

IEEE Standard Technical Specifications of a DC Quick Charger for Use with Electric Vehicles

IEEE Vehicular Technology Society

Sponsored by the
Intelligent Transportation Systems

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

IEEE Std 2030.1.1™-2015

IEEE Standard Technical Specifications of a DC Quick Charger for Use with Electric Vehicles

Sponsor

Intelligent Transportation Systems
of the
IEEE Vehicular Technology Society

Approved 3 September 2015

IEEE-SA Standards Board

Acknowledgments

Grateful acknowledgment is made to the CHAdeMO Association for permission to use the following source material in Annex A:

CHAdeMO 1.0.1 (21 May 2013), Technical Specifications of Quick Charger for the Electric Vehicle.

Abstract: Direct-current (dc) charging is a method of charging that facilitates rapid energy transfer from the electric grid to plug-in vehicles. This method of charging allows significantly more current to be drawn by the vehicle versus lower rated alternating-current (ac) systems. A combination of vehicles that can accept high-current dc charge and the dc supply equipment that provides it has led to the use of terminology such as “fast charging,” “fast charger,” “dc charger,” “quick charger,” etc.

DC charging and ac charging vary by the location at which ac current is converted to dc current. For typical dc charging, the current is converted at the off-board charger, which is separate from the vehicle. For ac charging, the current is converted inside the vehicle, by means of an on-board charger.

The location of the ac to dc conversion equipment, or converter, shapes the complexity of the equipment design. Regarding ac charging, as previously mentioned, the conversion is on board the vehicle. This allows the original equipment maker (OEM) designed systems to control the charging operation in its entirety. The on-board charger (converter) and battery controller solution is under direct control of the vehicle manufacturer.

For dc charging, an entirely new challenge exists for OEMs. The dc charger is now external to the vehicle and requires the vehicle engineers to control an external power device. For the reason of necessary interoperability, standards such as IEEE Std 2030.1.1 are provided to assist developers.

Keywords: automotive, CHAdeMO, dc charger, dc charging, electric vehicle, fast charger, fast charging, IEC 61851-23, IEEE, IEEE 2030.1.1™, rapid charging, SAE, SAE J1772, SAE J2836/2

The Institute of Electrical and Electronics Engineers, Inc.
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PDF: ISBN 978-0-7381-9999-3 STD20429
Print: ISBN 978-1-5044-0000-8 STDPD20429

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Introduction

This introduction is not part of IEEE Std 2030.1.1-2015, IEEE Standard Technical Specifications of a DC Quick Charger for Use with Electric Vehicles.

This standard defines requirements for the designs of electric vehicles and dc quick chargers that promote efficient and rapid charging between electric vehicles and dc quick chargers. This document specifies the collaborative actions between electric vehicles and quick chargers referencing relevant international specifications.

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1. Scope

This standard specifies the design interface of electric vehicles and direct current (dc) quick chargers that promote rapid charging of battery electric vehicles.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

IEC 61851-1, Electric vehicle conductive charging system—Part 1: General requirements.¹

IEC 62196-3, Plugs, socket-outlets, vehicle connectors and vehicle inlets—Conductive charging of electric vehicles—Part 3: Dimensional compatibility and interchangeability requirements for d.c. and a.c. /d.c. pin and contact-tube vehicle couplers.

¹ IEC publications are available from the International Electrotechnical Commission, Case Postale 131, 3 rue de Varembe, CH-1211, Genève 20, Switzerland/Suisse (<http://www.iec.ch/>). IEC publications are also available in the United States from the American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

ISO 11898-1, Road vehicles—Controller area network (CAN)—Part 1: Data link layer and physical signalling.²

ISO 11898-2, Road vehicles—Controller area network (CAN)—Part 2: High-speed medium access unit.

SAE J1772, Electric Vehicle and Plug in Hybrid Electric Vehicle Conductive Charge Coupler.³

SAE J2836/2, Use Cases for Communications between Plug-in Vehicles and Off-Board DC Charger.

SAE J2847/2, Communication Between Plug-In Vehicles and Off-Board DC Chargers.

SAE J2931/1, Digital Communications for Plug-in Electric Vehicles.

SAE J2931/4, Broadband PLC Communication for Plug-in Electric Vehicles.

3. Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.⁴

3.1 Vehicle terms

charging: Supplying direct current to a battery from an external power source, producing a chemical reaction of the active substances and storing electrical energy in the battery as chemical energy.

electric vehicle (EV): A vehicle using an electric motor as a powertrain.

electric vehicle (EV) contactor: A switching device on dc charging circuit to on-board battery.

on-board battery: A battery for propulsion mounted on an electric vehicle.

on-board dc 12 V power supply: An auxiliary electric vehicle battery used for communication and charging control

vehicle relay: The switch that controls the electric vehicle contactor

3.2 Charger terms

ac input power blackout: Voltage fall of ac input power supply below the specified voltage range.

charging cable: A cable that is connected to the electric vehicle for charging purposes.

charging connector: A connecting apparatus equipped with the charger in order to charge electric vehicles.

² ISO publications are available from the ISO Central Secretariat, Case Postale 56, 1 rue de Varembe, CH-1211, Genève 20, Switzerland/Suisse (<http://www.iso.ch/>). ISO publications are also available in the United States from the American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

³ SAE publications are available from the Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096, USA (<http://www.sae.org/>).

⁴ *IEEE Standards Dictionary Online* subscription is available at: <http://ieeexplore.ieee.org/xpls/dictionary.jsp>.

control power supply: Power supply to supply dc power to communication control circuit in the charger, vehicle, and other accessories.

converter: A device to convert ac power to dc power.

earth leakage circuit breaker (ELCB): A device to detect errors and to break the circuit in case of the following errors:

- a) Earth leakage current from the power line
- b) Overcurrent on the power line

enclosure: Exterior of the charger, including the knob, handle, grip, etc.

earth fault: Electrically energized condition where the insulation state between main circuit and earth, including insulation deterioration between dc power circuit and charger enclosure or vehicle chassis.

earth fault detection: To detect earth fault.

earthing: To electrically connect the enclosure and metallic pipes, etc., to the earth with electric wires.

inverter: A device to convert dc power to ac power.

main circuit: An electric circuit to supply dc charging current to on-board battery, which consists of power receiving part from input ac power, converting circuit from ac current to dc charging current and charging current output circuit.

main power supply: Power supply to supply dc power to on-board battery.

opto-coupler: An element that converts electric signals to light and transmits it as a signal.

3.3 Communications terms

bus off: A state in which participation in the communications on the shared transmission line for exchange of electronic signals is prohibited.

CAN communication: Communication that is one of the types of vehicle-mounted network protocol and is used between charger and vehicle. A communication method used for transmitting control signals between an electric vehicle and a quick charger in the CHAdeMO system. (ISO 11898-2)

error frame: A data frame that is transmitted when a bus error is detected.

ID: A name that is given to classify data information and transmission node.

4. Conventions

4.1 General

This standard uses binary and hexadecimal notation of fields in text and tables. The interpretation of the bit and nibble ordering in these fields adheres to the rules described in 4.2 through 4.7, unless specifically defined otherwise within Annex A or Annex B.

4.2 Binary representation

Binary fields are used with a prefix of “0b” to indicate the binary (or base-2) nature of the data. The field starts with the most significant bit (MSB).

A general binary representation of a field has the following format:

0bB_n...B₁B₀

with bit “B_n” representing the MSB and bit “B₀” representing the least significant bit (LSB).

Examples:

a) 0b001

In this example, “1” is the LSB. The value of this field is equivalent to the value of 1 in decimal notation.

b) 0b10000

In this example, “1” is the MSB. The value of this field is equivalent to the value of 16 in decimal notation.

4.3 Hexadecimal representation

Hexadecimal (Hex) fields are used with a prefix of “0x” to indicate the hexadecimal (or base-16) nature of the data. The field starts with the most significant nibble of the fields. Hex digits A, B, C, D, E, and F are capitalized.

A general hexadecimal representation of a field has the following format:

0xH_n...H₁H₀

with nibble “H_n” representing the most significant nibble and nibble “H₀” representing the least significant nibble.

Examples:

a) 0x00E

In this example, “E” is the least significant nibble.

b) 0xE00

In this example, “E” is the most significant nibble.

A hexadecimal field can be converted into a binary field by replacing each nibble with the corresponding binary value (following the representation of binary fields).

In this standard, the term “octet” is used to identify two consecutive nibbles of data (i.e., a bit string of length 8). The term “byte” is synonymous with the preferred term, “octet.” The use of the term “byte” has been preserved in normatively referenced material.

Hexadecimal numbers can also be represented in the following form:

H’_n,...,1,0

4.4 Decimal representation

Values specified in decimal are coded in natural binary unless otherwise stated.

The use of the decimal point in base-10 decimal numbers indicates the separation between units on the left and tenths of units on the right. This standard does not use a comma for the same purpose. Commas are used to separate units of one thousand and one hundred, one million and one-hundred thousand, and so on.

4.5 Transmission sequence

See Annex A, Annex B, and Annex C for their specific transmission sequence.

4.6 Formulas

Multiplication is represented as an “×” rather than as an “x” to avoid confusion with hexadecimal numbers and variables.

4.7 Units of measure

Metric units are used.

Interpretations of common units of measure are as follows:

- k (analog) = 1 000
- K (digital) (e.g., kilobits) = 1024 (2^{10})
- M (analog) = 1 000 000
- M (digital) = 1 048 576 (2^{20})
- n (analog) = 10^{-9}
- Ω = Ohm

5. Common requirements

5.1 Background

In electric vehicles, the charger may be located on board or off board the vehicle. When the charger is on board the vehicle, it is developed for the specific type and size of the battery used in the vehicle. Simple ac voltage may be connected to the on-board charger’s power inlet. However, it may be difficult to charge large batteries quickly using common residential ac voltage and current. If the charger is off board the vehicle, it requires communication with the battery control system. This communication protocol may be different by vehicle model, so off-board chargers can be designed to accommodate multiple technologies. The benefit is that dc chargers can provide more charging energy to the vehicle, which can reduce charge time (“quick charging”).

Clause 5 describes the common requirements pertaining to collaborative actions between electric vehicles and quick chargers.

Annex A and/or Annex B shall be used to implement these charging systems.

5.2 Requirements

These requirements are “common” requirements for the specifications in Annex A and Annex B.

a) General

- 1) Device shall be able to indicate to the user the status of the charging process and take corrective actions if required.
- 2) Both the charger and the vehicle shall be equipped with a means to confirm they stay physically and/or electrically connected with each other during charging.
- 3) The charger shall be equipped with a means to stop charging in the case that communication between the vehicle and the charger (via the communications interface) is interrupted.
- 4) When the protective conductor between the charger and the vehicle is disconnected, the charger shall stop charging within 10 s.
- 5) The charger shall be able to detect loss of isolation, short circuit, and earth faults.
- 6) The charger shall be equipped with an overvoltage protection function.
- 7) The system shall be designed so that a level of voltage that is dangerous to the human body shall not be applied on the charging connector when the connector is not connected to the vehicle.
- 8) The system shall be designed to prevent users from touching electrically energized parts on the vehicle and the charger.
- 9) The charger shall be equipped with a means of earth leakage current detection and automatic disconnection to help prevent electric shock.
- 10) The charger or charging connector shall be equipped with measures (e.g., plastic cap on connector power terminals) to reduce the risk of contact with exposed live parts as a measure against remaining electric charge on the charging connector.
- 11) The charger shall be equipped with a means of protection against overload and short circuit in the ac main circuit or internal circuit of the charger.
- 12) The charging system shall be designed so that the voltage level between any accessible conductive parts, including charging cable and charging connector, and any grounding parts decreases to less than 60 V within 1 s or less, after connector removal from station or vehicle.

b) Communications

A data communications interface shall be used to transmit parameters required for charging control. The charger and vehicle shall exchange the parameters through the interface.

c) Outdoor/indoor conductive charging

The charger shall be designed to endure the following environmental conditions:

- 1) The charger enclosure shall have a rating of IP33 or higher.
- 2) Ambient temperature (outdoor): $-25\text{ }^{\circ}\text{C}$ to $40\text{ }^{\circ}\text{C}$.
- 3) Ambient temperature (indoor): $-5\text{ }^{\circ}\text{C}$ to $40\text{ }^{\circ}\text{C}$.
- 4) Ambient humidity: 5% to 95%.
- 5) Altitude: Charger shall work between the atmospheric pressures of 860 hPa and 1060 hPa.

Annex A

(normative)

CHAdeMO specifications

A.1 Scope of application

This annex describes specifications that shall be incorporated into the designs of electric vehicles and quick chargers in order to enable efficient and rapid charging between electric vehicles and quick chargers.

This annex describes specifications pertaining to collaborative actions between electric vehicles and quick chargers. Design firms and manufacturers shall also reference relevant international specifications, listed in Clause 2, and domestic laws/regulations on electrical equipment.

IEC 61851-23:2014 [B39] and IEC 61851-24:2014 [B40] have specified general requirements on dc EV charging station.⁵ System A in Annex AA of IEC 61851-23:2014 and System A in Annex A of IEC 61851-24:2014 have given specific requirements for dc EV charging station, which use the same interface and digital communication method given in this annex. This annex gives detailed specification for charging station and vehicle manufacturers, which conform to Annex AA of IEC 61851-23:2014 and Annex A of IEC 61851-24:2014.

A.1.1 Protocol number and changing protocol in case of the different versions

Any revisions to specification documents shall be recorded in the revision history, along with the description of the changes or additions made. The CHAdeMO control protocol number is assigned to manage software compatibility between charger and vehicle developed under different specification versions.

A.2 Vehicle coupler

Vehicle coupler shall conform to IEC 62196-3 Standard sheets for configuration “AA.” Shapes and dimensions of the vehicle coupler in A.17 are given for information only.⁶

A.3 Installation conditions and main specifications

The manufacturer shall manufacture the charger with a design that conforms to the following:

- a) Standard usage conditions as shown in Table A.1
- b) Panel-related specifications as shown in Table A.2
- c) Device specifications as shown in Table A.3⁷
- d) Design specifications as shown in Table A.4

⁵ The numbers in brackets correspond to those of the bibliography in Annex D.

⁶ Information on references can be found in Clause 2.

⁷ Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

Table A.1—Standard usage conditions

Installation location	Outside
Altitude	1000 m or lower
Ambient temperature	–10 °C to 40 °C
Ambient humidity	30% to 90%, no dew condensation

Table A.2—Panel-related specifications

Panel performance	IP33 or higher
Panel color	In compliance with local ordinances for markings and visibility
Insulation performance	Test voltage a) Withstand ac voltage test (1 min, 50 Hz/60 Hz) 1) Primary side on main circuit (- FG): $U_n + 1200 \text{ Vrms}$ 2) Secondary side on main circuit (- FG): $U_n + 1200 \text{ Vrms}$ 3) Between primary side and secondary side of isolation transformer: — In case of basic insulation:^a $U_n + 1200 \text{ Vrms}$ — In case of reinforced insulation:^a $2 \times (U_n + 1200) \text{ Vrms}$ U_n: Nominal voltage between neutral and line, or phase and earth If dc voltage is used on this test instead of ac, applied dc voltage shall be equal to the peak value of regulated ac test voltage. b) Impulse withstand voltage test 1) Reinforced insulation part: 4 kV (overvoltage category 2), 6 kV (overvoltage category 3) 2) Basic insulation part: 2.5 kV (overvoltage category 2), 4 kV (overvoltage category 3)

^a Basic or reinforced insulation shall be implemented on secondary side of isolation transformer against the primary one.

Table A.3—Device specifications

Control method	Constant current control based on the current command from the vehicle
Input power supply	Nominal voltage in each country: AC ($\pm 15\%$), 50 Hz or 60 Hz ($\pm 5\%$). Total power factor: 0.95 or more (on the condition with maximum rated output power and current of the charger). Input power supply can be defined by each manufacturer, but its specification shall comply with standard or regulation of each country. If ac input voltage to earth exceeds 300 V, in case of 6 kV transient voltage application test on main circuit, transient voltage to earth on secondary circuit shall be depressed below 2.5 kV by using arrestor, etc. If an arrestor is used to mitigate transient voltage, the arrestor may be omitted on this test.
Output range	DC 50 V to 500 V, DC 0 A to 125 A or less (see NOTE)
Current ripple	Up to 10 Hz: 1.5 Ap-p or less Up to 5 kHz: 3.0 Ap-p or less
AC/DC conversion efficiency	90% ^a or higher (including auxiliary loss, on the condition with maximum rated output power and current of the charger)
Acoustic noise	65 dB or less (1 m far from each side surface; 1 m high from the floor surface) (on the condition with maximum rated output power and current of the charger)
Communication system	Communication protocol: CAN2.0B Active, [ISO11898-2], Standard format Transmission rate: 500 kbps Transmission cycle: 100 ms $\pm$ 10%
Protection system	Main circuit: Interrupt power supply on occurrence of earth faults and short circuits Control circuit: Interrupt power supply on occurrence of earth faults and short circuits
NOTE—In some countries, the upper limit of the maximum voltage requirement may be less than 500 V. (Japan: See A.15.)	

^a Minimum conversion efficiency recommended by CHAdeMO.

Table A.4—Design specifications

Operating panel	Charge start button: Blue (recommendation). Charge stop button: Green (recommendation). Each button or lamp is lighting during standby and blinking during operation (recommendation).
Emergency stop	Emergency stop button: Red. Emergency stop button shall retain its pushed condition until reset operation. Emergency stop button shall be reset only by manual operation. Clear panel window to prevent wrong operation (recommendation).

A.4 Requirements for basic design of the charger and the vehicle

A.4.1 Charging method

Constant current charging method is used for charging. The vehicle shall transmit a charging current request to the charger at a constant time interval. The charger shall output current that corresponds to the order value. If the order value from the vehicle changes, the charger shall vary output current that follows the new value.

A.4.2 Control signal line

Dedicated control signal lines shall be used to transmit signals concerning the start and termination of charging.

A.4.3 Data communications

A data circuit shall be used to transmit parameters required for charging control. The charger and vehicle shall exchange the parameters through the circuit.

A.4.4 Essential functions

- a) Connection confirmation (Proximity detection): Both the charger and the vehicle shall be equipped with a means to confirm that they stay connected with each other during charging.
- b) Power supply shutdown upon communications disruption:
 - 1) The charger shall be equipped with a means to stop charging immediately in the case that communication between the vehicle and the charger (via the control signal lines or data communication lines) is interrupted.
 - 2) In addition to data communication, there shall be a means that the vehicle instructs the charger to stop charging. When the vehicle detects disruption of data communication, the charger shall be notified to stop charging by the means.
- b) Prevention of false-drive (requirement for the vehicle): The vehicle shall be equipped with a means to prevent drive the vehicle while it is connected to the charger (whether it is before and during charging).
- c) Detection of protective conductor disconnection between charger and vehicle and charging termination: When the protective conductor between the charger and the vehicle is disconnected, the charger shall stop charging immediately.
- d) Detection and protection of earth fault on the dc power circuit: During charging, the charger shall detect any earth fault on the dc power circuit. In the event that earth fault is detected in the dc power circuit, the charger shall stop applying dc voltage or supplying dc current to the charging cable. If equipped, the on-board fault detection of the vehicle shall not interfere with the earth fault detection capability of the dc charger.
- e) DC short circuit protection: The charger shall be equipped with a short circuit protection function.
- f) Prevention of overvoltage on on-board systems: The charger shall be equipped with an overvoltage protection function on vehicle systems.
- g) Charge current interruption function: The vehicle shall have contactors with sufficient capacity to break charge current.
- h) Protection of EV contactor:

To protect the EV contactor, the charger shall follow the procedure in item 1), 2), and 3) of this subclause when stopping the power supply to the control relay of the EV contactor. This procedure shall be observed even in the event of ac input power blackout or voltage drop of ac input power. See A.7.2.8.

Procedure for stopping the control power supply (power supply to the EV contactor)

- 1) Stop the charging current.
- 2) Stop the power supply to the control relay of the EV contactor.
- 3) Open the EV contractor.

The charger shall have welding detection capability for monitoring the EV contactor. See A.10.

- i) Design of hardware associated with the stop signals: The stop signals from the vehicle to the charger shall be redundant. Charging processes shall be stopped in the event that analog signal or CAN data signal calls for the “stop” state. The charger shall be equipped with a mechanism to ensure terminating operation according to stop request from the vehicle.
- j) Voltage measurement and check: The charger shall be equipped with a means of measuring charging cable voltage in order to judge whether voltage may be applied to the vehicle circuit and charging connector may be removed.
- k) Error logging function: The charger and the vehicle shall be equipped with a means of storing the error information and investigating its cause when malfunctions occur on the other side.

A.4.5 Protection against electric shock

The charging system shall be designed so as to prevent users from approaching live parts on the vehicle and the charger.

The charging system shall be designed so that a level of voltage that is dangerous to the human body shall not be applied on the vehicle inlet and charging connector during normal connector removal action as well as the connector fall situation due to an accident.

The charging system shall be designed so that voltage level between any accessible conductive parts, including charging cable and charging connector, and any grounding parts decreases less than 60 V within 1 s after the appearance of live parts on the charger in the case of normal operation or abnormal situation.

The charger shall be equipped with a means of earth leakage current detection and automatic disconnection to prevent electric shock.

The vehicle shall have the function, structure, or combination of function and structure to avoid high voltage application on the vehicle inlet if welding has occurred to prevent users from touching live parts (e.g., redundant EV contactors and protection cover for the vehicle inlet).

The charger or charging connector shall be equipped with measures (e.g., plastic cap on connector power terminals) to reduce the risk of contact with exposed live parts as a measure against remaining electric charge on the charging connector.

A.4.6 Overcurrent protection

The charger shall be equipped with a means of protecting itself and ac main circuit against overload (over current) and short circuit.

A.4.7 CPU monitoring

The charger and vehicle shall each monitor its own CPU status. Any malfunction or failure affecting charge control capability shall result in a termination to the charge operation, initiated by the vehicle or dc charger.

A.5 Circuit requirements

A.5.1 Main circuit

Basic configuration of main circuit is shown in Figure A.1.

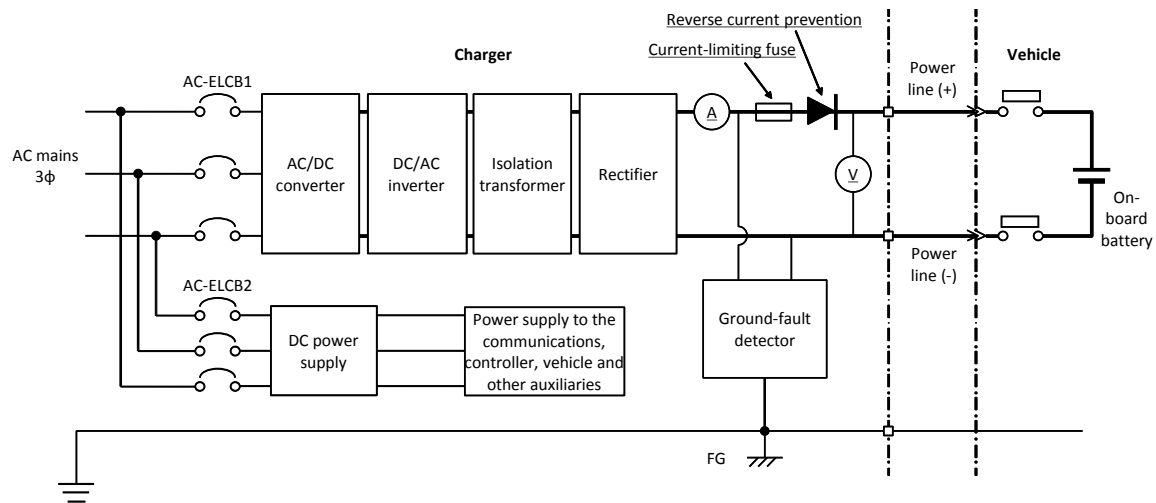


Figure A.1—Typical circuit configuration

A.5.1.1 Isolation of ac and dc circuits

Input ac circuit and output dc circuit shall be separated by reinforced insulation or double insulation.

A.5.1.2 Separation of main power supply and control power supply

Main power supply unit (power supply to supply charging current to on-board battery) and control power supply unit (see A.5.2 and A.5.3) shall be diverged at receiving point of electricity in the charger. Each of the branched circuits shall have circuit breakers (AC-ELCB1 and AC-ELCB2 shown in Figure A.1) that protect short-circuit/overcurrent and earth fault.

Even if a fault occurs on the main power supply circuit, the control power supply circuit shall remain active to maintain the control/communications function with the vehicle, as well as the function for protecting and monitoring the charger itself.

A.5.1.3 Reverse current prevention diode

The charger shall be equipped with reverse current prevention diode on the output circuit in order to prevent reverse current flowing from on-board battery to the charger, and to prevent reverse current flowing to the on-board battery.

The main circuit on the downstream of the reverse current prevention diode shall meet the following requirements.

- a) In case that there are capacitive components, the inrush current shall be 20 A or less when the EV contactors are closed.

NOTE 1—Compliance is checked with the condition that no connecting components exist between P and N on the vehicle-side main circuit between the EV contactor and the vehicle inlet.

- b) The components connected in the series on the downstream of the reverse current prevention diode shall meet one of the following conditions:
 - 1) No fuse shall be installed.
 - 2) Insulation between the internal wiring downstream of the reverse current prevention diode and other output circuit shall be at least double insulation or equivalent.

- c) If there are any components that connect P and N, the downstream of the reverse current prevention diode shall require one of the following conditions:
 - 1) Rapid-type fuse rated 2 A or less shall be provided.
 - 2) In the downstream of the reverse current prevention diode, single failure shall not cause a dead short circuit.

NOTE 2—The single failure means a failure of discrete component or a sequence of failures.

- d) Cross section of DC charging cable conductor shall be at least 22 mm².
- e) Fuse that is possible to protect against a short circuit shall be provided on the vehicle.

A.5.1.4 Current-limiting fuse

The charger shall be equipped with current limiting fuse on the output circuit, so as to prevent short circuit if charging cable is accidentally connected in reverse polarity. The current-limiting fuse shall be in the immediate cut-off type (Rapid type fuse) and its breaking capacity shall be below 250 A. Select a fuse that provides short-circuit protection of the charger, charging cable, and charging connector. The current-limiting fuse shall be installed on the anode side of reverse current prevention diode. See Figure A.1.

NOTE—A similar protective mechanism should be equipped on the vehicle circuit.

A.5.1.5 Power supply to the vehicle

The charger shall prepare dc 12 V power supply to provide power to operate EV contactor (described in A.5.2). This dc 12 V power supply shall be obtained from control power supply described in A.5.1.2. That is, control power supply shall be installed on the circuit configuration that has no influence from malfunctions on the main power supply circuit. Power supply to the vehicle shall comply with the specifications shown in Table A.5.

Table A.5—Requirements of power supply to the vehicle

Supply voltage	12 V (dc) Voltage fluctuation tolerance: $\pm 10\%$ of supply voltage (See Table A.7 and Table A.8)
Continuous rating	2 A, 24 W
Others	The charger shall protect the vehicle from short circuit on the dc 12 V lines. The protection measures shall limit the short-circuit current to the vehicle to 6 A maximum. The wiring for the dc 12 V PS shall also meet this requirement.

A.5.1.6 Current and voltage measurement

The charger shall be equipped with a measuring equipment to measure its output current and voltage. Output voltage shall be measured between reverse current prevention diode and charging connector.

The measured voltage shall adjust to the voltage value of connector terminals taken into account voltage drop in charging cable, and utilizes the charging control described in A.7.2.6.

A.5.1.7 Earthing, grounding and protective conductor

A.5.1.7.1 AC circuit side

- a) Conductive parts such as enclosures shall be earthed with protective conductors.
- b) Standards regarding earthed conductors shall comply with technical specifications in each country.
- c) Design and install the earthed and protective contactors with consideration of electrical noise reduction and electrical shock protection best practices.

A.5.1.7.2 DC circuit side

- a) Earth terminals in the charger shall be connected to ones in the vehicle by protective conductor in the charging cable.
- d) Protective conductor described in A.5.2 shall be directly connected to earth terminals of the charger rather than via the enclosure of the charger.
- e) Chassis ground terminal in the vehicle shall connect to the vehicle chassis.
- f) DC earth leakage current monitoring device (see A.5.1.9) shall be connected to earth terminals of the charger. The following insulation conditions shall be monitored:
 - 1) Between secondary side circuit (from secondary side of insulation transformer) and charger enclosure
 - 2) Between charging circuit of the vehicle and vehicle chassis
- g) In the event that the protective conductor between charger and vehicle is disconnected, the charger shall stop applying voltage and supplying current to the charging cable by passive stop of the communication with control signal line ("Vehicle charge permission" line) between the charger and the vehicle.

A.5.1.7.3 General requirements

The protective conductor shall be connected without resistance.

A.5.1.8 Internal protection

The charger shall have a mechanism for monitoring earth fault, short-circuit, overcurrent, and temperature rise inside the charger, and immediately disconnecting main circuit from external power grid upon detection of any fault.

A.5.1.9 Earth fault detection on the dc power circuit

A leakage current monitoring device for detecting earth fault on dc power circuits (secondary circuit of the charger and vehicle-side circuit) shall be installed in the charger. Figure A.2 and Table A.6 specify a detection circuit and detection sensitivity for dc leakage current monitoring. Requirements for the monitoring device are given in item e) of A.7.2.7.2. The insulation monitoring device on the vehicle shall be disabled while the EV contactors are closed, and shall not affect the operation of the leakage current monitoring in the charger while the vehicle is connected with charging connector.

The charger shall stop in the event of leakage detection and shall not be operable until the expected operating conditions are satisfied.

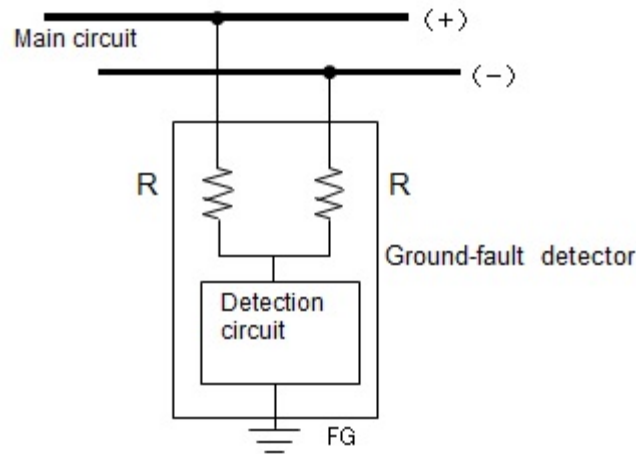


Figure A.2—DC leakage current monitoring circuit

Table A.6—Specification of dc leakage current monitoring

	Item	Specification
1	Detection voltage range	DC 50 V to 500 V
2	Detection method	DC leakage current detection through neutral grounding
3	Sensing performance	The monitoring device shall output trip signal when insulation resistance ratio between main circuit and charger enclosure (including vehicle chassis) gets lower than 100 Ω /V. [V: output voltage] ^a
4	Operating time	1.0 s or less
5	False operation prevention time	0.2 s or more (see NOTE 2)
6	Resistance R	40 k Ω or more (see NOTE 3)
NOTE 1—To prevent accidental activation due to short-term noise current. NOTE 2—Resistance should be able to suppress DC leakage current less than 12.5 mA.		

^a In the operation voltage less than 60 V, the criteria of 100 Ω /V may be not applicable. [In some countries, 100 Ω /V criterion is required from operation voltage of 50 V (UL-standard)]. However, the charger shall be able to detect 0 Ω fault at less than 60 V operation voltage.

A.5.1.10 Overvoltage protection in the event of EV contactor interruption

The charger shall have overvoltage protection function to keep applied voltage on charging connector lower than 600 V during charging in order to protect on-board systems against the following faults:

- Voltage over shoot in the event that “Charge current request” is changed
- Voltage rise in the event of EV contactor interruption during charging (including the voltage uprisng resulting from a control by the charger to maintain target current value)

A.5.1.11 Support for EV contactor welding detection

The charger shall have circuit characteristics described in A.7.5 to support the EV contactor welding detection.

A.5.1.12 Charger protection against overvoltage including voltage surge

It is preferable to use voltage surge protection device depending on the usage environment. The criterion of selecting a surge protection device is included in IEC 61643-12 [B38].

A.5.2 Sequence circuit

The interface with the vehicle shall have a sequence circuit as shown in Figure A.3. Circuit constants of this sequence circuit shall be in accordance with Table A.7 (charger side) and Table A.8 (vehicle side).

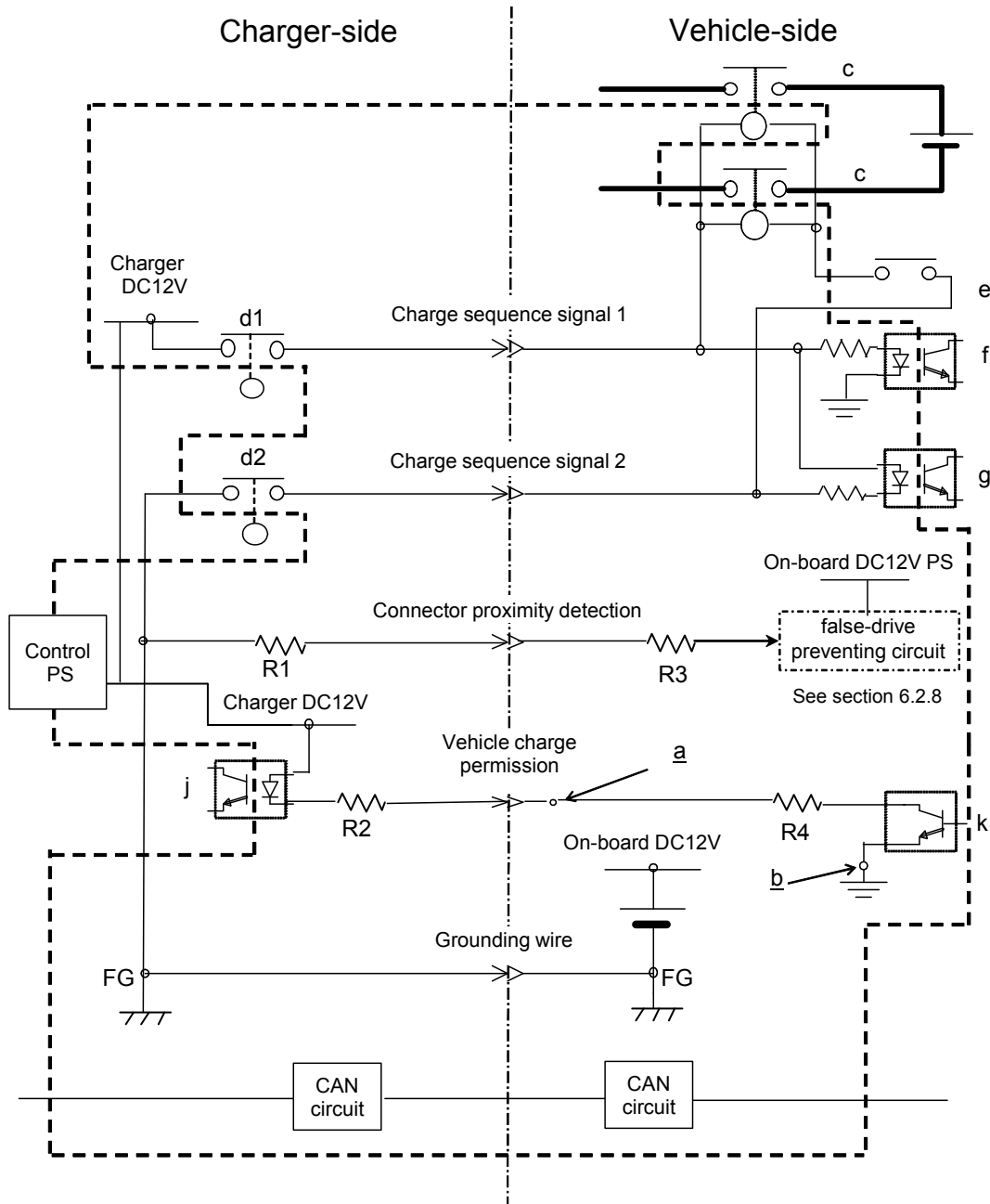


Figure A.3—Sequence circuit

Table A.7—Specification for sequence circuit (charger side)

Terminal	Item	Minimum value	Typical value	Maximum value	Unit
Charge sequence signal 1	Charger dc 12 V	10.8	12.0	13.2	V
Connector proximity detection	Resistor R1	190	200	210	Ω
Vehicle charge permission	Resistor R2	950	1000	1050	Ω
Charge sequence signal 1	Relay d1 load current	2		2000	mA
Charge sequence signal 2	Relay d2 load current	2		2000	mA

Table A.8—Specification for sequence circuit (vehicle side)

Terminal	Item	Minimum value	Typical value	Maximum value	Unit
Charge sequence signal 1	Load current (when d1 ON)	10		2000	mA
Charge sequence signal 2	Load current (when d1 and d2 ON)	10		2000	mA
Connector proximity detection	Resistor R3	950	1000	1050	Ω
	On-board dc 12 V	8	12	16	V
Vehicle charge permission	Resistor R4	190	200	210	Ω
Vehicle charge permission	Load current (leakage current) between a-b when switch k OFF			2	mA
	Vce (collector-emitter voltage of transistor “k”) at collector current = 10 mA			0.5	V

NOTE—The purpose to install resistors on the sequence circuit is as follows:

- R1, R3: Current limiting resistors against short circuit between Connector proximity detection line and dc 12 V or FG.
- R2, R4: Current limiting resistors against short circuit between Vehicle charge permission line and dc 12 V or FG.

A.5.2.1 Circuit voltage

The charger and the vehicle shall supply dc 12 V to the other side.

A.5.2.2 Signal line

The wire diameter shall be selected and determined so as not to affect opto-coupler operation on both the charger and the vehicle and equipotential bonding of signal ground.

A.5.2.3 Prevention of noise and unintended current flow

The noise and unintended current flow from the vehicle or the charger to the interface circuit shall be prevented by opt-coupler or other means. Reference Figure A.3.

A.5.2.4 Power supply to the EV contactor

The charger shall supply dc 12 V power to make EV contactor on the main circuit operable.

This is intended to help protect users from electric shock caused by applied voltage of on-board battery in the event of charging connector detachment or EV contactor activation before charging connector attachment.

A.5.2.5 Grounding wire

Negative terminal of on-board dc 12 V system shall be connected to the vehicle chassis ground terminal (connected to vehicle chassis). Negative terminal of the charger's dc 12 V system shall be connected to the charger's earth terminal (connected to charger enclosure).

A.5.2.6 Signal line protection

On the charger and vehicle, the "Connector proximity detection" line and "Vehicle charge permission" line shall have resistors with specified resistance and be connected in series to prevent short-circuit and ground fault on dc 12 V system on each signal circuit. See Table A.7 and Table A.8 for resistance values.

The vehicle shall have current-limiting fuses (less than $15\text{ A} \times 5\text{ s}$) on other vehicle signal lines that may short to "charge sequence signal 1 and 2."

A.5.2.7 Redundancy of hardware associated with stop signal

To improve the reliability of stop request to the charger, the vehicle shall use both "Vehicle charge permission" signal and "CAN communication" data as a means of transmitting termination signal. This shall prevent the charger from losing the function (ability to break output charging current according to termination signal sent from the other side) in the event that one of these signals is lost. The control signals for "Vehicle charge permission" and "Connector lock malfunction" shall be transmitted to an inverter unit through a different connection from the Inverter control start/stop signal. Each path may be installed on one printed circuit board.

In addition, in case the internal inverter unit is controlled by software, the following conditions shall be met.

- a) The "vehicle charge permission" shall be processed by a separate CPU other than the CPU that runs the inverter control.
- b) The Monitoring function for "connector malfunction detection" shall run in a separate CPU other than the CPU that runs the inverter control

Other than using the gate block on the inverter unit, installing a contactor on the output circuit may be used for a means to interrupt the current flow. "Vehicle charge permission" and "connector malfunction detection" may be installed onto a single CPU. The requirement in this clause may be overridden if the vehicle protocol number is 1.0 or less connected.

The charger and the vehicle shall meet the following specifications in order to achieve these functions:

A.5.2.7.1 Charger

- a) Signal path and processing unit of "signal communication" on "control signal line ("Vehicle charge permission")" and "digital communication ("CAN")" shall be divided in the hardware design.
- b) To separate the processing units for "signal communication" and "digital communication." The "control signal line" shall be physically connected to inverter circuits in the charger, and the charger shall be directly terminated by the control signal on this line. An example of system configuration is shown in Figure A.4.

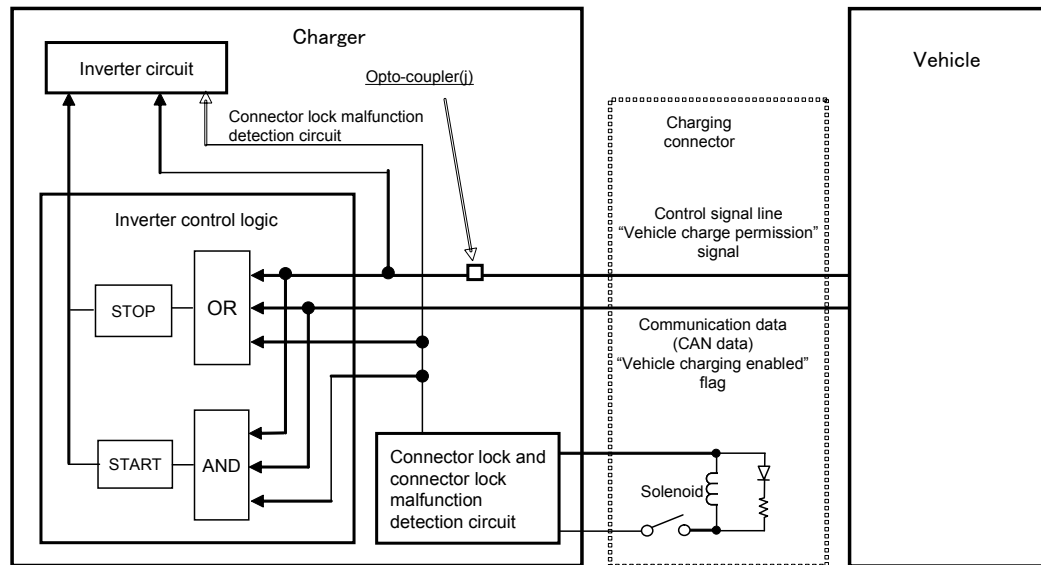


Figure A.4—System configuration example of inverter circuit termination system

- c) Control sequence shall be programmed to check the changing point where “control signal line” (“Vehicle charge permission”) and “CAN data” (“Vehicle charging enabled” flag described in 0) change from OFF (Charging prohibition) to ON (Charging permission) at the beginning of charging process.
- d) Proper filtering components shall be installed on the signal processing units for “control signal line” with consideration for operating frequency of the charger to avoid its noise influence.
- e) The charger shall monitor logical discrepancy between “control signal line” and “CAN data.” In the event of discrepancy detection, the charger shall set “Charging system malfunction” flag and stop charging.
- f) Monitoring items are described as follows:
 - 1) When the charge start button is pushed:
When the “control signal line “Vehicle charge permission” from the vehicle is in the ON state before transmitting first CAN communication data from the charger, the charger shall regard it as logical inconsistency, since the “control signal line: Vehicle charge permission” could be always ON due to vehicle CPU error (as indicated as “1” in Figure A.5).
Also when the “communication data: Vehicle charging enabled” flag from the vehicle is ON before the “control signal line: Vehicle charge permission” from the vehicle is turned ON, the charger shall regard it as logical discrepancy (as indicated as “2” in Figure A.5).
 - 2) Before charging:
If “control signal line” and “CAN data” both do not indicate ON, the charger shall regard this situation as logical discrepancy.
Time delay shall be taken into consideration due to the difference of processing system or signal transmission method.
 - 3) When charging process is terminated:
The charger shall stop charging if either of “control signal line” and “CAN data” indicates OFF. The charger shall not evaluate logical discrepancy.

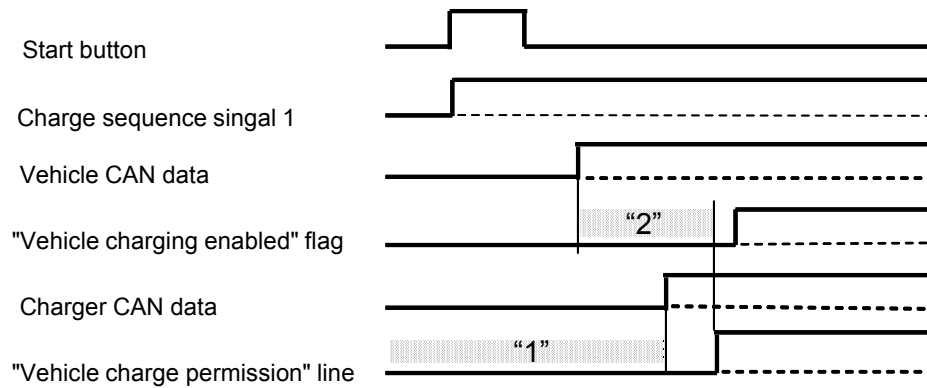


Figure A.5—Timing of logical discrepancy detection after charge start button pressed

A.5.2.7.2 Vehicle

The vehicle shall comply with the following requirements to secure redundancy of terminating system. (See the timing shown in Figure A.6.)

- At the beginning of the charging, the vehicle shall maintain a certain time interval "a" for turning on both the "Vehicle charge permission" and the "Vehicle charging enabled flag." This regulation is required to make the inverter circuit of the charger ready for operation as soon as possible.
- At the end of the charging, except in an emergency stop, the vehicle shall maintain a certain time interval "b" for turning off both the "Charging stop control flag" and "Vehicle charge permission line." This regulation allows the inverter to soft-stop so that fluctuations on the ac mains shall be mitigated.
- These regulations shall not be applied in case of emergency stop.

A.5.2.8 Usage of "Connector proximity detection" line

The vehicle shall not always connect "Connector proximity detection" line and vehicle ECU circuit during the period from charge permission [Switch (k) ON] to EV contactor open. See Figure A.3.

If the vehicle uses "Connector proximity detection" line during this period, the vehicle can adopt only the method that does not form the bypass circuit between the vehicle and the charger (the bypass circuit is explained in detail in A.12. An example of "false-drive preventing circuit" that does not form the bypass circuit is shown in Figure A.7.

If the vehicle needs to check the proximity of charging connector continuously or intermittently without the aforementioned false-drive preventing circuit, the vehicle shall use other signal lines [opto-coupler (f), (g)] or CAN data information from the charger. Figure A.3.

A.5.2.9 Vehicle false-drive prevention measures during the charging connector connection

The vehicle shall be equipped with a means to prevent from moving by driving force of its own during connecting the charging connector. Also, the vehicle may be equipped with a means to stop moving without driving force of its own if needed.

The vehicle shall use the "Connector proximity detection" line for a means of connection confirmation of the charging connector during all except for the charging operations.