C	≤ 3 seconds	Delay from change of ventilation request to EVSE oscillator off/ventilation start

4.1.7 Mechanical Interoperability

These requirements determine that a specific SAE J1772 EVSE connector is interoperable with a specific SAEJ1772 PEV inlet.

4.1.7.1 Insertion of connector into vehicle inlet is intuitively obvious and free of multiple orientations.

4.1.7.2 Human effort for coupling and decoupling is less than 75 Newtons.

4.1.7.3 Connector and inlet provide an audible and/or tactile feedback once fully engaged.

4.1.7.4 Latch mechanism is present and prevents inadvertent or accidental decoupling.

4.1.7.5 Latching mechanism provides a means in the connector to open the proximity circuit during decoupling.

4.2 AC Level 1 and Level 2 Interoperability Tiers

A tiered system approach is being utilized in order to measure levels of interoperability. Four key areas of functionality include charge functionality, safety feature functionality, system robustness and non-essential feature functionality. AC interoperability contains three tiers, Tier 1 being the most essential while tiers 2 and 3 are incrementally less essential. Each tier contains a breakdown of interoperability requirements specific to its testing. The testing environment and procedures will be spelled out in the following document, SAE J2953/2.

4.2.1 Tier I

Charge Functionality Test – This is a test of a normal charge session under normal conditions. Requirements that must be met include the following:

- Start-up Sequence Requirements
  - 4.1.1.3
- Pilot Voltage Requirements
  - 4.1.2.2
  - 4.1.2.3
  - 4.1.2.4
  - 4.1.2.7
- Control Pilot Waveform Requirements
  - 4.1.3.1 through 4.1.3.12
- Shutdown Sequence Requirements
  - 4.1.4.1
- Proximity Circuit Requirements
  - 4.1.5.1
  - 4.1.5.2
  - 4.1.5.3
- Mechanical interoperability Requirements
  - 4.1.7.1 through 4.1.7.5

Safety Feature Functionality Test – This is a test of the system error handling capabilities in the case that a system operator terminates a charge session by unplugging the EVSE connector from the EV inlet during energy transfer. This system must meet the following requirements:

- Error Handling Requirements
  - 4.1.6.1
  - 4.1.6.2
  - 4.1.6.7

4.2.2 Tier II

System Robustness Testing – These tests will be conducted using two different grid event models. Model 1, Indefinite Grid Events, includes events that will be programmed to begin upon startup of the testing. Model 2, Momentary Grid Events, will include programmed grid events that will only be applied during the energy transfer phase of a charge session.

Indefinite Grid Events Test – Static voltage and frequency variations shall be applied to the system before a charge session begins and will remain until the testing is complete.

Momentary Grid Events Test – Dynamic voltage and frequency variation will be applied to the system during the energy transfer section of a charge session. This test also includes power outage and cold-load-pickup testing. Both test methods must pass the following system requirements.

- Start-up Sequence Requirements
  - 4.1.1.3
- Pilot Voltage Requirements
  - 4.1.2.2
  - 4.1.2.3
  - 4.1.2.7
- Control Pilot Waveform Requirements
  - 4.1.3.1 through 4.1.3.12
- Proximity Circuit Requirements
  - 4.1.5.1
  - 4.1.5.2
  - 4.1.5.3

4.2.3 Tier III

Non-Essential Feature Functionality Test – Non-essential features are system capabilities that are not required to function in order for an EVSE-PEV charge session to be successful. These features may or may not be listed in the J1772 standard.

- Start-up Sequence Requirements
  - 4.1.1.3
- Shutdown Sequence Requirements
  - 4.1.4.1
- Error Handling Requirements
  - 4.1.6.6
  - 4.1.6.8
  - 4.1.6.9

5. TECHNICAL REQUIREMENTS FOR DC LEVEL1 AND LEVEL 2

5.1 DC Level1 and DC Level2 Charging Interoperability Requirements

To be addressed in next revision.

6. TECHNICAL REQUIREMENTS FOR VEHICLE TO GRID COMMUNICATION

6.1 Vehicle to Grid Communication Interoperability Requirements

To be addressed in next revision.

6.2 Vehicle to Grid Communication and DC Charging Compatibility Combined Tests

To be addressed in next revision.

7. DOCUMENT MAPPING

7.1 Summary

SAE has published multiple documents relating to PEVs and vehicle-to-grid interfaces. The various document series are listed below, with a brief explanation of each.

SAE J2954 Defines the wireless charging interface PEVs and EVSEs.

SAE J2836™ General Requirements and Use Cases. This document is divided into several sections. SAE J2836/1™ is for Utility/Smart Grid messaging, SAE J2836/2™ is for DC Charge Control, SAE J2836/3™ is for Reverse Energy Flow. SAE J2836/4™ is for Diagnostics. SAE J2836/5™ is for Consumer Requirements and the HAN.

SAE J2847 Functional Messaging Requirements. This document defines the functional messages required for a given function. This document is divided into several sections that correspond to SAE J2836 above. SAE J2847/1 is for Utility/Smart Grid messaging, SAE J2847/2 is for DC Charge Control, SAE J2847/3 is for Reverse Energy Flow. J2847/4 is for Diagnostics. SAE J2847/5 is for Consumer Requirements.

SAE J2931 Digital Communications for PEVs. This series of documents defines the requirements to enable digital communications for PEVs. It is divided into several sections. J2931/6 describes overall requirements.

SAE J2953 Plug-In Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE). This is the series that include the requirements and test procedures for all the previous documents, including SAE J1772.

Figure 7.1 shows the sequencing of these documents and their primary function (e.g., the /1 documents start with Utility information, /2 then adds DC charging, etc.). The intent is to have subsequent slash sheets complement each other as more functions and features are included. The /6 series of documents add wireless charging items not already included in the proceeding documents. These are all then included in Interoperability in SAE J2953 and security in SAE J2931/7.

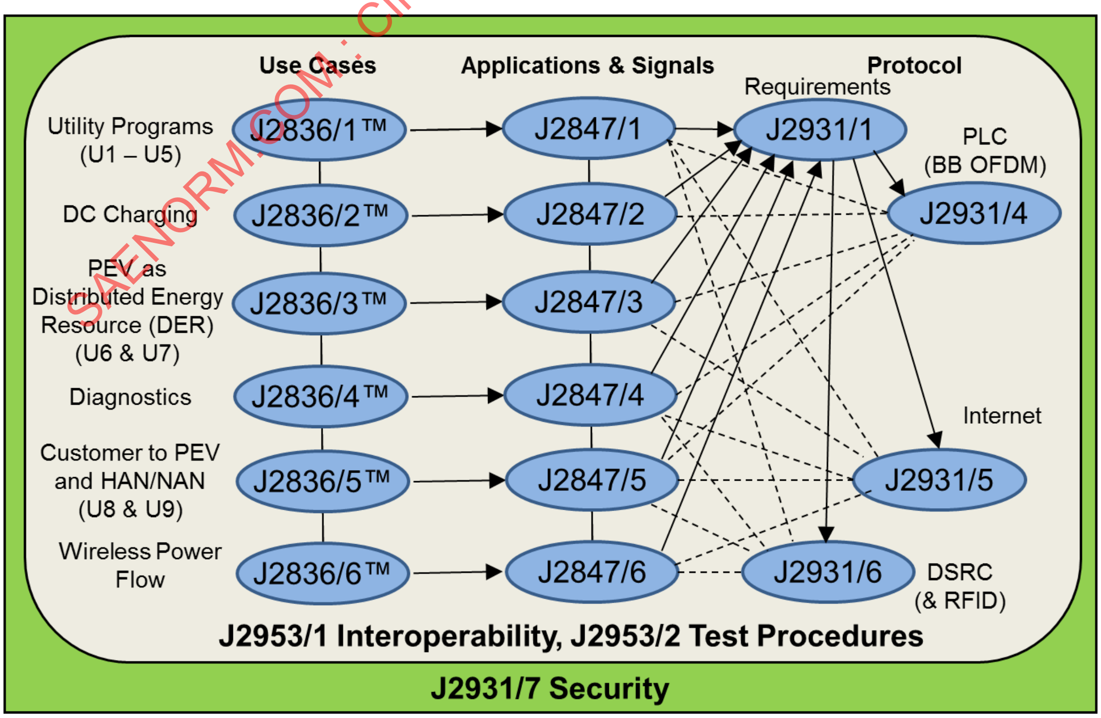

FIGURE 7.1 - DOCUMENT INTERACTION

8. NOTES

8.1 Marginal Indicia

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

A.1 PROXIMITY CIRCUIT REQUIREMENT ANALYSIS

All proximity circuit analysis is based on circuit parameters described in SAE J1772. Figure 4.4 shows an equivalent proximity circuit for AC level 1 and 2 charging. Proximity circuit parameters are shown in the following table from J1772.

TABLE A.1 – PROXIMITY DETECTION CIRCUIT PARAMETERS (SEE FIGURE 4.4)

Parameter(1)	Symbol	Units	Nominal value	Max value	Min value
Equivalent load resistance	R4	Ohms	330	363(2)	297(2)
Equivalent load resistance	R5	Ohms	2700	2970(2)	2430(2)
Equivalent load resistance	R6	Ohms	150	165(2)	135(2)
Equivalent load resistance	R7	Ohms	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.

Requirement 4.1.5.1 Analysis:

Requirement 4.1.5.1 describes the voltage range of the proximity pin in reference to ground when the EVSE coupler is unplugged from the PEV inlet. This voltage will be described as $V_{Unplugged}$. The equation to describe $V_{Unplugged}$ for 4.1.5.1 is as follows:

$$V_{Unplugged} = \frac{5.0V * R5}{R4+R5} \quad \text{(Eq. A.1)}$$

To calculate the max value of 4.1.5.1, R4 must equal 297 Ω and R5 must equal 2970 Ω for the equation A.1. This yields $V_{Unplugged}$ = 4.55 V after rounding to the nearest tenth of a mV.

To calculate the min value of 4.1.5.1, R4 must equal 363 Ω and R5 must equal 2430 Ω for the equation A.1. This yields $V_{Unplugged}$ = 4.35 V.

Thus requirement 4.1.5.1 has an acceptance criteria of 4.35 V≤ Voltage ≤ 4.55 V when the EVSE coupler is unplugged from the PEV inlet.

Requirement 4.1.5.2 Analysis:

Requirement 4.1.5.2 describes the voltage range of the proximity pin in reference to ground when the EVSE coupler is plugged into the PEV inlet and the latch button is pressed (S3 is open in Figure 4.4). This voltage will be described as $V_{S3\ Open}$. The equation to describe $V_{S3\ Open}$ for 4.1.5.2 is as follows:

$$V_{S3\ Open} = \frac{5.0V * (R5 \| (R6+R7))}{R4 + (R5 \| (R6+R7))} \quad \text{(Eq. A.2)}$$

To calculate the max value of 4.1.5.2, R4 must equal 297 Ω, R5 must equal 2970 Ω, R6 must equal 165 Ω, and R7 must equal 363 Ω for the equation A.2. This yields $V_{S3\ Open}$ = 2.51V.

To calculate the min value of 4.1.5.2, R4 must equal 363 Ω, R5 must equal 2430 Ω, R6 must equal 135 Ω and R7 must equal 297 Ω for the equation A.2. This yields $V_{S3\ Open}$ = 3.01 V.

Thus requirement 4.1.5.2 has an acceptance criteria of 2.51 V≤ Voltage ≤ 3.01 V when the EVSE coupler is plugged into the PEV inlet with the latch button pressed (open).

Requirement 4.1.5.3 Analysis:

Requirement 4.1.5.3 describes the voltage range of the proximity pin in reference to ground when the EVSE coupler is plugged into the PEV inlet and the latch button not pressed. This voltage will be described as $V_{S3\ Closed}$. The equation to describe $V_{S3\ Closed}$ for 4.1.5.3 is as follows:

$$V_{S3\ Closed} = \frac{5.0V*(R5\|R6)}{R4+(R5\|R6)} \quad \text{(Eq. A.3)}$$

To calculate the max value of 4.1.5.3, R4 must equal 297 Ω, R5 must equal 2970 Ω, and R6 must equal 165 Ω for the equation A.3. This yields $V_{S3\ Closed}$ = 1.72 V.

To calculating the min value of 4.1.5.3, R4 must equal 363 Ω, R5 must equal 2430 Ω, and R6 must equal 135 Ω for the equation A.3. This yields $V_{S3\ Closed}$ = 1.30 V.

Thus requirement 4.1.5.3 has an acceptance criteria of 1.30 V≤ Voltage ≤ 1.72 V when the EVSE coupler is plugged into the PEV inlet and the latch button is not pressed (closed).

A.2 PILOT CIRCUIT WAVEFORM REQUIREMENT ANALYSIS

All pilot circuit analysis is based on an equivalent pilot circuit for AC level 1 and 2 charging, referenced from SAE J1772 and shown in Figure A.1. Pilot circuit parameters for the EVSE circuit and the PEV circuit are shown in Tables A.2 and A.3 referenced from SAE J1772.

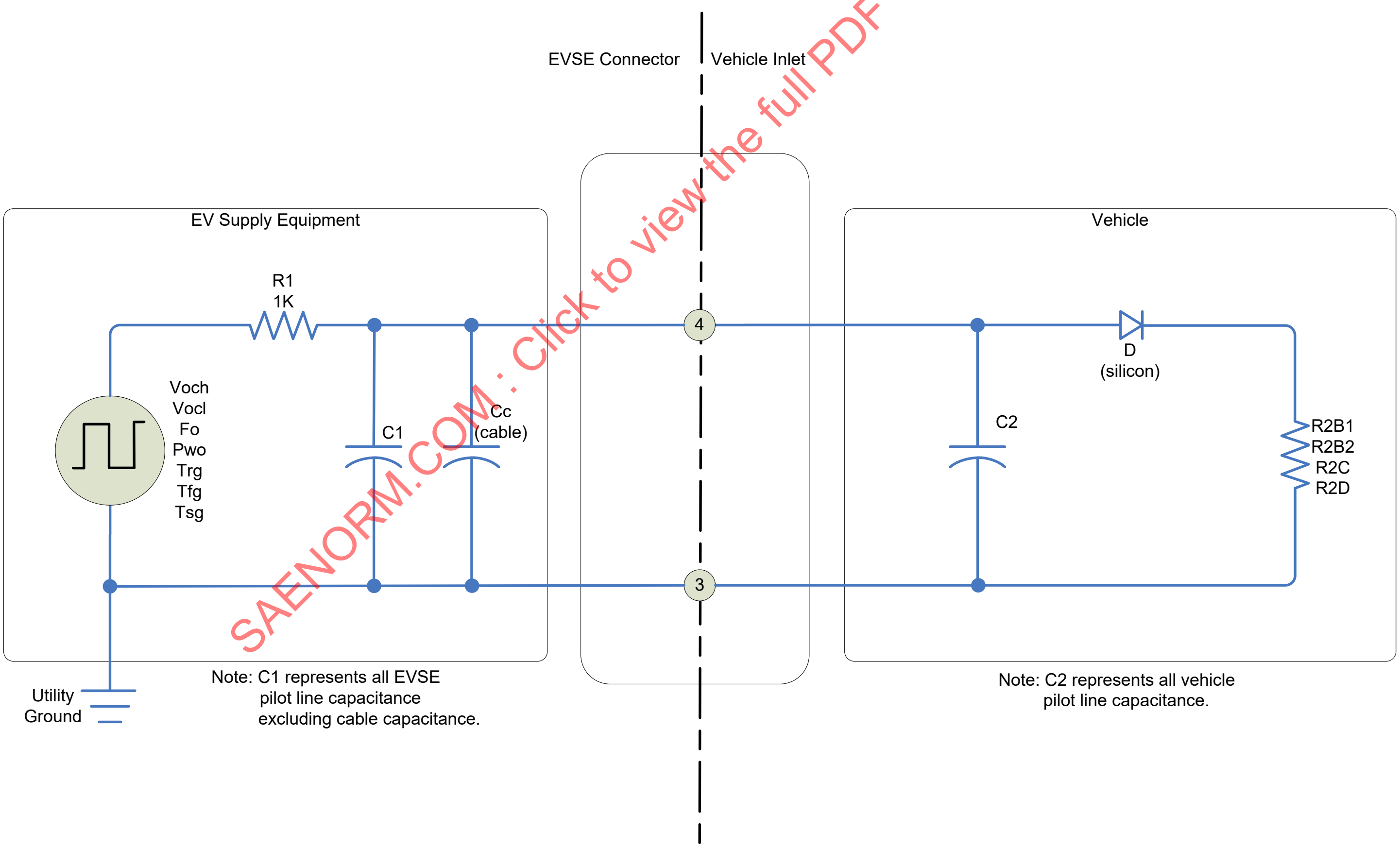

FIGURE A.1 - CONTROL PILOT EQUIVALENT CIRCUIT

TABLE A.2 – EVSE CONTROL PILOT CIRCUIT PARAMETERS

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 4.3	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	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 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 should 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 A.3 – EV/PHEV CONTROL PILOT CIRCUIT PARAMETERS

Parameter[1]	Symbol	Units	Nominal value	Max value	Min value
Equivalent load resistance – State B1&B2	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	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 2.75 to 10.0 ma.

Requirement 4.1.3.3 - 4.1.3.11 Analysis:

General equations for 10% to 90% rise time and 90% to 10% fall time for a standard RC circuit are as follows;

$$Rise\ time = \ln(9) * C_T * R_{THEV} \quad \text{(A.4)}$$

$$Fall\ time = \ln(9) * C_T * R_{THEV} \quad \text{(A.5)}$$

where C_T is the total system capacitance R_{THEV} is the total circuit equivalent resistance as seen by the capacitance.

The above equations only holds true for circuits consisting of a voltage source and R and C components and assume that switching times of the voltage source are instantaneous. Both of these assumptions do not hold true for the SAE J1772 pilot circuit.

The pilot circuit contains a diode that begins to forward conduct when the voltage between the diode and ground is greater than the diode's threshold voltage (0.55 V to 0.85 V) and is reversed biased when the voltage between the diode and ground is less than the diode's threshold voltage (0.55 V to 0.85 V).

Thus during the rise of the pilot waveform, R2 is not seen by the capacitor and source until the diode begins to forward conduct, adding R2 to the circuit and changing the value of R_{THEV}. During the fall of the pilot waveform R2 is part of the circuit until the capacitor voltage reaches a level below the diode's threshold voltage, removing R2 from the circuit and changing the value of R_{THEV}.

It is also important to note that the EVSE pilot waveform generator does not generate a perfect switch (instantaneous rise/fall time) between the high side and low side of the square waveform. For these reasons it is not possible to use equations A.4 and A.5 to calculate rise, fall and settling times for the control pilot waveform. However, the proportionality of these equations proves that larger R_{THEV} and C_T values result in larger rise times and fall times; the same principle holds true for settling time. This information becomes useful when simulating worst-case scenario rise, fall, and settling times.

The schematic shown in Figure A.1 was simulated in MATLAB with the script found in Appendix A.2.1 to determine the worst case rise times and settling times of the control pilot circuit at the EVSE coupler/PEV inlet interface. The script found in Appendix A.2.2 was utilized to determine the worst case fall times of the control pilot circuit at the EVSE coupler/PEV inlet interface. These scripts were verified with SPICE simulation and were utilized to populate Table A.4, Table A.5, and Table A.6. For all simulations a source rise time of 2.5 μs was utilized (10% - 90% rise time = 2.0 μs) as well as a max total capacitance of 5500 pF. The times highlighted in red were the worst case values and are utilized as the maximum rise, fall and settling time requirements.

TABLE A.4 - PILOT STATE RISE TIMES WITH MAXIMUM TOTAL CAPACITANCE AND VARYING CIRCUIT PARAMETERS

State B Rise (μs)

EVSE Source Voltage	Nominal Values (R1, R2, Vd)	Maximum Values (R1, R2, Vd)	Minimum Values (R1, R2, Vd)
-11.40 V to 11.4 V	9.347	**9.624**	9.071
-12.0 V to 12.0 V	9.344	9.621	9.069
-12.6 V to 12.6 V	9.343	9.618	9.068

State C Rise (μs)

EVSE Source Voltage	Nominal Values (R1, R2, Vd)	Maximum Values (R1, R2, Vd)	Minimum Values (R1, R2, Vd)
-11.40 V to 11.4 V	6.727	**6.937**	6.519
-12.0 V to 12.0 V	6.721	6.93	6.515
-12.6 V to 12.6 V	6.716	6.923	6.51

State D Rise (μs)

EVSE Source Voltage	Nominal Values (R1, R2, Vd)	Maximum Values (R1, R2, Vd)	Minimum Values (R1, R2, Vd)
-11.40 V to 11.4 V	4.525	**4.689**	4.365
-12.0 V to 12.0 V	4.514	4.675	4.357
-12.6 V to 12.6 V	4.504	4.663	4.35