



SURFACE VEHICLE TECHNICAL INFORMATION REPORT	J3271™	MAR2025
	Issued	2025-03
SAE Megawatt Charging System for Electric Vehicles		

RATIONALE

The SAE J3271 document was created to support high current/high power dedicated DC charging referred to as Megawatt Charging System (MCS). It is intended to serve any large vehicle battery system for on- and off-road applications. In short, any electric vehicle (EV) that rolls, flies, or floats, such as electric aviation, rail, marine, construction, mining, agriculture, or similar vehicles.

FOREWORD

Energy stored in a battery provides power for an EV. 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 information between the EV and the supply equipment. This document describes the electrical and physical interfaces between the EV and supply equipment to facilitate conductive charging as well as related subsystems/communication between the point of utility interconnection and net energy delivered to the vehicle battery.

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1. SCOPE

This SAE Technical Information Report (TIR) is based on the initial assumption that a system level standard covering all aspects of EV charging components and use cases would grow to be too large for one comprehensive document. Hence, the SAE J3271 work group was launched with five subtopics that could be subsections of one standard or a separate document for each topic.

In this document, all five subtopics are compiled into one document. The recommended practice level documents will follow this structure, with added detail and streamlined content.

The five subtopics that are now subsection numbers in this document include:

- SAE J3271/1 (see [5.1](#)) Electromechanical Coupler Specifications
- SAE J3271/2 (see [5.2](#)) Communication and Controls
- SAE J3271/3 (see [5.3](#)) Cables/Cable Handling, Cooling, and Automated Connection Systems
- SAE J3271/4 (see [5.4](#)) Use Cases Including Grid Interconnection, Black Start, and Bidirectional Power Transfer
- SAE J3271/5 (see [5.5](#)) Interoperability Testing Requirements and Test Procedures

Hierarchical numbering schemes are used in this document with section, subsection, and subtopic levels. First digit is section, second digit is subsection, third digit is subtopic, etc.

This SAE TIR 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.

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 J1715	Hybrid Electric Vehicle (HEV) and Electric Vehicle (EV) Terminology
SAE J1772	SAE Electric Vehicle and Plug-in Hybrid Electric Vehicle Conductive Charge Coupler
SAE J1939	Serial Control and Communications Heavy-Duty Vehicle Network - Top-Level Document
SAE J1939DA	J1939 Digital Annex
SAE J1939-15	Physical Layer, 250 Kbps, Un-Shielded Twisted Pair (UTP)
SAE J1939-76	SAE J1939 Functional Safety Communications Protocol

SAE J2284-5_201609	High-Speed CAN (HSC) for Vehicle Applications at 500 kbps with CAN FD Data at 5 Mbps
SAE J2847-2_201504	Communication Between Plug-in Vehicles and Off-Board DC Chargers
SAE J2931/7	Security for Plug-In Electric Vehicle Communications
SAE J3068	Electric Vehicle Power Transfer System Using a Three-Phase Capable Coupler
SAE J3105	Electric Vehicle Power Transfer System Using Conductive Automated Connection Devices

2.1.2 CharIN Publications

Copies of these documents are available online at <https://www.charin.global/>.

CharIN Whitepaper, Megawatt Charging System (MCS), Recommendations and requirements for MCS related standards bodies and solution suppliers, Version 1.0, 2022-11-24, https://www.charin.global/media/pages/technology/knowledge-base/c708ba3361-1670238823/whitepaper_megawatt_charging_system_1.0.pdf.

2.1.3 CiA Publications

Available from CAN in Automation (CiA), Kontumazgarten 3, DE-90429 Nuremberg, Tel: +49-911-928819-0, www.can-cia.org.

CiA 611-1	CAN XL higher-layer functions - Part 1: Service data unit types
CiA 613-2	CAN XL add-on services - Part 2: CANsec data plane

2.1.4 IEC Publications

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

IEC 60335-2-76	Household and similar electrical appliances - Safety - Part 2-76: Particular requirements for electric fence energizers
IEC 60479-1	Effects of current on human beings and livestock - Part 1: General aspects
IEC 61508	Functional safety of electrical/electronic/programmable electronic safety-related systems
IEC 61851-1	Electric vehicle conductive charging system - Part 1: General requirements
IEC 61851-21-2	Electric vehicle conductive charging system - Part 21-2: Electric vehicle requirements for conductive connection to an AC/DC supply - EMC requirements for off board electric vehicle charging systems
IEC 61851-23	Electric vehicle conductive charging system - Part 23: DC electric vehicle supply equipment
IEC 61851-23-3	Electric vehicle conductive charging system - Part 23-3: DC electric vehicle supply equipment for Megawatt charging systems
IEC 61851-24	Electric vehicle conductive charging system Part 24: Digital communication between a d.c. EV charging station and an electric vehicle for control of d.c. charging
IEC 61938:2018	Multimedia systems - Guide to the recommended characteristics of analogue interfaces to achieve interoperability

IEC 62196-1	Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles - Part 1: General requirements
IEC TS 62196-3-1	Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles - Part 3-1: Vehicle connector, vehicle inlet and cable assembly for DC charging intended to be used with a thermal management system
IEC TS 63379	Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles - Vehicle connector, vehicle inlet and cable assembly for Megawatt DC charging

2.1.5 IEEE Publications

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

IEEE 802.3af	Power over Ethernet
IEEE 2030.13	IEEE Guide for Electric Transportation Fast Charging Station Management System Functional Specification

2.1.6 ISO Publications

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

ISO 2768	General tolerances
ISO 5474-1	Electrically propelled road vehicles - Functional requirements and safety requirements for power transfer - Part 1: General requirements for conductive power transfer
ISO 5474-3:2024	Electrically propelled road vehicles - Functional and safety requirements for power transfer between vehicle and external electric circuit - Part 3: DC power transfer
ISO 14229	Road vehicles - Unified diagnostic services (UDS)
ISO 15118-2:2014	Road vehicles - Vehicle-to-Grid Communication Interface - Part 2: Network and application protocol requirements
ISO 15118-3	Road vehicles - Vehicle to grid communication interface - Part 3: Physical and data link layer requirements
ISO 15118-6	Road vehicles - Vehicle to grid communication interface - Part 6: Physical layer and data link layer requirements for differential HomePlug Green PHY
ISO 15118-10	Road vehicles - Vehicle to grid communication interface - Part 10: Physical layer and data link layer requirements for single-pair Ethernet
ISO 15118-20:2022	Road vehicles - Vehicle to grid communication interface - Part 20: 2nd generation network layer and application layer requirements
ISO 15765	Road vehicles - Diagnostic communication over Controller Area Network (DoCAN)
ISO 20457:2018	Plastics moulded parts - Tolerances and acceptance conditions
ISO 26262	Road vehicles - Functional safety
ISO 26262-5	Road vehicles - Functional safety - Part 5: Product development at the hardware level

2.1.7 UL Publications

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

UL 2251	Plugs, Receptacles, and Couplers for Electric Vehicles
UL 2263	UL Standard for Safety Electric Vehicle Cable
UL 2278	Outline of Investigation for Megawatt Charging Configured Electric Vehicle Couplers

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 ISO Publications

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

ISO 11898-1	Road vehicles - Controller area network (CAN) - Part 1: Data link layer and physical coding sublayer
ISO 15118-1	Road vehicles - Vehicle to grid communication interface - Part 1: General information and use-case definition

3. DEFINITIONS

This document relies on definitions from SAE J1772 and SAE J1715.

NOTE: Additional definitions will be added in the next version of this document.

This section contains definitions for terms used in this document.

3.1 BASIC COMMUNICATIONS

Definitions for analog safety signaling are found in IEC 61851-23-3, except that they don't use the more enigmatic phrase "basic communication."

3.2 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.

3.3 CHASSIS GROUND

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

3.4 CONDUCTIVE

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

3.5 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.

3.6 CONTACT (CHARGE)

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

3.7 COUPLER (CHARGE)

A mating vehicle inlet and connector set.

3.8 ELECTRIC VEHICLE (EV)

In the context of this document, an electrically propelled vehicle including but not limited to applications for road, rail, air, marine, off road, etc., and intended for DC charging power on the order of 1 MW and above.

3.9 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.

3.10 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.

3.11 FOUR-PIN COMMUNICATIONS

A technique to monitor safety ground connection by use of separate pins.

3.12 HIGH LEVEL COMMUNICATION (HLC)

High Level Communication (HLC) is the communication between the charger and the vehicle that is used to indicate voltage and current needed for charging the vehicle.

3.13 TWO-PIN COMMUNICATIONS

A technique to monitor the safety ground connection by superimposing a small common mode current over the isolated differential digital communication pins.

3.14 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.

3.15 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.

3.16 LIGHT SLEEP

For two-pin communications when no predefined baseband communications are required, light sleep allows the vehicle to power down except for the 5 V pullup to the 191-Ω resistor tied to the center tap of the twisted-pair termination resistors. Light sleep provides an analog wake up if there is no baseband option in common between SE and EV. Deep sleep is prohibited when the charging inlet is empty and unlocked in these cases, and when a billing system must detect disconnect during delayed charging and the inlet is coupled and locked. There are cases where baseband digital communication traffic (CAN or Ethernet) will wake up the communications controller, which may relieve these requirements for light sleep in the future.

3.17 DEEP SLEEP

For the two-pin solution, deep sleep turns off the 5 V pullup tied to the center tap of the twisted-pair termination resistors in the EV. In applications where baseband communications controller will wake up on digital traffic, deep sleep may be allowed regardless of whether the inlet is empty and unlocked. In cases where a delayed charging session authenticates billing before going to sleep to wait for better electricity prices (or whatever), deep sleep may be prohibited so that the SE can verify with analog monitoring that no unplug event has occurred before charging starts. This requirement to lock an empty inlet before deep sleep also applies to applications that might allow only CAN on one side and only Ethernet on the other side, as this combination might not wake up on data.

4. DC MEGAWATT CHARGING OVERALL PROCESS

4.1 Description of Multi-Topic Functions That Apply to More than One Section

More information provided on overall MCS charging requirements to be defined in the recommended practice version of SAE J3271.

5. SAE J3271 SPECIFIC VOLUMES (SUBTOPIC SECTIONS)

5.1 Electromechanical Coupler Specifications

Some parts of this document refer to the “CharIN Whitepaper Megawatt Charging System (MCS)” that has been graciously provided by CharIN. Authors of the publicly available white paper are the same authors of this paper as a successor to the CharIN MCS work group that has ramped down activities while transitioning to SDO based development of documents.

Source: https://www.charin.global/media/pages/technology/knowledge-base/c708ba3361-1670238823/whitepaper_megawatt_charging_system_1.0.pdf

5.1.1 Definition for Coupler

SAE J3271 shall conform to:

- IEC TS 63379 - Plugs, socket-outlets, vehicle connectors and vehicle inlets - conductive charging of electric vehicles - Vehicle connector, vehicle inlet and cable assembly for Megawatt DC charging
- IEC 62196 - Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles - Part 1: General requirements.

NOTE 1: IEC TS 63379 is specific to MCS, and IEC 62196 is more generic.

NOTE 2: IEC TS 63379 includes provisions for a locking actuator, as well as insertion force, durability, etc.

NOTE 3: IEC TS 63379 points to IEC 62196 for additional requirements.

CharIN MCS group has spent considerable time on a definition for the plug and socket, most of which has been transferred to IEC TS 63379. Note that the last version from CharIN was labeled V3.2 (with circular power connectors, and triangular body). Refer to https://www.iec.ch/dyn/www/f?p=103:14:417393528596389:::FSP_ORG_ID:27429.

5.1.2 Safety

5.1.2.1 Short Circuit Protection

The EV shall limit short circuit current to a peak current of 70 kA and 12 MA²s between the DC terminals. The EVSE shall limit the short circuit current to a peak current of 30 kA and 1 MA²s at the vehicle connector. In case EV and EVSE are both faulted and the short circuit current flows through the protective conductor, the peak short circuit current must be limited to 55 kA and 11 MA²s. The EV, EVSE, and locked coupler must be able to bear these currents. The EV and EVSE output circuits shall have inductance limited as needed by the short circuit protection devices.

The cable shall be able to withstand a short circuit current of 11 MA²s and a minimum cross section of 25 mm².

5.1.2.2 Touch Current Protection

IEC 61851-23 includes touch energy protection provisions, and SAE J3271 is subject to those protections. However, SAE J3271 has higher voltage, larger physical size, and higher power levels, so higher Y capacitances will be needed but are limited as shown in [Table 1](#).

Table 1 - Maximum system Y capacitance

V_{dc+} to V_{dc-}	$V_{dc+/-}$ to PE	$C_{system}(\mu F)$	$C_{EVtotal}(\mu F)$	$C_{EVperDCline}(\mu F)$
$1078 < V_{dc} \leq 1250$	$620 < V_{toPE} \leq 700$	$\frac{\ln((0.5 * V_{dc} + 75)/758)}{-0.007}$	$1/2 C_{system}$	$1/4 C_{system}$
$V_{dc} \leq 1078$	$V_{dc} \leq 620$	30	15	7.5

NOTE 1: The formula in [Table 1](#) is still being verified and should be considered under development.

NOTE 2: The following assumptions were made to derive [Table 1](#):

- The c1 limit of Figure 22 (DC) of IEC 60479-1 (more conservative than c1 in Figure 20 [AC])
- 5 J limit of IEC 60335-2-76 (electric fence)
- With a human body resistance of 575 Ω

5.1.3 Bus Voltage Range

An SAE J3271 compliant EVSE is recommended to operate from 400 to 1250 VDC. Between 400 and 500 VDC, the power may be limited.

NOTE: The charging coupler was originally designed for 1500 VDC.

5.1.4 Maximum and Minimum Current

3000 A DC is considered the maximum current.

NOTE: Higher current may require additional safety measures and additional standard compliance.

According to IEC 61851-23 and IEC 61851-23-3, 0 A is the minimum current supported by SAE J3271. This is because communication may occur with ISO 15118-20:2022, the mode that is supported may be one that allows communication to occur or continue without charging, either with contactors closed or not, at 0 A.

5.1.5 Auxiliary Low Voltage Supply

An auxiliary low voltage supply from the EVSE to the EV may exist. However, such a subsystem shall not degrade communication or safety functions. This subsystem shall be an optional feature.

When there is no auxiliary low voltage supply integrated with the EVSE, if the EVSE needs an ability to communicate for supporting Vehicle-to-grid operations, the EVSE may be supplied with an uninterruptable power supply (UPS).

NOTE: If the EV has a low voltage battery and cannot begin charging, an electrical source external to the EVSE may be utilized to temporarily provide low voltage until the EV can begin charging normally.

5.1.6 Coupler Mechanical Requirements

See [Appendix A](#).

5.1.6.1 EVSE/EV Inlet Location

SAE J3271 is meant to be utilized on many different vehicles, in many different use cases and configurations. The vehicle inlet for trucks shall be on the left side of the vehicle, behind the most-forward axle. The inlet position on the EV may be between 2 and 4.8 m, as measured from the front of the EV. [Figure 1](#) shows the reference directions of the variables specifying reasonable distances from the EVSE and EV inlet relative to vehicle datum.

The key to the variables on the diagram are:

X = minimum reasonable distance from the bumper

Y = maximum reasonable distance from the bumper

C = maximum reasonable setback of the bumper

A = minimum cable reach

B = cable origin setback

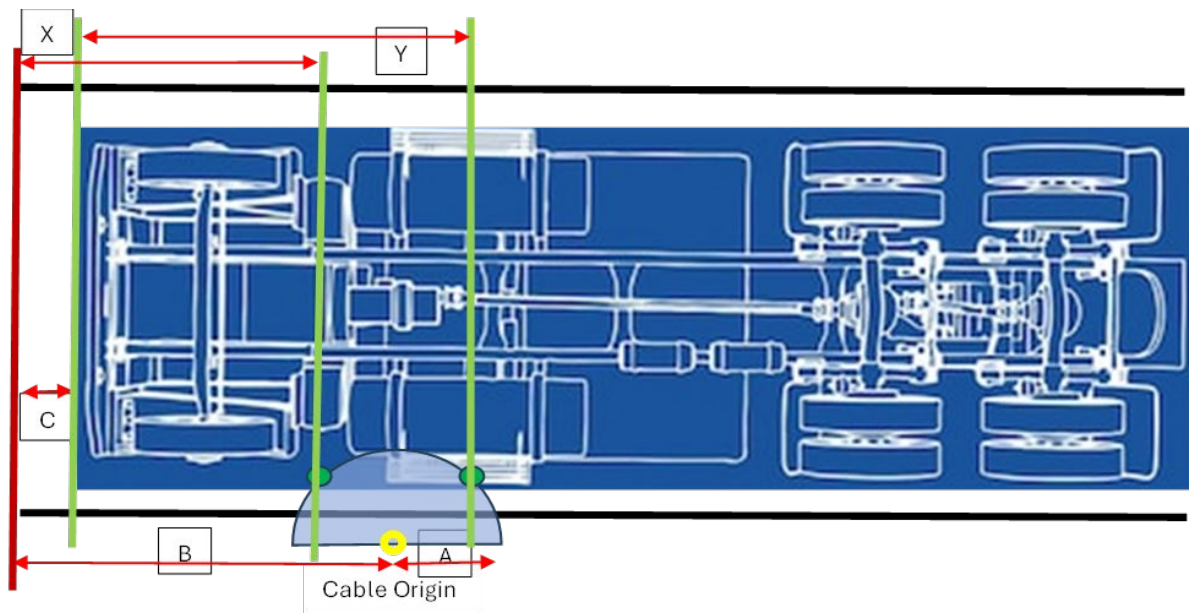


Figure 1 - Vehicle inlet location references

5.1.6.2 Coupler Retention Requirements

The SAE J3271 connector shall include an activated lock to ensure the connector remains engaged with the inlet during normal operation or in case of a short circuit. The activated retaining function shall provide feedback to the EV and shall be controlled independently of buttons or switches used for either normal user requested shutdowns or emergency shutdowns. The retaining means may be integrated into the inlet side of the coupler on at least one location, and up to three locations, as included in the charging coupler connector dimension requirements. The lock shall have a pin or slot design that operates consistently in all expected operating conditions, especially considering temperature and weather variations for charging operations in extreme environments, and with expected tolerances and wear.

5.1.6.3 Coupler Drive-Away Protection

Coupler drive-away protection is provided using the proximity pin on the coupler.

5.1.6.4 Torque Requirements

SAE J3271 shall adhere to UL 2251 and IEC 62196 series requirements for coupler strain relief compliance.

5.1.6.5 Insertion and Extraction Force Requirements

SAE J3271 may follow the same criteria as IEC 62196 for insertion and removal forces, which is currently 100 N. Ergonomics may be considered for any equipment (such as cables/connectors) that are meant to be handled by users.

5.1.6.6 Connector Durability Requirements

The SAE J3271 cable to the coupler may be implemented so it doesn't impact the floor or ground when dropped. The coupler may adhere to IEC 62196-1 for drop durability. The coupler may be designed to exceed IEC 62196-1 drop durability requirements.

UL 2251 or IEC 62196 may be followed for mating cycle durability testing requirements. SAE J3271 is designed for commercial applications; therefore, the connector may be tested to 20000 mating cycles.

5.2 Communication, Connection Detection, and Charging Control

This section is harmonized with IEC 61851-23-3 where possible.

5.2.1 Communication and Signaling between the EVSE and the EV - Overview

There are two parts to this communication - the analog safety signaling (Basic Communication), and the high-speed digital communications (high-level communication or HLC) used for charging control. The MCS 3.x coupler affords four physical lines to be used for controls and optional low voltage auxiliary power. The MCS 2.x coupler and the legacy CCS charging couplers offer two physical lines for controls and do not support auxiliary power. Concepts are described for both the “four pin comms” and “two pin comms” solutions. In the “four pin comms” case, two pins are dedicated for the safety signaling with optional superimposed auxiliary power returned over PE, and two pins are dedicated exclusively for HLC. In the “two pin comms” case, analog safety signaling is superimposed as a common mode signal over the differential digital signals, and optional auxiliary power is supported exclusively on pins three and four and does not need to return over PE.

5.2.2 Auxiliary Power Option - Coupler with Four Small Pins Only - Overview

The MCS 3.x coupler can also support auxiliary low voltage power. This can be useful in case of a dead 12-V battery on the vehicle, in which case the EVSE could supply 12 V to wake up the vehicle without needing traditional 12-V “jumper cables.” (24 V is common in Europe, and 48 V is emerging.) It could also be useful for a “black start” ability of a bidirectional EVSE when the electrical supply grid is down, allowing an appropriately equipped EV to start an EVSE to export AC in recovery situations. Support for both of these options is voluntary, although specific applications outside of the scope of this document might require them.

Note that the MCS 2.x and CCS couplers probably cannot support these functions, as only two of the small pins are available. (Power over Ethernet might be an exception but is out of scope for this document.)

5.2.2.1 Requirements Checklist, Vehicle Connector Side (SE Optionally Powers EV via Aux Pins)

1. Can insertion be detected if the EV has no power?
2. Can the EV aux voltage requirement be determined? With no power?
3. Can the EV aux voltage be safely applied to the appropriate pin at all times? If not, is there a failsafe?
4. What are the initial minimum requirements for extra power to the EV? How is this coordinated?
5. If the pin has dual function, is this always covered?
6. Is there interference with the loss of PE detection?
7. Is the Aux supply active during energy transfer?
8. If Aux supply is not supported, can the EVSE/EV withstand the prospective voltage?
9. Can the EVSE detect and withstand a fault to EV batt and PE?
10. How much is the maximum power during mating/unmating?

5.2.2.2 Requirements Checklist, Vehicle Inlet Side (EV Optionally Powers SE via Aux Pins)

1. Can insertion be detected if the EVSE has no power?
2. Can the EVSE aux voltage requirement be determined? With no power?
3. Can the EVSE aux voltage be safely applied to the appropriate pin at all times? If not, is there a failsafe?
4. What are the initial minimum requirements for extra power to the EVSE? How is this coordinated?
5. If the pin has dual function, is this always covered?
6. Is there interference (or even just interaction with) with the loss of PE detection?
7. Is the Aux supply active during energy transfer?
8. If Aux supply is not supported, can the EVSE/EV withstand the prospective voltage?
9. Can the EV detect and withstand a fault to EV batt and PE?
10. How much is the maximum power during mating/unmating?

5.2.3 Lessons Learned from Legacy Charging Systems

5.2.3.1 Safety (Analog Connection Detection)

5% PWM degrades the response time for detecting loss of Ground (PE), hence all options described in this TIR use DC (or 100% PWM in that sense) for monitoring the Ground connection. Since this coupler is for DC only, this is not an issue. Even if the “two pin comms” solution were used on an AC and DC coupler with 5% PWM being used to indicate high speed digital communication is required, the 5% PWM can be discontinued once digital comms are established.

While the prohibition in ISO 15118 against using the digital communications channel for safety-related functions is necessary for IP based controls, it makes no sense for control links such as CAN which are routinely used for safety-related functions in automotive applications. CAN is suitable as a backup for the analog connection detection safety signaling and, in fact, is often faster and can be much more granular.

5.2.3.2 Robustness

Single ended ground referenced signaling has poor to zero noise immunity. Balanced differential physical layer using twisted pair wiring typically provides at least 20 dB of inherent noise immunity, even in the unshielded variant. All options for physical layer communication described in this TIR are based on this best practice approach of balanced differential signaling over twisted pair wiring.

5.2.3.3 Flexibility

Not all applications require the complete feature set available in ISO 15118-20:2022. Some of the options described in this TIR support a less expensive interface with reduced functionality, for example, “behind the fence” and other applications that do need to use public on-road charging may dispense with features such as Plug-and-Charge and therefore also dispense with IP communications and its attendant increased cyber security risks compared to local signal oriented control links without remote access.

5.2.4 Forward Looking Aspiration: “Multi-Lingual” Support

The intent is to support multiple solutions that can interoperate without user intervention. This “multi-lingual” ability might, for example, support both CAN and Ethernet physical layers with the ability to determine at the time of connection which systems are available on the other side and act accordingly.

5.2.5 High Level Communication

High Level Communication (HLC) is the communication between the charger and the vehicle that is used to indicate voltage and current needed for charging the vehicle, etc. Additional functionality can include charging scheduling, Bidirectional Power Transfer (BPT), and Automatic Connection Devices (ACD).

5.2.5.1 Industry Best Practices versus Protocol Options

HLCs based on internet protocol shall not be used for safety-related signaling. Native CAN should not be used for value added services such as plug-and-charge. CAN may be used as backup for analog safety signaling but NOT as the only method. Internet protocol HLCs may be used for controls with the caveat that IP HLCs generally cannot support the low latency guaranteed delivery of high priority signals, nor the fast error recovery that CAN supports. Note that while SAE J1939 does map 15118 scheduling to CAN, it is recommended not to use this but use the Ethernet tunnel instead (if available).

5.2.5.2 Superset of ISO 15118-20:2022

NOTE: ISO 15118-20:2022 requires use of MAC/PHY defined in one of the published 15118 documents, which at this time does not include CAN. This TIR goes beyond the PHYs described in ISO 15118-20:2022 at the moment, and adds a CAN mapping of essential charging functions, with an optional Ethernet tunnel (or mapping in the case of CAN XL) for value added services. Other possible options not described in this TIR include value added services provided over Wi-Fi or proprietary telematics while essential charging controls are implemented over balanced differential CAN.

This document proposes that ISO 15118-20:2022 protocol will be used for HLC, regardless of the selected PHY. For this TIR, these PHYs include 10Base-T1s Ethernet, and CAN (only ISO 15118 power delivery charging protocols mapped to CAN signals as described in SAE J1939, not value-added-services). Other application layers could be supported in parallel by CAN but are not described in this document. For example, GB/T 27930, CHAdeMO, and various proprietary charging control methods existing in the market, could all be supported with selection made at run time. The physical interface could therefore be truly global, including existing Asian standards.

5.2.5.3 Target Data Speed

The MAC/PHY should be able to transport large files in a timely manner (e.g., over 5 Mbits within 1 second). One use case is autonomous vehicle needs - they will need to deliver large video files and, in turn, receive large map files and software updates. These needs should be achievable with 10Base-T1s (recently available, at least in samples) and CAN XL (when available, sampling soon) and exceeded by 100Base-T1 (if it proves practical with the suboptimal pin spacing of communication pins). CAN FD with an Ethernet tunnel (probably based on ISO 15765/14229) should be able to reach these speeds with hardware that is available now.

5.2.6 Basic Communication

Definitions for analog safety signaling are found in IEC 61851-23-3, where it is called “basic communication.”

5.2.6.1 Wiring Faults, All Interfaces

Continuous verification of PE continuity must be possible in all states.

5.2.6.2 Wiring Faults, “Four Pin Comms” Interface Specific

The expected nominal aux voltage range of the EV is $V_{\text{batt}} = 9\text{-}32\text{ V}$, 6 A (optionally up to 48 VDC nominal not to exceed 60 VDC, no AC).

1. The expected aux voltage range of the EVSE is $24\text{ V} \pm 10\%$, 25 A.
2. A fault of the wiring to vehicle chassis or V_{batt} should not give a false reading (also should be diagnoseable).
3. Signaling cannot use voltages $>9\text{ V}$; 5 V is used as a basis.

4. 0 V should indicate a fault, i.e., not valid or not inserted (EV side in CharIn design, EVSE side in PGC/CAN design).
5. All signals should withstand a fault to Vbatt@32 V, without damage (and be diagnoseable).
6. All signals should withstand a fault to vehicle chassis/protective conductor, without damage (and be diagnoseable).
7. Aux supplies will need self-resetting short-circuit protection.
8. TVS Protection diodes will need to be bidirectional and >32 V for all signals, in order not to interfere with operation or withstand capabilities.
9. Under some fault conditions the analog signals lines may become negative.

5.2.6.3 Wiring Faults, “Two Pin Comms” Interface Specific

See [5.2.10.2](#).

5.2.6.4 Auxiliary Supply Rules (CharIn “Four Pin Comms” Design Only)

1. EV or EVSE must disable the AUX supply if an implausible state of “Charge Enable” or AUX supply voltage occurs.
2. Aux supply from only one side may be active:
 - If the EVSE detects >5.5 V on the “Insertion Detection” line, the EVSE Aux supply may not be enabled additionally.
 - If the EV detects >5.5 V on the “Insertion Detection” line, the EV Aux supply may not be enabled additionally.
3. If available, enabling EVSE Aux supply:
 - The EV may request Aux supply while in B-state, by going to Bx State, EV may not switch request in other states.
 - The EV may have the “x” state-resistor for aux supplies permanently wired (when EV cannot supply aux supply to EVSE).
 - EVSE will enable aux supply and latch this state for any other state than “B” state, or “A” state.
 - The EV will not load the Aux supply from the EVSE if the voltage <7 V and will only restart once the voltage has been below <1.5 V, and subsequently above 9 V.
4. If available, enabling EV Aux supply:
 - When the EV detects insertion with $0.5\text{ V} < \text{“Insertion Detection”} < 1.5\text{ V}$ but sees <0.5 V on the “Charge Enable,” the EV Aux supply will be enabled.
 - The Aux supply will be enabled for the duration of the mated connector.
 - If the EVSE detects an Aux supply <9 V, it moves to Error state.
 - The EVSE will not load the Aux supply from the EV if the voltage is <7 V and will only restart once the voltage has been below <1.5 V, and subsequently above 9 V.

5.2.6.5 Auxiliary Low Voltage Supply Electrical Specifications

This section is under development for:

- EVSE aux supply to EV droop, inrush, short-circuit, and current limit/“charging” behavior
- EV aux supply to EVSE circuit protection, short-circuit, and overload behavior

5.2.6.6 Proposed Analog Safety Circuit Consideration Checklist

All proposed analog safety circuits must fulfill:

1. Check of PE continuity must be possible in all states.
2. Check of CP continuity must be possible in all states (differs from above due to RC time constant).
3. Signaling should minimize circuit capacitance in order to minimize time to change state for emergency shutdown.

NOTE: PWM modulation of CP is not recommended.

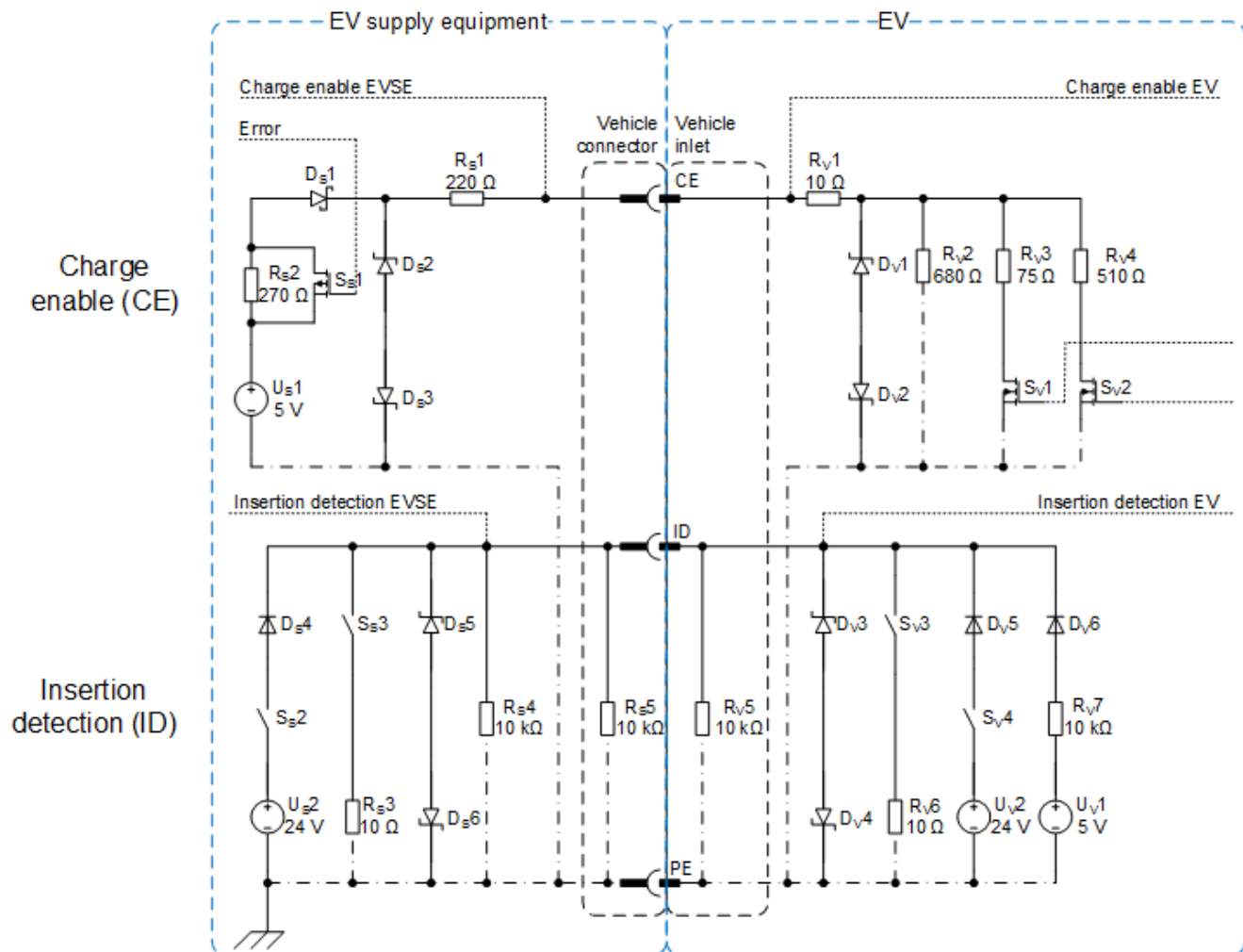
4. EV and EVSE shall both be able to initiate and detect emergency shutdown from the other device.
5. Detection and signaling scheme shall allow fault detection and robustness for the vehicle system's supply voltage (i.e., 12/24/48 V).
6. EV and EVSE should both be able to initiate and detect a wakeup signal from the other device during delayed charging. (Baseband solutions might do this with wake up on data.)

5.2.7 Concept Diagram: the “Four Pin Comms” Solution

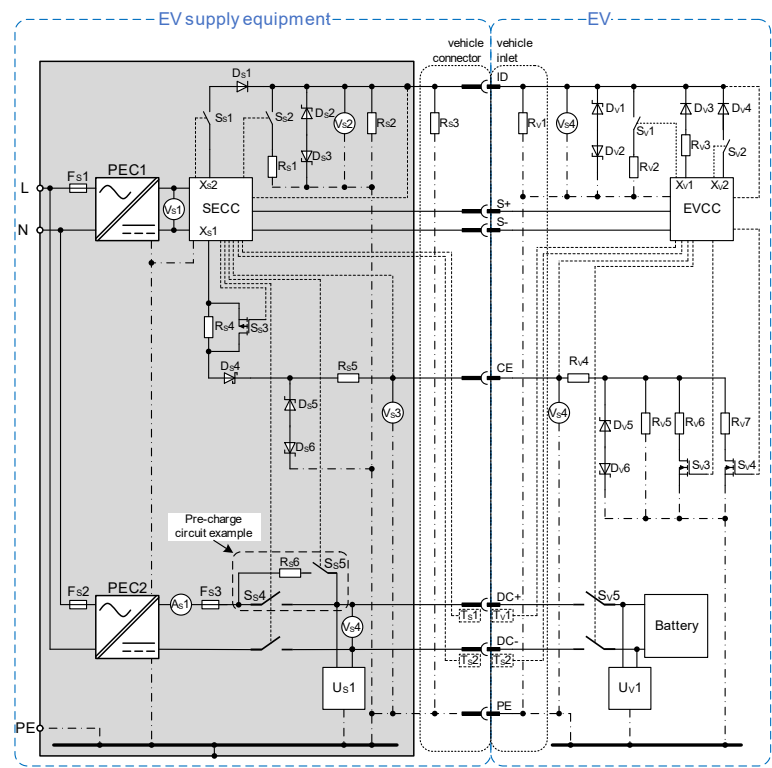
This approach implements connection detection on separate pins with an optional to superimposed Aux power over the connection detection pins.

NOTE 1: This design requires four communications pins (two for analog connection-detection and two for balanced differential digital communications) even when the optional Aux Power is omitted. Therefore, it will be referred to as the “four pin comms” option, meaning two pins for high-speed digital communication and two pins for the analog safety circuit or connection detection (“basic communication” in IEC terminology). A “two pin comms” solution is described later.

NOTE 2: In this document, balanced differential digital communications may refer to either Ethernet or CAN physical layers.



System diagram: connection detection superimposed over Aux LV power



5.2.7.1 Signal States

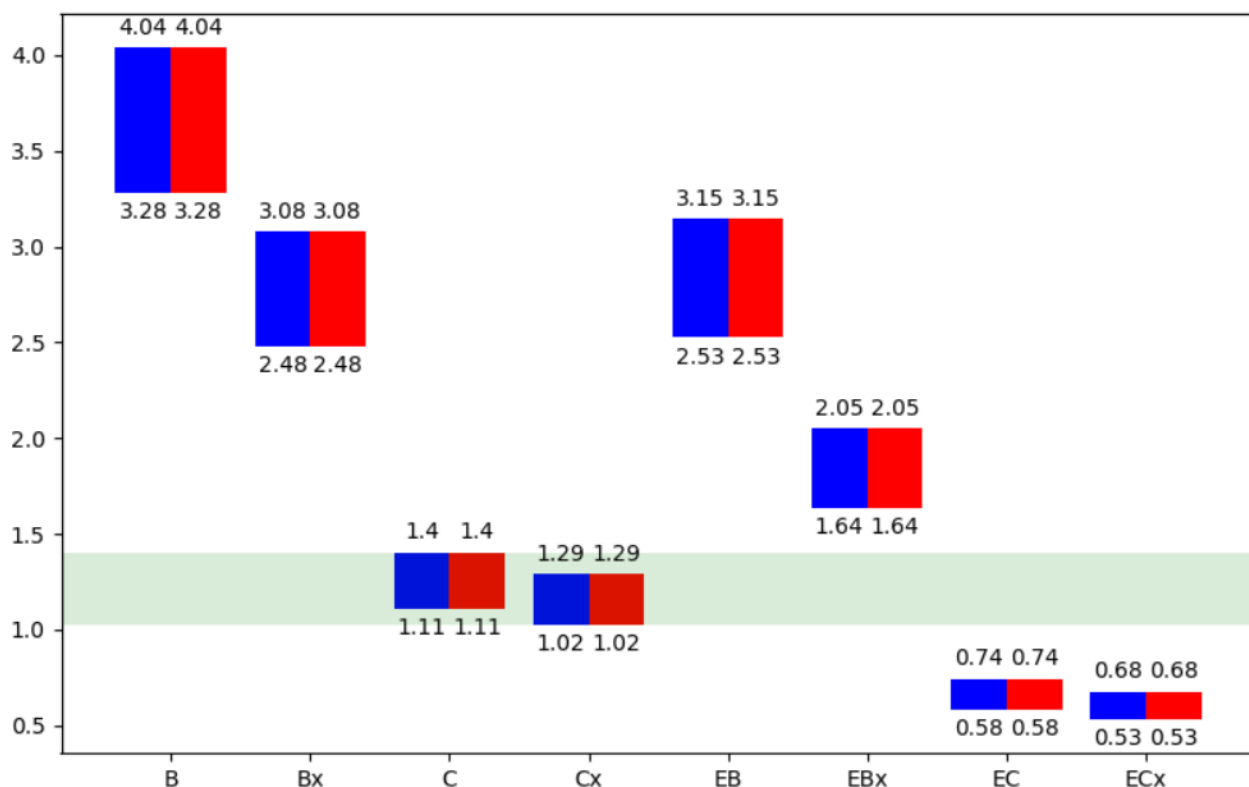
The signal states are explained in the following table:

Explanation	Charge Enable State
Should not occur, go to error	Implausible
Coupler not mated	State A
Coupler mated, not charging	State B
EV needs Aux supply	State x
Energy transfer possible	State C/Cx
Error state (wakeup EV)	State EB
Error state (wakeup EV)	State EBx
Error state during transfer	State EC/ECx
Should not occur, go to error	Short to PE

Explanation	Insertion Detect State
Should not occur, go to error	Implausible
EVSE supplies Aux to EV	EVSE2EV aux
EV supplies Aux to EVSE	EV2EVSE aux
Wiring fault EV, no inlet	No Inlet
No wiring fault EV, no connector	Inlet, no Connector
Connector inserted, wire fault charge cable	Connector, no EVSE
Connector inserted, EVSE connected	EVSE Connected
Should not occur, go to error	Short to PE

The Charge Enable voltage ranges are explained in the following table:

EVSE	EV	Charge Enable Voltage
Implausible	Implausible	>6 V
Gap	Implausible	5.5-6 V
State A	Implausible	4.5-5.5 V
Gap	Gap	4.04-4.5 V
State B	State B	3.28-4.04 V
Gap	Gap	3.15-3.28 V
State x/EB	State x / EB	2.48-3.15 V
Gap	Gap	2.05-2.48 V
State EBx	State Ebx	1.64-2.05 V
Gap	Gap	1.40-1.64 V
State C/Cx	State C/Cx	1.02-1.40 V
Gap	Gap	0.74-1.02 V
State EC/ECx	State EC/ECx	0.53-0.74 V
Gap	Gap	0.10-0.53 V
Short to PE	State A	-0.10-0.10 V
Implausible	Gap	-0.50-0.10 V
Implausible	Implausible	<-0.5 V



The Insertion Detect voltage ranges are explained in the following table:

EVSE	EV	Insertion Detect Voltage
Implausible	Implausible	>32.5 V
Gap	Gap	32-32.5 V
EVSE2EV aux	EVSE2EV aux	21.0-26.4 V
EV2EVSE aux	EV2EVSE aux	8.4-32 V
Gap	Gap	5.5-8.4 V
Gap	No Inlet	4.5-5.5 V
Gap	Gap	2.75-4.5 V
Gap	Inlet, no Connector	2.19-2.75 V
Gap	Gap	1.82-2.19 V
Gap	Connector, no EVSE	1.43-1.82 V
Gap	Gap	1.37-1.43 V
EVSE Connected	EVSE Connected	0.74-1.37 V
Gap	Gap	0.10-0.74 V
Short to PE	Short to PE	-0.10-0.10 V
Implausible	Implausible	<0.1 V

Voltage bands of signals (esp. PP) should have sufficient margin and tolerances.

5.2.8 MAC/PHY Technologies

This design will have to handle much higher current than CCS, and as a result, the CCS PLC design is not considered adequate (in terms of reliability and throughput).

This document is developing a CAN mapping of ISO 15118 essential local charging control, for applications that require or desire real time control response. An optional Ethernet tunnel over CAN FD will follow for applications that require value added services. CAN XL is expected to support higher ethernet speeds via CAN XL's predefined Ethernet mapping and CAN XL SiC transceivers.

IEC/ISO are developing a solution based on 10Base-T1s, which provides value added services by default, but does not support real time digital controls. Value added services are required for on-road public charging but may not be needed in other applications.

5.2.8.1 Differential PLC

Differential PLC was to be defined in ISO 15118-6; however, recent voting in IEC 61851-23-3 has dropped support for balanced differential PLC over twisted pair wiring in favor of Ethernet.

5.2.8.2 Single Pair Ethernet

Two possible versions of automotive ethernet are 10Base-T1s and 100Base-T1. IEC/ISO are developing the former for megawatt charging. This document may eventually offer multilingual support adding 100Base-T1 if the connector pin spacing is proved to be adequate for it.

These technologies will be defined in ISO 15118-10.

NOTE: Both technologies were developed for and are used in the automotive industry.

5.2.9 Multilingual Selection

This section describes feasible methods for negotiating between multiple PHYs, with no constraints on what PHYs might be required in particular applications. Of course, particular PHYs are likely to be required in particular applications, which will likely simplify the selection between options significantly compared to the following completely general treatment. The purpose of this discussion is to establish the feasibility and reasonableness of achieving a truly multi-lingual interface with the minimum constraints. As this discussion is generalized, it includes the case where the EV and SE do not have a PHY in common, yet the system still wakes up and reports this error. A possible example if this extreme case might be a vehicle intended solely for off-road use that implements only classical CAN for essential charging controls, which somehow arrives at a public on-road charging station that support only internet protocol communications, such as Ethernet.

↓EVSE↓ →EV→	CAN only	CAN + Ethernet	Ethernet only
CAN only	Both sides start in CAN. CAN is used. Negotiate for other MACPHY if available.	Both sides start in CAN. CAN is used. Negotiate for other MACPHY if available.	Round robin times out.
CAN + Ethernet	Start up in CAN. Negotiate for other MACPHY if available.	Start up in CAN. Negotiate for other MACPHY if available.	EVSE starts up in CAN. Round robin selects Ethernet only.
Ethernet only	Round robin times out.	EV starts in CAN. Round robin selects Ethernet. Ethernet only.	Ethernet

If you are not familiar with round-robin scheduling, refer to https://en.wikipedia.org/wiki/Round-robin_scheduling.

Detailed timing is discussed in later sections in this document.

Note that the intention is to recommend specific PHY requirements for specific markets when this document matures into a recommended practice. This early TIR is only documenting the possibilities that have been discussed.

Communication signals over CAN and Ethernet are considered for this TIR. For Ethernet, only 10Base-T1s is discussed for now; after comms are established, we might later support switching to 100Base-T1 via negotiation in 10Base-T1s.

CAN and Ethernet physical layers support wake up through digital communication. For the two-pin communications, the supply equipment may wake up the vehicle using digital comms, even if the EV is in deep sleep (5 V pull-up turned off).

For the four-pin solution, the analog safety signal (basic signaling) is sufficient all wake up functions. Basic signaling is defined in IEC 61851-23-3. This can simplify wakeup (remove a constraint) compared to some extreme combinations of PHYs with two-pin communication. The tradeoff is more pins, which implies more points of failure, more cost, more mechanical tolerance stack up, etc.

In both cases (two-pin and four-pin communications), the EV and EVSE will negotiate baseband communication PHY layer using a round-robin trial and error approach, without the involvement of inflexible analog signaling.

5.2.9.1 Round-Robin Example, Four-Pin Communications

The four-pin communications case is described first, as the wake up is the same for all possible combinations of PHYs, even the case where there is no shared PHY between the SE and EV (which is admittedly extreme but included for completeness). There are more wake up options in the two-pin communications case, sometimes introducing reasonable constraints; hence, the two-pin case will be addressed separately.

The purpose of the following four-pin example is to provide an informative description at a high level, not an implementation. The gist is that the examples are how negotiation and discovery of a common PHY layer may be implemented.

The EVSE initiates communication with baseband options, if one is supported. If both baseband options are supported, the SE starts with CAN if it connects faster than Ethernet.

“Four pin comms” example, SE side:

1. Plug connector into EV inlet
2. Wake up on analog safety signal (basic communication)
3. If the SE supports CAN, the SE shall start sending CAN frames. If the SE does not support CAN, go to step 4, Ethernet.
 - a. If the EV responds with CAN frames, the PHY layer has been successful discovered. Continue to charging sequence (PHY selection complete).
 - b. If there is no CAN response from EV after x seconds (timeout), go to next step. x is suggested to be 100 ms to start.
4. If SE supports Ethernet, the SE starts sending Ethernet frames. If EV does not support Ethernet, go to step 5.
 - a. If EV responds with Ethernet frames, the PHY layer has been successful discovered. Continue to charging sequence (PHY selection complete).
 - b. If no response from EV (Ethernet) after y seconds (timeout), go to step 5. y is suggested to be 100 ms to start.
5. Retry steps 3 to 4 again, up to two times, before proceeding to step 6.
6. After timeout of z seconds, go to step 3 again (loop).
 - a. After three loops through the above, report an error, EV may go to sleep.

The round robin for the EV side mirrors the SE, except that the timeouts equivalent to x and y are longer (at least twice) to ensure that the SE can present both PHYs to the EV before the EV switches to the next baseband PHY it supports, if any.

This round-robin approach may be used to start an initial conversation (handshake) between the EV and EVSE. Once digital communication is established, negotiation may indicate a preference for another PHY for whatever reason. A switchover to the preferred PHY may be handled during digital communication. For example, CAN might be selected first in the round robin merely because it connects faster/first. At a public on road charger, Ethernet may be preferred to support value added features if the CAN option does not support an Ethernet tunnel on both sides. The details of this negotiation may be supported at a later time. (SAE J1939 is working on support signals for this process now.)

5.2.9.2 Wake Up and Sleep Mode Concept for “Two Pin” Communications

The two-pin communications concept (with the common-mode analog safety signal superimposed over differential digital communications) has a 5 V pullup voltage supplied from the EV so that it can detect connection even to an unpowered EVSE without using extra pins and immobilize when connected. This differs from the legacy solution where the pullup is provided by the SE. Since this pull up voltage is a small load on the EV's low voltage battery, it is necessary to have a deep sleep mode where the pull up voltage on the EV is powered down when not needed.

In the case where the 5 V pull up voltage from the EV is powered down, wake up on plug in is not triggered by the analog voltage, but by digital data for the baseband options (wake up on CAN, wake up on Ethernet) with the EVSE continuously sending data, even when disconnected.

It may be advantageous to require that an empty inlet be locked before turning off the 5 V pullup in the vehicle. Clearly, this is not strictly necessary for baseband but may be considered advantageous.

Light sleep is defined as the vehicle being powered down except for the 5 V pull up to the charging inlet, which consumes about 10 mA.

This requirement to lock an empty charging inlet before EV deep sleep is unlikely to be needed if, for example, a common baseband PHY is required and the other PHY options would be supported in addition. The simplest and cheapest PHY to require would probably be classical CAN, which could support essential charging functions but not value added services (VAS). VAS could be supported by adding CAN XL which defines a standard Ethernet mapping, or CAN FD which can implement an Ethernet tunnel, or by simply negotiating a switchover to Ethernet once CAN communications are established and the details of supported options are exchanged between both sides. Note that internet protocol based controls have disadvantages in terms of latency, particularly in the presence of cyclic data loss (errors induced by periodic noise) and therefore are not to be used for safety-related signaling. CAN is designed precisely to support low latency controls with guaranteed delivery of high priority signals (CAN generally degrades more gracefully in the presence of errors induced by noise), and therefore CAN may be used to supplement and improve the analog safety signal with faster and more granular indications of a problem.

5.2.9.3 Simplified Wake Up When a Common Baseband PHY Is Required on Both Sides

For the more reasonable case where either CAN or Ethernet is a required PHY on both sides, wake up works as follows (CAN used in this example):

1. EV is allowed a very low-power mode (deep sleep) when unplugged, meaning the 5 V pullup can be unpowered and the EV wakes up on CAN, which is an established technique that can be very low power. There is no requirement to lock an empty inlet before going into deep sleep.
 - a. The SE must send CAN continuously when disconnected, and thus be able to wake up an EV on plug-in.
 - i. The SE must reset or disable its error counter while unplugged so as not to enter bus-off state. Error counters shall be re-enabled when a response from the EV is detected, which confirms connection.
 - ii. Upon wake up via CAN, the EV shall power the 5 V pull up to provide analog monitoring of the ground connection.
 - iii. Once both sides are awake, the round-robin PHY arbitration process begins as in [5.2.9.1](#), step 3.

2. A medium low power mode (light sleep) for the EV may be desired, for example after charging completes and the battery is at 100% SOC. The 5 V pull up from the EV shall stay powered while connected so that the EV can detect an unplug event with only analog means. This is required for certain billing systems that support delayed charging but require manual authorization at time of plug in. The rest of the EV may go to sleep at this point, but the 5 V pullup shall remain powered until disconnection.
3. After charging completes, the SE shall be able to stop sending CAN so as not interfere with the EVs medium low power mode (light sleep) following charge completion. Unplug detection is based on loss of the 5 V pullup voltage from the EV; see step 2. Detection of unplug shall cause the SE to start sending CAN continuously again so that the SE is able to wake up the next EV that connects.
4. Both sides need to be able to wake up the other side if something changes (during light sleep with no CAN traffic but the 5 V pull up remains powered). This is accomplished with wake up on CAN in either direction.

5.2.9.4 General Wake Up with No PHY Option Required, Any Combination Allowed

1. Before entering deep sleep (5 V pull up from the EV to the charging inlet powered down) with an empty charging inlet (no charging connector coupled), the EV shall lock the charging inlet. This forces the operator to wake up the EV to unlock the inlet before plugging in, thus applying 5 V to the EV pull up resistor.
 - a. If asleep, the SE wakes up on seeing the pull up voltage and begins the round-robin PHY arbitration process as in [5.2.9.1](#), step 3.
2. As in [5.2.9.1](#), step 2.
3. As in [5.2.9.1](#), step 3.
4. After charging completes (or in the case of delayed charging) and both sides enter light sleep (no digital traffic but the EV keeps the 5 V pullup powered), there needs to be a method for either side to wake up the other side. Baseband PHYs can do this with digital wake up on data as in [5.2.9.3](#), step 4.

5.2.9.5 Delayed Charging Constraint, All PHY Options

Since the EV must power the 5 V pull up resistor while connected, it is permissible to forbid delayed charging at very low SOC. For example, if the EV plugs in below 5% state of charge, it may refuse delayed charging and require charging with at least the minimum power level until a safe SOC is reached to go into waiting mode. This allows the high voltage battery to have enough charge to maintain the low voltage battery while waiting for delayed charging at full power to begin.

5.2.9.6 Interoperability between CAN and Ethernet Interfaces

The following questions are under consideration for the next revision to describe the interoperability between communication subsystems:

1. Can a sleeping CAN port and a sleeping Ethernet port be connected together on the EV so that one will wake up regardless of whether the SE has CAN or Ethernet? This seems likely to be true but needs to be tested. Of course, whichever PHY on the EV wakes up first shall cause the other PHY to be disconnected, since they will interfere with each other once awake. This helps if the EV has both, but it does not help if the EV has only one baseband PHY and the SE has only the other. Still, there is a small advantage to not requiring both on the SE, even if the EV is required to have both. But there might be a better option.
2. Will CAN traffic wake up a sleeping Ethernet port on the EV? And vice-versa, will Ethernet activity wake up a sleeping CAN transceiver on the EV? If so, this could be a way to obviate the need for locking an empty inlet when the EV goes into deep sleep, which is intrusive.

5.2.10 “Two Pin Comms” Circuit Concept Overview for CAN and Ethernet

A common technique is used in applications such as Phantom Powered Microphones and Power Over Ethernet, wherein a common mode DC current is superimposed over the differential signal. Refer to IEC 61938:2018, 9.4, and IEEE 802.3af for details. We propose using a similar technique to superimpose a small current (approximately 10 mA) over isolated differential CAN lines to monitor the safety ground (PE) connection. The simplified concept looks like this:

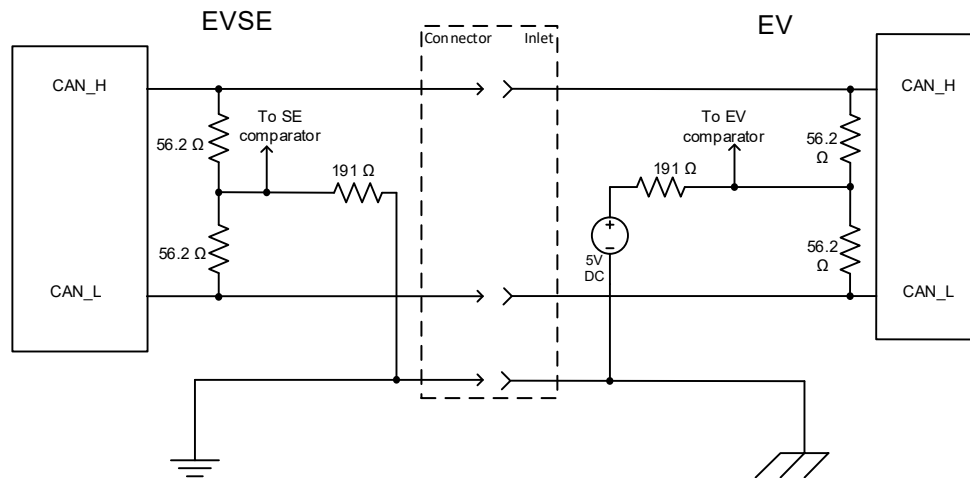


Figure 2A - Basic concept for connection detection over CAN (before FMEA considerations)

While the 5 V pull up resistor is referenced to chassis ground, the CAN transceivers shall be isolated in this design, much like the transformer isolated Ethernet PHY or phantom powered microphones are. Due to this, the voltage at the center tap of the split CAN termination resistors floats to the level set by the 191 Ω pull-up resistor in the EV and the 191 Ω pull-down resistor in the SE. The voltages at V_{cp} and V_{prox} are set such that the CAN recessive state is 2.5 V when the SE is connected to the EV. This voltage is monitored by a comparator at V_{prox} and V_{cp} to detect whether the ground wire is connected and thus OK to charge.

This circuit forms a simple DC voltage divider under all normal circumstances, as long as the CAN transceivers are isolated. Non-isolated CAN transceivers would impose an AC voltage (square wave remnant of the CAN signal) on the divider when PE is open, making connection detection much more complex. Hence, isolated transceivers are required.

This technique is well established in the analog domain since the 1960s and the digital domain since the early 2000s. It is well known that there is no possibility of interaction between the DC monitoring current and the high-speed digital signals.

When the SE is disconnected from the EV, the EV_PGC voltage moves toward 5 V and the EVSE_PGC voltage moves toward zero. When this is detected, both sides shall open contactors.

Note that this approach enabled the EV to detect connection to an unpowered SE, much the way the separate “Proximity Pin” or PP in the legacy design does. However, it does not provide wake up on connection with the analog voltage the way “Control Pilot” or CP does in the legacy design. Therefore, wake up is provided by the well-established wake-up-on-CAN technique to allow the EV to power-down the 5 V pull-up resistor after a period of inactivity.

The approach is similar for 10Base-T1s except that the transceiver is capacitively coupled to the termination resistors.

Additional requirements for detecting whether the charging inlet in the EV is connected to the controller are provided by adding two 5620 Ω resistors in the inlet as follows:

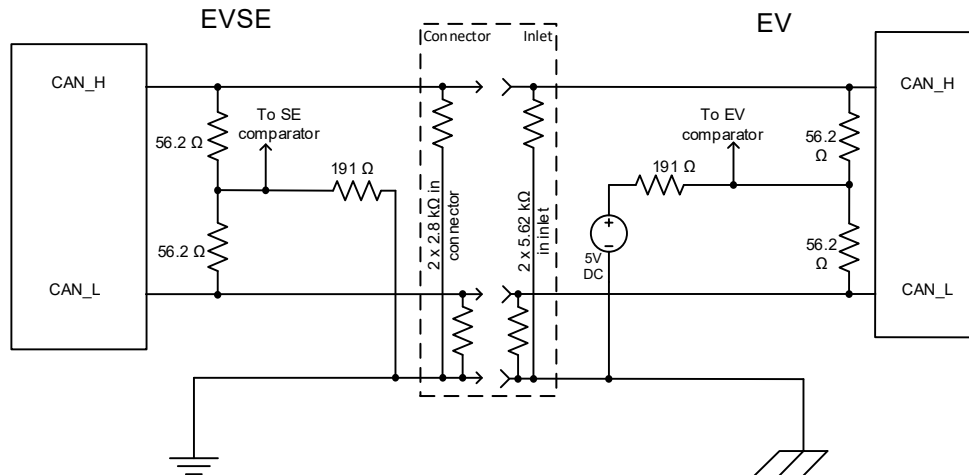
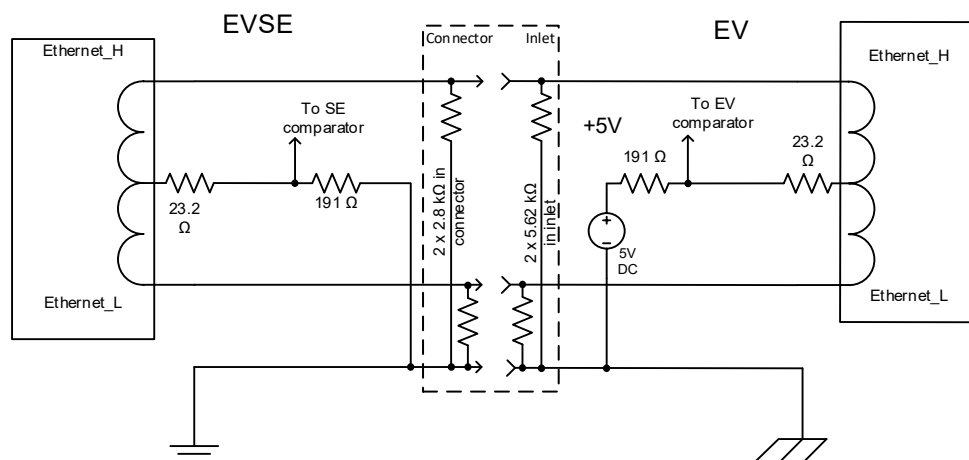


Figure 2B - Connection detection over CAN with added inlet and severed cord detection

This allows the controller to detect disconnection from the inlet, in which case the vehicle shall be immobilized until the operator can confirm that the charging cable is unplugged.

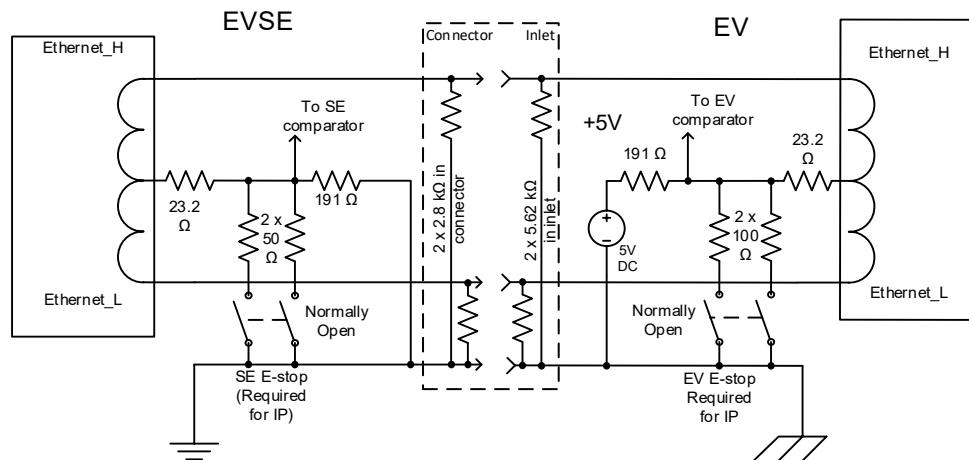
The two 2800 Ω resistors similarly allow for detection of a severed cable. It is unclear if this is necessary and should be reconsidered for removal if not required. Severed charging cords have been used to immobilize EVs during “carjacking” attempts, leading to defeating this ability in some markets if the vehicle has already been in motion. Therefore, this requirement is controversial and would further complicate adapting this concept to the legacy Type 2 coupler in a backwards compatible design, due to loading the legacy PWM signal.

The equivalent concept for 100 Base-T1 Ethernet maintains the same detection voltages by adding series resistors, as follows:



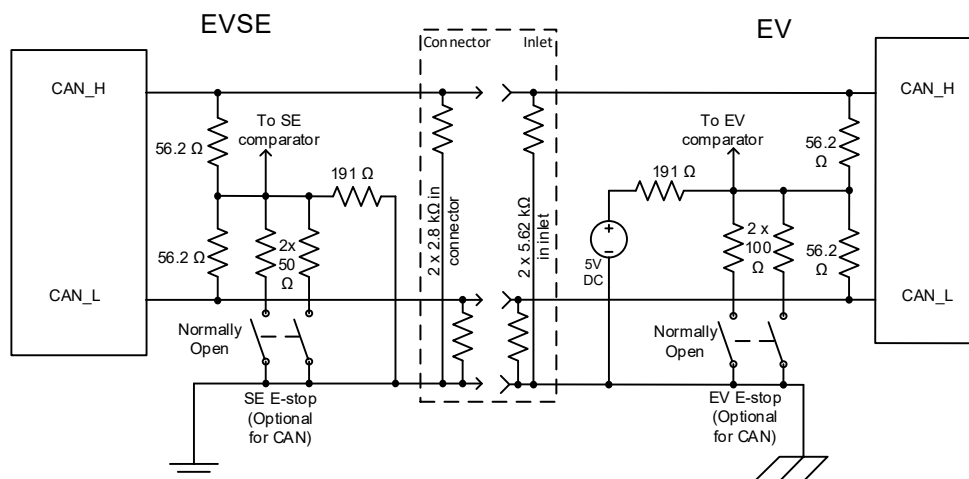
The $23.2\ \Omega$ resistors provide the equivalent voltage drop compared to the CAN termination resistors, and the detection point moves from the center of the CAN termination resistors to the junction of the $191\ \Omega$ and $23.2\ \Omega$ resistors in the Ethernet case. Note: UNECE 100 has been interpreted to mean that there is a requirement to detect severed cords and immobilize the vehicle. This is why the $2.8\ \text{k}\Omega$ resistors are present. However, they would pose a problem interoperating with legacy PWM/PLC charging, since they would load the $-12\ \text{V}$ portion of the PWM. Arguably, detection of severed cords is superfluous and relaxing this requirement to only require detection of a cord attached to the SE would allow the $2.8\ \text{k}\Omega$ resistors to be removed.

While CAN is a controller datalink design to provide deterministic and prioritized signaling for safety critical functions, the intent of this concept is also to support internet protocol solutions that do not provide guaranteed control response times in a deterministic way, especially after error recovery (which is common in high noise environments such as DC charging). Therefore, an analog signal for emergency stop is also provided:



The redundant switches and resistors nominally provide the equivalent of a $25\ \Omega$ resistor on the SE side (left) and a $50\ \Omega$ resistor on the EV (right) side. Even if one resistor or switch fails, the remaining circuit will still pull the detection voltages outside of the “OK to charge” window.

The equivalent schematic for the CAN configuration with optional analog E-Stop added is given below:



For delayed charging, the EV must keep the $5\ \text{V}$ pull up on for billing verification. This could be called light sleep.

Detection voltages for the complete concept with FMEA additions are given in the following table:

Connection Detection over CAN State	SE Volts Nominal	SE Range	EV Volts Nominal	EV Range	
OK to drive (disconnected)	0		4.61	4.43 to 4.85	Tolerances confirmed
Connected, both Estops on	0.413		1.175		Check tolerances
Connected, EV Estop on	0.655		0.87		
Connected, SE Estop on	0.394		1.4195		
OK to charge (connected)	2.03		2.595		

Comparison to equivalent SAE J1772 states:

Connection State in SAE J1772 Terms	SE Nominal Positive V	SE Nominal Negative V	EV Nominal Positive V	EV Nominal Negative V
SE State A EV state E	12	-12	0	0
State B1 (oscillator off, nobody ready)	9	9	9	9
State B2 (EV not ready)	9	-12	9	-12
State C1 (oscillator off, SE not ready)	6	6	6	6
State C2 (OK to charge)	6	-12	6	-12

The pullup and pulldown resistors of 191 Ω approximates the recessive load of the maximum number of CAN nodes allowed in SAE J1939-15. Additionally, if this design were retrofitted to a CCS coupler, the 191 Ω value (combined with other components) also presents a resistance at the CAN H and CAN L pins of the connector roughly equal to the proximity resistor in a 32-A Type 2 connector. This ensures immobilization of legacy PWM-based EVs in the future, should this differential CAN interface be adapted to CCS couplers.

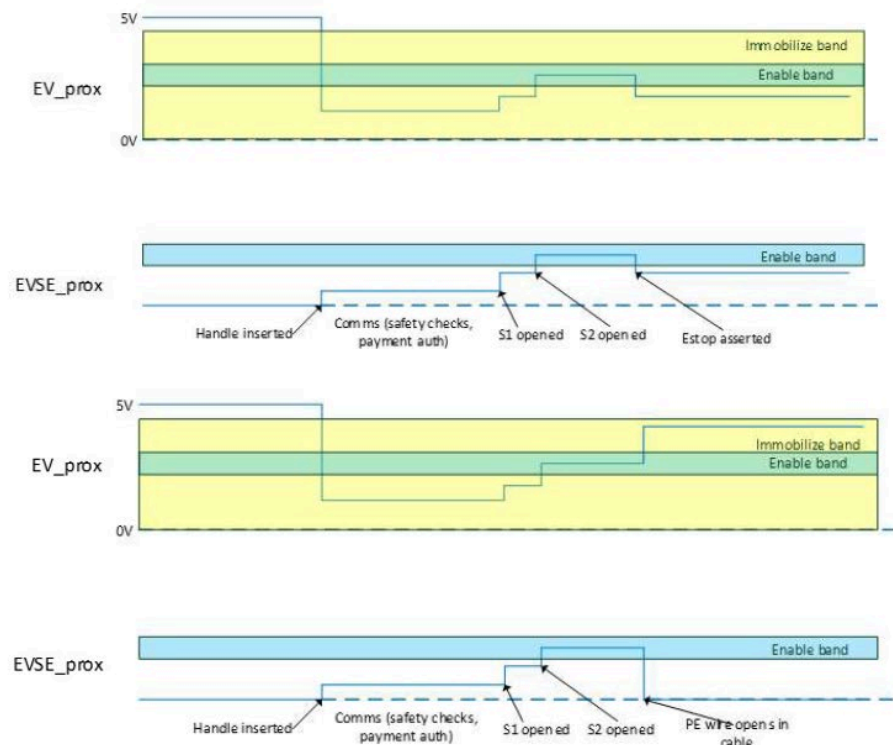
The four CAN termination resistors of 56.2 Ω are presently specified at 1%. Tighter tolerance improves noise immunity. IEC 61938:2018 §9.4.3 says $\leq 0.4\%$ tolerance for similar phantom power circuit. The value of 56.2 Ω provides a close match to the 115 Ω CAN FD termination resistance specified in SAE J2284-5_201609 Table 3.

The E-stop (or “State B” or charge disable) switches will be exercised at startup thusly:

Sequence Diagrams

Estop assertions can be tested in sequence on initial power-up to prove health of estop circuits before charging allowed.

Wake-on-CAN can support can provide EVSE side wake function.



5.2.10.1 CAN Bus

CAN bus technology is defined in ISO 11898-x. This technology is not yet defined in any ISO 15118-x document.

CAN XL has built in support for TCP/IP, with preliminary specification in CiA 611-1. Further work will be needed to add in standardized support for TCP/IP and IPV6 in CAN FD.

NOTE 1: SAE J1939 also defines the use of CAN specifically in heavy truck applications.

NOTE 2: CAN technology was developed for and is used in the automotive industry and elsewhere.

CAN communication shall be limited to only the messages defined in SAE J3271, explicitly not allowing reprogramming and not allowing general access to the main vehicle control bus. Testing should cover at least a few examples.

Security for CAN communication shall support SAE J2931/7 or equivalent. For example, see SPN 13168, and CAN SEC for CAN XL as in CiA 613-2 Security.