



SURFACE VEHICLE INFORMATION REPORT

J2954™/2

DEC2022

Issued

2022-12

Wireless Power Transfer for Heavy-Duty Electric Vehicles

RATIONALE

Electrified powertrains, in both light-duty vehicles (LDVs) and heavy-duty vehicles (HDVs), are projected to become more prevalent in production internationally due to environmental factors (such as GHG, CO₂ emissions), regulations (such as the EU, China, U.S. EPA regulations, and the California ZEV mandates), as well as the increasing price of fossil fuels. The main benefit of electrified powertrains is eliminating or significantly reducing local emissions while increasing the overall well-to-wheels efficiency. In addition, autonomous vehicles are soon to be more commonplace to allow more convenient and safer transportation, especially in traffic settings and long-distance driving.

Standardized wireless power transfer (WPT, also called wireless charging) allows the battery electric vehicles (BEVs) and plug-in hybrid (PHEV) customer an automated, seamless, and more convenient alternative to plug-in (conductive) charging. Essentially, the customer simply needs to park in an SAE J2954-compatible parking space in order to charge the vehicle. WPT offers the additional advantage to autonomous vehicles enabling autonomous parking with alignment assistance and automated charging.

This SAE Information Report, SAE J2954/2, is the first guideline to assist in both static and dynamic wireless power transfer (DWPT) for fleets as well as preliminary demonstrations for HD WPT. Though there are more use cases than in LD WPT, the goal is to have the minimum complexity and to maximize interoperability between systems over the common use cases.

There are planned to be future SAE Recommended Practices following this document with the purpose of implementing validated specifications and test procedures to standardize wireless power transfer for wide scale commercialization.

TABLE OF CONTENTS

1.	SCOPE.....	6
1.1	Wireless Power Transfer General System Description.....	6
2.	REFERENCES.....	8
2.1	Applicable Documents	8
2.1.1	SAE Publications.....	8
2.1.2	ANSI Accredited Publications	8
2.1.3	IEC Publications.....	8
2.1.4	International Commission on Non-Ionizing Radiation Protection (ICNIRP) Publications	9
2.1.5	IEEE Publications.....	9
2.1.6	ISO Publications.....	9
2.1.7	National Fire Protection Agency Publications.....	10
2.1.8	ITU Publications	10
2.1.9	NIST Publications.....	10
2.1.10	UL Publications	10
2.1.11	Code of Federal Regulations (CFR) Publications.....	10
2.1.12	United Nations Publications	10

SAE Executive Standards Committee Rules provide that: "This report is published by SAE to advance the state of technical and engineering sciences. The use of this report is entirely voluntary, and its applicability and suitability for any particular use, including any patent infringement arising therefrom, is the sole responsibility of the user."

SAE reviews each technical report at least every five years at which time it may be revised, reaffirmed, stabilized, or cancelled. SAE invites your written comments and suggestions.

Copyright © 2022 SAE International

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior written permission of SAE.

TO PLACE A DOCUMENT ORDER: Tel: 877-606-7323 (inside USA and Canada)
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
http://www.sae.org

SAE WEB ADDRESS:

Full document details: SAE J2954_2_202212

For more information on this standard, visit
https://www.sae.org/standards/content/J2954/2_202212/

Documents

Document Sharing Hub

3.	DEFINITIONS	11
4.	ABBREVIATIONS	15
5.	WPT CLASSIFICATIONS	16
5.1	Applications and Use Cases	16
5.2	SAE J2954/2 HD WPT System Power Classes	17
5.3	SAE J2954/2 HD WPT Z-Classes	17
5.4	Ground Assembly (GA) Installation Categories	19
5.5	SAE J2954 Interoperability Classifications	19
5.5.1	Interoperability Class I GA	19
5.5.2	Interoperability Class II GA	19
6.	WIRELESS CHARGING SYSTEM FUNCTIONS AND OPERATION	20
6.1	Power Transfer Functional Description	20
6.1.1	Physical Partitions of the Power Transfer Function	20
6.1.2	Main Functional Elements of the Power Transfer Function	21
6.2	Communication Function	21
6.3	Safety Functions	21
6.4	Description of Wireless Power Transfer Operation	21
6.4.1	General	21
6.4.2	Wireless Power Transfer Frequency	22
6.4.3	Centered Position, Natural Offset, and Module Array Offset	22
7.	PHYSICAL DIMENSIONS AND PARAMETERS	23
7.1	GA Coil Dimensions	23
7.2	GA Coil Mounted Height	23
7.3	GA Coil Location	23
7.4	VA Coil Size	23
7.5	VA Coil Ground Clearance	23
7.6	VA Coil Mounting Location	23
8.	PERFORMANCE, INTEROPERABILITY, AND SAFETY REQUIREMENTS	24
8.1	General	24
8.2	Power Transfer Performance Requirements	25
8.2.1	Test Configurations	25
8.2.2	Alignment Tolerance	25
8.2.3	Roll Pitch and Yaw	26
8.2.4	Output Voltage and Power	26
8.2.5	Input Power	27
8.2.6	Power Factor	27
8.2.7	Frequency	27
8.2.8	System Efficiency	27
8.3	Ramp Rates and Control Loop Bandwidth	28
8.4	Interoperability Across Power Classes	29
8.5	Interoperability Regarding Z Class	29
8.6	Allowance for Reactance Variation (in the GA)	29
8.7	Safety Requirements	29
8.7.1	Safe Operation/Non-Operation	29
8.7.2	Heating of Foreign Object	29
8.7.3	Exposure to Electromagnetic Fields	30
8.7.4	Managed Power Transfer Applications	30
9.	ELECTROMAGNETIC COMPATIBILITY/ELECTROMAGNETIC EMISSIONS	30
9.1	Radiated Emissions Due to Wireless Power Transfer	30
9.1.1	Unintentional Radiation	31
9.1.2	Intentional Radiation	31
9.2	Conducted Emissions, System Level	36

9.3	Radiated Immunity	36
9.4	Conducted Immunity	36
9.5	Electrostatic Discharge (ESD)	36
10.	EMF EXPOSURE TO HUMANS AND CARDIAC IMPLANTABLE ELECTRONIC DEVICES (CIED).....	36
10.1	General	36
10.2	Vehicle-Level EMF Requirements	39
10.2.1	Cardiac Implantable Electronic Device (CIED) EMF Requirements	40
10.3	Touch Current Requirements.....	41
10.4	Vehicle Human/CIED EMF Assessment - General Considerations	41
10.5	Instrumentation	44
10.6	Facility for EMF/CIED Exposure Assessment	47
10.7	Vehicle Regions 2 and 3 Exposure Assessment	47
10.8	Touch Current Assessment Procedure.....	48
10.9	Laboratory EMF and CIED Exposure Management	49
10.9.1	ICNIRP 2010 Safety Compliance.....	50
11.	ADDITIONAL SAFETY REQUIREMENTS	50
12.	STATIC WPT COMMUNICATIONS AND ALIGNMENT	50
12.1	Introduction	50
12.2	WPT Parking Space Discovery	51
12.3	Guidance	52
12.4	Fine Alignment	52
12.4.1	Details of Interoperability for Fine Alignment Method	53
12.4.2	WPT Alignment and Vehicle Automated Driving Systems.....	53
12.5	Pairing	53
12.5.1	Generalized Pairing Process	53
12.6	Alignment Check	54
12.6.1	Generalized Alignment Check Process	54
13.	STATIC WPT CONTROL STABILITY AND MONITORING	55
13.1	Control States of Operation	55
13.2	Power Transfer Cycle Control	55
13.2.1	Anomaly Monitoring During Power Transfer	55
13.2.2	Monitoring of the Power Transfer Process.....	55
13.2.3	Control Bandwidth/Update Rates and Stability	56
13.2.4	Frequency Modification During Charge Cycle/Power Transfer.....	57
14.	SAE J2954/2 PARKING SPACE.....	57
14.1	Location of GA Coil Center Point in SAE J2954/2 Parking Space	57
14.2	SAE J2954/2 Parking Space Parking Direction and Visual Cues.....	59
14.3	SAE J2954/2 Parking Space Markings	59
15.	PERFORMANCE TESTING	59
15.1	Power Transfer Testing.....	59
15.1.1	SAE J2954 WPT Test Station.....	59
15.1.2	Component Power Transfer Test for Product VA	60
15.1.3	Vehicle Test for Product VA.....	60
15.1.4	Test for Interoperability Class I Product GA.....	61
15.1.5	Interoperability Class II Product GA.....	61
15.1.6	Coordinate System.....	61
15.1.7	Test Environment	62
15.1.8	System Efficiency Test Procedure	62

16.	SAFETY VERIFICATION	64
16.1	Safety Verification Prior to Power Transfer	64
16.2	Safety Verification During Power Transfer	64
16.2.1	Safe Operation with Respect to Metallic Foreign Objects	64
16.2.2	Live Object Protection	68
17.	SAE J2954/2 HD APPLICATION USE CASES AND VA/GA PLACEMENT	68
18.	DYNAMIC WIRELESS POWER TRANSFER (DWPT).....	68
19.	NOTES	69
19.1	Revision Indicator.....	69
19.2	Patents	69
APPENDIX A	HD WPT SPECIFICATION (INFORMATIVE)	70
APPENDIX B	CONSIDERATIONS FOR DWPT (INFORMATIVE)	74
APPENDIX C	NORMATIVE TEST STATION VA	81
APPENDIX D	NORMATIVE TEST STATION GA.....	82
Figure 1	SAE J2954/2 WPT flow diagram (harmonized with ISO 19363)	7
Figure 2	VA coil ground clearance	17
Figure 3	Clearance for GAs with Z-mover systems	18
Figure 4	GA mounting schemes.....	19
Figure 5	Typical functional elements of a wireless charging system	20
Figure 6	Definition of GA coil mounted height.....	23
Figure 7	Recommended limits.....	31
Figure 8	Recommended In Situ static HD WPT setup, top view, for transit bus radiated emissions testing.....	32
Figure 9	Recommended in situ static HD WPT setup, top view, for truck radiated emissions testing	33
Figure 10	Recommended in situ static HD WPT setup, side view, for transit bus radiated emissions testing	34
Figure 11	Recommended in situ static HD WPT setup, side view, for truck radiated emissions testing.....	34
Figure 12	Recommended in situ dynamic HD WPT setup, side view, for radiated emissions drive by testing.....	35
Figure 13	In situ static HD WPT setup, top view, for transit bus EMF testing (shown is only one; other examples are possible)	37
Figure 14	In situ static HD WPT setup, top view, for truck EMF testing	38
Figure 15	In situ static HD WPT setup, top view, for transit bus EMF testing	38
Figure 16	In situ static HD WPT setup, top view, for truck EMF testing	39
Figure 17	IEC 60990 touch current measuring circuit.....	41
Figure 18	Flowchart for combined EMF and CIED assessment.....	43
Figure 19	Reference scan example with measurement above reference level	45
Figure 20	Region for reference level average measurement - 2 x 2 grid with light color points indicate points of measurement centered around peak	46
Figure 21	Locations for standard field probe averages around peak - 2 x 2 grid separated equidistantly by 7.5 cm center-to-center	46
Figure 22	Region 3 EMF data points on bus or truck passenger and driver seat, stationary and dynamic	48
Figure 23	Wireless power transfer process flow diagram	51
Figure 24	SAE J2954/2 vehicle alignment concept.....	52
Figure 25	SAE J2954/2 GA geometric center location diagram for transit busses.....	58
Figure 26	SAE J2954/2 GA geometric center location diagram for articulated semi-tractors.....	58
Figure 27	Block diagram of a WPT system (including VA and GA) illustrating the efficiency points (1) and (2).....	62
Table 1	SAE J2954/2 typical HD application use cases	16
Table 2	SAE J2954/2 HD-WPT system power classifications	17
Table 3	Specification of the SAE J2954/2 VA Z-classes	18
Table 4	Specification of the SAE J2954/2 GA-VA Z-mover classes.....	18
Table 5	X, Y, Z operating range requirements for product VAs.....	25
Table 6	Ground clearance operating range requirements for product GAs.....	26
Table 7	SAE J2954/2 roll, pitch, and yaw operating range requirements for product VAs	26
Table 8	Range of output power (kW) by class of product GA.....	27

Table 9	Class I minimum system efficiency requirements	28
Table 10	Class I and II minimum system efficiency requirements	28
Table 11	Interoperability expectations of Class I and II GAs across power classes	29
Table 12	Human EMF exposure, ICNIRP 2010 reference levels for general public	39
Table 13	Human EMF exposure, ICNIRP 2010 basic restriction levels for general public	40
Table 14	CIED EMF reference level	40
Table 15	Touch current limits	41
Table 16	Reference EMF exposure measurement standards	44
Table 17	Example worksheet for worst-case operating condition search	47
Table 18	Touch current measurement points	48
Table 19	Coupler configurations for touch current measurement	49
Table 20	Combined EMF limits for laboratory use	49
Table 21	Measurements of fields	50
Table 22	Sample system efficiency test form	63
Table 23	Table of test objects	65

1. SCOPE

The published SAE J2954 standard established an industry-wide specification that defines acceptable criteria for interoperability, electromagnetic compatibility, EMF, minimum performance, safety, and testing for wireless power transfer (WPT) for light-duty plug-in electric vehicles. This SAE Information Report, SAE J2954/2, defines new power transfer levels in the higher power ranges needed for heavy-duty electric vehicles. This document addresses the requirements based on these charge levels and different vehicle applications as a first step in the process of completing a standard that the industry can use, both for private (fleet) and public wireless power transfer, including for charging electric vehicle batteries.

This document is the first step in a process towards HD static and dynamic WPT. This document lacks specific requirements and solutions, for which field data is needed. This document is not intended to be a guideline to enable manufacturers to design systems with minimal assistance; the goal is to inform readers about many of the things to consider in addressing this market and is an outline for the SAE J2954/2 committee for continued work. Based on data, there will be much more detail in the next version of this document. This document represents experience from the SAE J2954 light-duty standard along with active participation of industry providers developing and deploying non-standardized HD wireless power transfer systems with the goal of creating standardized systems in the future.

SAE J2954/2 addresses unidirectional power transfer, from grid to vehicle; bidirectional transfer may be evaluated for a future document. This document is intended to be used in stationary applications (power transfer while vehicle is not in motion) and some dynamic applications.

SAE J2954/2 covers requirements for safety, performance, and interoperability. Further development of detailed requirements will be based on performance-based evaluations of candidate designs, including evaluations against electrical safety and human safety standards.

SAE J2954/2 also covers recommended methods for evaluating electromagnetic emissions, but the requirements and test procedures are controlled by regulatory bodies.

1.1 Wireless Power Transfer General System Description

WPT systems consist of a ground assembly (GA) subsystem and a vehicle assembly (VA) subsystem as depicted in Figure 1. The GA broadly consists of a connection to an AC or DC power source, with suitable filtering and phase correction in the case of an AC source, in order to minimize the disturbances to others sharing the power source followed by a DC-AC inverter, a filter and an impedance matching network (IMN) that is connected to the GA coil. The magnetic energy created by the GA coil is coupled to the VA coil. The VA consists of the VA coil connected to an IMN and filter, a rectifier, and an optional impedance converter that produces suitable voltages and currents to the connected battery.

In order to ensure safety, a certain set of requirements are met by both the GA and the VA, including monitoring for safe operation (voltage, current, and temperature) and the ability to take corrective action in the event that a limit indicating unsafe operation is being approached.

The GA and the VA share a communication system that allows the GA to know the state of the VA and for the GA to receive and respond to messages from the VA. It is critical that power transfer is not initiated until the GA determines that a vehicle with a compatible VA is in place and properly aligned.

The following steps describe the high-level operation of the closed loop power transfer system with respect to the sub-system blocks in the diagram in Figure 1, after necessary safety and compatibility checks have been performed and passed.

- Within the vehicle, the VA (25) determines the power desired to charge the battery and to provide power for other purposes.
- The request for power is communicated over the wireless communication channel (b) from the VA to the GA (15).
- The GA recognizes the request, draws power from the grid, converts it to high frequency AC, and sends it to the GA coil (11).
- The high frequency AC couples (a) to the VA coil (21), is rectified and processed in the VA, and delivers it to the vehicle electrical system to charge the batteries and provide power for other purposes.
- This process continues until the VA signals a different power level requirement, including no power required, as would be the case when the demand no longer exists.

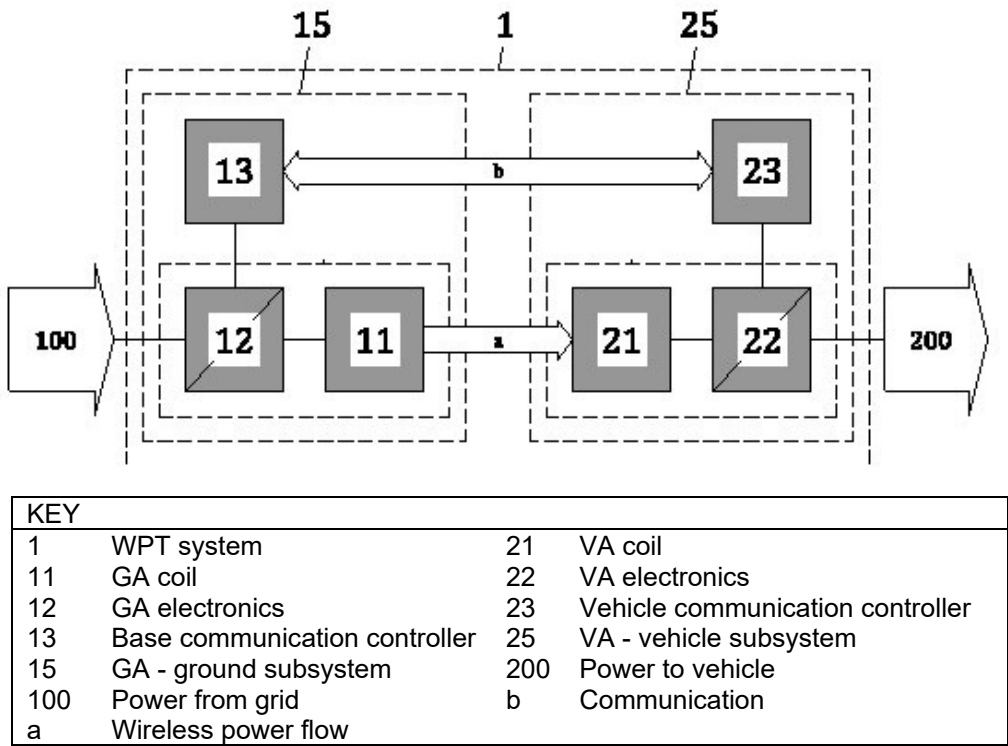


Figure 1 - SAE J2954/2 WPT flow diagram (harmonized with ISO 19363)

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 J1772 | SAE Electric Vehicle and Plug-in Hybrid Electric Vehicle Conductive Charge Coupler |
| SAE J2836/6 | Use Cases for Wireless Charging Communication for Plug-in Electric Vehicles |
| SAE J2847/6 | Communication for Wireless Power Transfer Between Light-Duty Plug-in Electric Vehicles and Wireless EV Charging Stations |
| SAE J2931/6 | Signaling Communication for Wirelessly Charged Electric Vehicles |
| SAE J2954 | Wireless Power Transfer for Light-Duty Plug-in/Electric Vehicles and Alignment Methodology |
| SAE J3016 | Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles |

Schneider, J., Carlson, R., Sirota, J., Sutton, R. et al., "Validation of Wireless Power Transfer up to 11kW Based on SAE J2954 with Bench and Vehicle Testing," SAE Technical Paper 2019-01-0868, 2019, <https://doi.org/10.4271/2019-01-0868>.

Schneider, J., Kamichi, K., Mikat, D., Sutton, R. et al., "Bench Testing Validation of Wireless Power Transfer up to 7.7kW Based on SAE J2954," *SAE Int. J. Passeng. Cars - Electron. Electr. Syst.* 11(2):89-108, 2018, <https://doi.org/10.4271/07-11-02-0009>.

2.1.2 ANSI Accredited Publications

Copies of these documents are available online at <https://webstore.ansi.org/>.

- | | |
|-------------|---|
| ANSI C63.30 | American National Standard for Methods of Measurement of Radio Noise Emissions from Wireless Power Transfer Equipment |
|-------------|---|

2.1.3 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.

- | | |
|---------------|--|
| CISPR 11 | Industrial, Scientific and Medical Equipment - Radio-Frequency Disturbance Characteristics - Limits and Methods of Measurement |
| CISPR 12 | Vehicles, Boats and Internal Combustion Engines - Radio Disturbance Characteristics - Limits and Methods of Measurement for the Protection of Off-Board Receivers |
| CISPR 25 | Vehicles, Boats and Internal Combustion Engines - Radio Disturbance Characteristics - Limits and Methods of Measurement for the Protection of On-Board Receivers |
| IEC 60990 | Methods of Measurement of Touch Current and Protective Conductor Current |
| IEC 61000-3-7 | Electromagnetic Compatibility (EMC) - Part 3-7: Limits - Assessment of Emission Limits for the Connection of Fluctuating Installations to MV, HV and EHV Power Systems |

- IEC 61786-2 Measurement of DC Magnetic Fields, AC Magnetic and Electric Fields from 1 Hz to 100 kHz with Regard to Exposure of Human Beings - Part 2: Basic TIR for Measurements
- IEC 61980-1 Electric Vehicle Wireless Power (WPT) Systems - Part 1: General Requirements
- IEC 61980-2 Electric Vehicle Wireless Power Transfer (WPT) SYSTEMS - Part 2: Specific Requirements for MF-WPT System Communication And Activities
- IEC 61980-3 Electric Vehicle Wireless Power (WPT) Systems - Part 3: Specific Requirements for Magnetic Field Wireless Power Transfer (MFWPT) Systems
- IEC 62764-1 Measurement Procedures of Magnetic Field Levels Generated by Electronic and Electrical Equipment in the Automotive Environment with Respect to Human Exposure

2.1.4 International Commission on Non-Ionizing Radiation Protection (ICNIRP) Publications

Copies of these documents are available at <https://www.icnirp.org/>.

ICNIRP 2010 ICNIRP Guidelines for Limiting Exposure to Time-Varying Electric and Magnetic Fields (1 Hz to 100 kHz)

ICNIRP 2020 ICNIRP Guidelines for Limiting Exposure to Electromagnetic Fields (100 kHz to 300 GHz)

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 C95.1 IEEE Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz
- IEEE C95.3 Recommended Practice for Measurements and Computations of Electric, Magnetic and Electromagnetic Fields with Respect to Human Exposure to Such Fields, 0 Hz to 100 kHz
- IEEE 802.11n IEEE Standard for Information technology - Local and metropolitan area networks - Specific requirements - Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications Amendment 5: Enhancements for Higher Throughput
- IEEE 1609.2 IEEE Standard for Wireless Access in Vehicular Environments - Security Services for Applications and Management Messages

2.1.6 ISO Publications

Copies of these documents are available online at <https://webstore.ansi.org/>.

- ISO 4130 Road Vehicles - Three-Dimensional Reference System and Fiducial Marks - Definitions
- ISO 14117 Active Implantable Medical Devices - Electromagnetic Compatibility - EMC Test Protocols for Implantable Cardiac Pacemakers, Implantable Cardioverter Defibrillators, and Cardiac Resynchronization Devices
- ISO 19363 Electrically Propelled Vehicles - Magnetic Field Wireless Power Transfer - Safety and Interoperability Requirements
- ISO 26262 Road Vehicles - Functional Safety

2.1.7 National Fire Protection Agency Publications

Available from NFPA, 1 Batterymarch Park, Quincy, MA 02169-7471, Tel: 617-770-3000, www.nfpa.org.

NFPA 70 National Electric Code (NEC)

NOTE: The applicable edition of NFPA (70) National Electric Code (NEC) may be called out by the local code and may not be the latest revision.

2.1.8 ITU Publications

Available from International Telecommunication Union (ITU), Place des Nations, 1211 Geneva 20 Switzerland, <https://www.itu.int/>.

ITU-R SM.2110 Guidance on Frequency Ranges for Operation of Non-Beam Wireless Power Transmission for Electric Vehicles

ITU-R SM.2303 Wireless Power Transmission Using Technologies Other than Radio Frequency Beam

ITU-R SM.2451 Assessment of Impact of Wireless Power Transmission for Electric Vehicle Charging on Radiocommunication Services

2.1.9 NIST Publications

Available from NIST, 100 Bureau Drive, Stop 1070, Gaithersburg, MD 20899-1070, Tel: 301-975-6478, www.nist.gov.

NIST Handbook 44 Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices

2.1.10 UL Publications

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

UL 2231-2 Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits: Particular Requirements for Protection Devices for Use in Charging Systems

UL 2594 Standard for Electric Vehicle Supply Equipment

UL 2750 Investigation for Wireless Charging Equipment for Electric Vehicles (under development)

2.1.11 Code of Federal Regulations (CFR) Publications

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

47 CFR Telecommunication

2.1.12 United Nations Publications

Available from <http://www.unece.org/trans/main/wp29/wp29regs1-20.html>.

ECE REG 10 Uniform Provisions Concerning the Approval of Vehicles with Regard to Electromagnetic Compatibility

3. DEFINITIONS

3.1 ALIGNMENT

The relative position of the VA coil and the GA coil.

NOTE: When aligned, the VA coil is within the defined allowed offsets for the WPT system, as described in 8.2.2.

3.2 AMBIENT TEMPERATURE

The ground-level temperature of the air measured at the subsystem under consideration and not in direct sun light.

3.3 CARDIAC IMPLANTABLE ELECTRONIC DEVICE (CIED)

A classification of implanted medical devices comprising pacemakers and other implanted cardiac devices.

3.4 CENTERED POSITION

The position of the VA coil relative to the GA coil when the VA is placed in the middle of the defined X and Y offsets, as described in 6.4.3.

3.5 DYNAMIC WIRELESS POWER TRANSFER (DWPT)

Wireless power transfer (WPT) to and/or from a vehicle while the vehicle is in motion.

3.6 ELECTRIC VEHICLE (EV)

A vehicle intended for highway use, powered by an electric motor that draws current from an on-vehicle energy storage device, such as a battery, which is rechargeable from an off-vehicle source.

3.7 ESSENTIAL AUXILIARY LOAD

An auxiliary load which is required for the proper functioning of the WPT system, such as low voltage power supplies, communication, foreign object detection, or live object protection systems.

3.8 GRID

For the purposes of this document, the connection point for the wireless power transfer system. The connection could be AC or DC and the specifics are dependent on the power levels involved and the infrastructure available.

3.9 GROUND ASSEMBLY (GA)

The portion of a WPT system for electric vehicles that takes energy from a DC or AC grid or other power source and converts it to magnetic fields for capture by a vehicle assembly (VA). The GA consists of GA power transfer functions, communication functions, and auxiliary functions, as needed.

NOTE: A GA can consist of multiple GA modules in some instances.

3.10 GA COIL or GA MAGNETICS

The portion of the GA comprising the litz wire and any magnetic materials that are used to convert the high frequency alternating current from the GA power electronics to an evanescent magnetic field for capture by the VA.

3.11 GA COIL PACKAGE

The physical housed portion of the GA that is located below the vehicle to allow wireless power transfer. It contains the GA coil and any other components, including housings, fasteners, electronic assemblies, and auxiliary systems, as specified by the manufacturer.

3.12 GA POWER ELECTRONICS

The circuitry that takes the input from the grid and converts it to a high frequency alternating current used to energize the GA magnetics.

3.13 GA MODULE

A physical unit that includes GA magnetics and some portion of the GA power electronics. A GA module is used when there is more than one GA coil in a complete GA.

3.14 GA MODULE ARRAY

An arrangement of multiple GA modules. These modules can be energized independently or together to provide a higher power level to a vehicle assembly (VA) than is possible from a single GA module within the array.

NOTE: There might be multiple GA coil packages present when there is a GA module array in some cases.

3.15 GA-VA CLEARANCE

The GA-VA clearance is the vertical distance between the GA surface and the lower surface of the VA coil package. See Figure 3.

3.16 GEOMETRIC CENTER (of the GA Coil or VA Coil)

The spatial X, Y center of the GA or VA coil.

NOTE: The GA coil is defined in 3.10, and the VA coil is defined in 3.34.

3.17 GUIDANCE

The method that provides assistance to the vehicle or driver to navigate into the parking bay/slot. See Section 12.

3.18 HEAVY-DUTY (HD) PLUG-IN ELECTRIC VEHICLE

A four or more-wheeled vehicle propelled by an electric motor drawing current from a rechargeable storage battery or other energy devices for use primarily on public streets, roads, and highways, and rated up to 40000 kg gross vehicle weight (GVW) depending on local requirements.

3.19 IMPEDANCE MATCHING NETWORK (IMN) or COMPENSATION NETWORK

An electrical network that transforms an input impedance to an output impedance.

3.20 INDUCTIVE COUPLER

The coupled system formed by the coil in the GA coil and the coil in the VA coil that allows power to be transferred with galvanic isolation.

3.21 INDUCTIVE COUPLING

The coupled system formed by the coil in the GA coil and the coil in the VA coil that allows power to be transferred with galvanic isolation.

3.22 INTEROPERABILITY CLASS I GA

A product GA which has been verified to meet the interoperability, performance and safety requirements for an Interoperability Class I GA as described in 5.5.1.

3.23 INTEROPERABILITY CLASS II GA

A product GA for deployment in a home garage or locations for a captive fleet and not intended to be generally available to the public. It has been verified to meet the interoperability, performance, and safety requirements for an Interoperability Class II GA, as described in 5.5.2.

NOTE: For proprietary WPT systems not compliant to SAE J2954, refer to safety considerations in this document, UL 2750, IEC 61980-1, and IEC 61980-3.

3.24 LIGHT-DUTY (LD) PLUG-IN ELECTRIC VEHICLE

A three- or four-wheeled vehicle propelled by an electric motor drawing current from a rechargeable storage battery or other energy devices for use primarily on public streets, roads, and highways, and rated at less than 4545 kg gross vehicle weight (GVW).

3.25 MAGNETIC RESONANCE

Inductive wireless power transfer (WPT) that occurs when operating one or more high quality factor coils with their IMN (or compensation network) at or near resonance.

3.26 MODULE ARRAY OFFSET

The offset required between an array of GA modules and VA modules from the geometric center of the array sets.

3.27 NATURAL OFFSET

The offset required between the geometric center points of a given GA coil and VA coil pair to achieve the centered position for power transfer. When the VA and GA coil topologies are the same, the natural offset is generally zero. See 6.4.3 and 12.4.1.

3.28 POWER ELECTRONICS (PE)

The PE is the electronic assembly (assemblies) of electronic devices which controls and converts electric power, acting as an interface between the grid and the GA coil(s) on the infrastructure side and between the VA coil(s) and the vehicle high voltage electrical system.

3.29 PRODUCT GA

An SAE J2954/2 GA for commercialization which has been verified to meet both operational and safety requirements in this document.

3.30 PRODUCT VA

A product VA is a VA that has been developed for series commercialization that has been verified with SAE J2954/2 to meet the performance and safety requirements in this document.

3.31 TEST STATION (VA/GA) COMMUNICATION MODULE

A device which meets the communication requirements of Section 12 and which adds communication capability to test station devices to enable validation testing.

NOTE: There is one version used with the test station GAs and another version used with the test station VAs.

3.32 TEST STATION GA

The GA used to verify the performance of candidate product VAs. The test station GA is listed in Appendix D.

3.33 TEST STATION VA

The test station VA is used to verify the performance of candidate product GAs. The test station VAs are listed in Appendix C.

3.34 VEHICLE ASSEMBLY (VA) COIL

The portion of the VA comprising the litz wire and ferrite material.

3.35 VA COIL GROUND CLEARANCE

The VA coil ground clearance is the vertical distance between the ground surface and the lower surface of the VA coil package. See Figure 2.

3.36 VA COIL PACKAGE

The physical device located on the vehicle which allows wireless power transfer. It contains the VA coil and any other components, including housings, fasteners, electronic assemblies, and auxiliary systems as specified by the manufacturer.

3.37 VA MODULE

A VA coil and any associated electronics packaged together as a single module. This can be combined in an array with other modules within a designated package space to create the VA. Each VA module may be controlled and operated independently as a single unit or together with other modules in the array. When operating together they can provide a higher level of power to the on board battery system than is possible from a single VA module.

3.38 VEHICLE ASSEMBLY (VA)

The equipment on the vehicle consisting of the VA coil, power electronics, control, and communication necessary to safely transfer power to the vehicle.

3.39 VEHICLE GROUND CLEARANCE

The vertical distance between the ground surface and the lowest part of the vehicle underbody.

3.40 WATCHDOG TIMER

A special purpose timer that will reset the system if it has not been periodically serviced by normal activity.

3.41 WIRELESS POWER TRANSFER (WPT)

The transfer of electrical power from the AC supply network to the electric vehicle by contactless means. WPT is a charging system that transfers power across an airgap from a GA to a VA and then rectifies that power into DC voltage to charge the batteries.

3.42 Z MOVER

Mechanism which moves either the GA or the VA to make the gap between the two smaller to improve performance.

4. ABBREVIATIONS

ALSE	Absorber-Lined Shielded Enclosure
CAN	Controller Area Network
CFR	United States Code of Federal Regulations
CIED	Cardiovascular Implantable Electronic Device
D-GA	DWPT Ground Assembly
DWPT	Dynamic Wireless Power Transfer
EAPR	ERS Average Power Rating
EIP	ERS Input Power
EIPR	ERS Instantaneous Power Rating
EMC	Electromagnetic Compatibility
EMF	Electromagnetic Field
EMI	Electromagnetic Interference
EPCR	ERS Power Capacity Rating
ERS	Electric Road System
ESD	Electrostatic Discharge
ESIP	ERS section Input Power
EVCC	Electric Vehicle Communication Controller
EVSE	Electric Vehicle Supply Equipment
FOD	Foreign Object Detection
FCC	Federal Communications Commission (U.S.)
HD	Heavy-Duty
IEC	International Electrotechnical Commission
IMD	Implantable Medical Device
IMN	Impedance Matching Network
ISM	ISM
LIN	Local Interconnect Network
LOP	Live Object (Human) Protection
LTE	Long-Term Evolution
OATS	Open Area Test Site

OBC	On-Board Charger
PE	Power Electronics
SECC	Supply Equipment Communication Controller
SOC	State of Charge (in percent)
UL	Underwriters Laboratories
VAOP	Vehicle Assembly Output Power
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
WPT	Wireless Power Transfer

5. WPT CLASSIFICATIONS

5.1 Applications and Use Cases

Unlike light-duty vehicles, there are almost an infinite number of different types and configurations, along with applications for commercial HD electric vehicles. In this document, some of the more relevant applications will be captured along with common use cases. Future versions of this document will cover additional applications and use cases. Typical applications are defined by the type of work performed and often linked with a typical range of charging times. These applications are listed in Table 1.

Use cases within each application where interoperability is required are a focus of this document. For example for application A, interoperability is necessary in some use cases such as at transfer charging points, but may not be required for other use cases such as at charging stops along a dedicated bus route. Typical use cases within each application that are of interest to this document are discussed further in Section 17 and Appendix A, and include charging stops, dedicated resting places, and overnight parking applications.

Table 1 - SAE J2954/2 typical HD application use cases

A	B	C	D	E	F	G	H
Opportunity charging at bus stops	Depot charging	Highway idling stop	Loading dock	Tractor/trailer parking	Fast charging	Semi-dynamic	Dynamic

For this document, a subset of use cases within applications (A, B, E, and F) discussed below, are included here. These include uses cases representative of bus opportunity charging and others suited to tractor/trailer charging scenarios at parked locations or fast charging stops. Other applications and use cases will be added at a later stage. For example Section 18 and Appendix B consider some of the unique aspects that need to be taken into account for future semi-dynamic and dynamic application use cases (G and H), but these are not directly considered in this first document.

- A: Opportunity charging

The most typical application is a transit bus that drives a standard, recurring route with multiple brief stops and then receives an in-route or opportunity charge at a transit hub located within a city route, thus extending the range beyond what the standard battery pack offers. Alternate cases can include charging that takes place at an available charger that may or may not be shared with other transit agencies.

- B and E: Depot and parked charging

The vehicle is charged during the time it does not have a mission and is parked.

- F: Fast charging stop

The vehicle is charged with high power during a planned stop.

5.2 SAE J2954/2 HD WPT System Power Classes

SAE J2954/2 WPT system power classes WPT4-9 are defined in kW as the output power delivered to the HV battery and load. This method of power rating differs from the SAE J2954 standard for light-duty vehicles. HD WPT systems may comprise more than one GA and VA module all grouped together in a common packaging space as indicated in Appendix A, Figure A5, to achieve the system power classification. For example, a WPT7 system may comprise two GA and VA modules that individually would be classified within the WPT6 class, or four or more modules that individually would be classified within the WPT4 or WPT5 classes.

Table 2 - SAE J2954/2 HD-WPT system power classifications

HD-WPT4	HD-WPT5	HD-WPT6	HD-WPT7	HD-WPT8	HD-WPT9
20 kW	50 kW	75 kW	150 kW	250 kW	500 kW

5.3 SAE J2954/2 HD WPT Z-Classes

The vertical distance over which the power must be transferred is an important parameter for the WPT system specification. Three Z-classes are defined to classify the range of ground clearances over which systems operate and are specified as VA coil ground clearance.

5.3.1 The VA coil ground clearance is the vertical distance between the ground surface and the lower surface of the VA coil package (Figure 2).

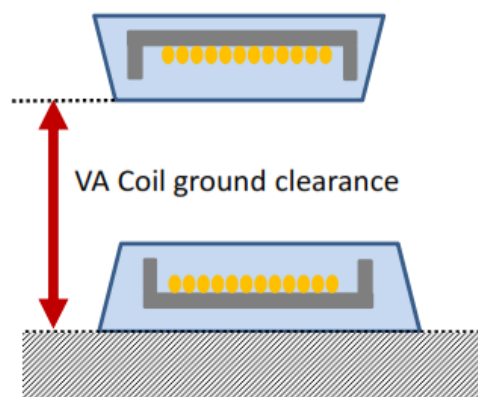


Figure 2 - VA coil ground clearance

The VA coil ground clearance range for each SAE J2954/2 Z-class is specified in Table 3.

Table 3 - Specification of the SAE J2954/2 VA Z-classes

HD Z-Class	VA Coil Ground Clearance Range (mm)
HD Z1	100-150
HD Z2	150-200
HD Z3	200-250

NOTE: Some application classes might not require the full HD Z1-Z3 ground clearance range.

For systems where the GA employs a Z-mover to shorten the gap between the VA and GA to improve coupling for higher power charging, the expected GA-VA clearance is important. This is shown in Figure 3 with Z-mover classes specified in Table 4. While examples of such systems are present in industry and may be desirable for extreme fast charging applications (for example, targeting application class F) as described in Table 1, these GAs will need to be designed with higher coupling and tighter alignment tolerance zones due to system coupling sensitivities to movement. As such, it is expected the GA specifications with Z-movers will be very different from other use cases within this document, and they will therefore be captured in later document release.

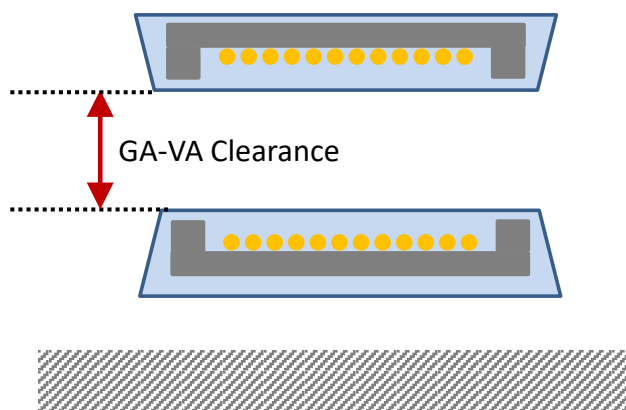


Figure 3 - Clearance for GAs with Z-mover systems

Table 4 - Specification of the SAE J2954/2 GA-VA Z-mover classes

HD Z-Mover-Class	GA-VA Clearance Range (mm)
HD ZM1	20-40
HD ZM2	40-70
HD ZM3	70-110

5.4 Ground Assembly (GA) Installation Categories

GAs could be installed differently relative to the ground surface:

- Above ground mounting of the GA (e.g., private garage or covered parking structure). The GA is mounted on top of a ground surface.
- Flush mounting of the GA (e.g., public parking lot). The outer casing of the GA is flush mounted with the ground surface.
- Buried mounting of the GA. The outer casing of the GA is buried at a distance under the ground surface.

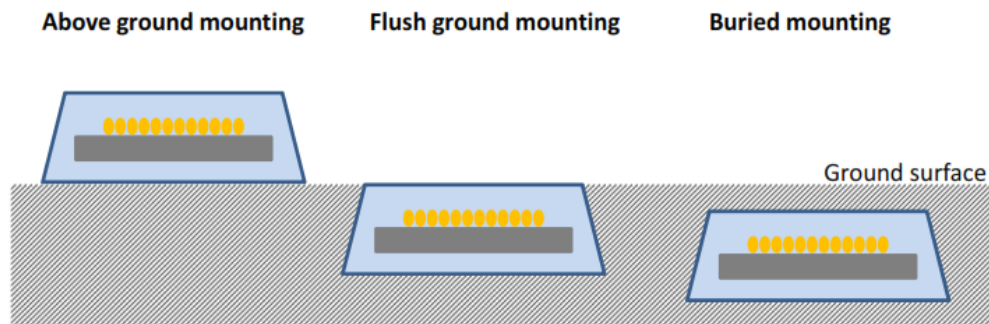


Figure 4 - GA mounting schemes

5.5 SAE J2954 Interoperability Classifications

Product GAs are classified by their intended application interoperability and are expected to be application dependent as in Table 1.

5.5.1 Interoperability Class I GA

Interoperability Class I is the classification of a GA that is intended for a specific application use case but available for public usage. An Interoperability Class I GA will work over the full VA coil ground clearance range and input power range.

Full performance is expected by a VA system when charging over an Interoperability Class I GA. The performance requirements and the test configurations for an Interoperability Class I GA are covered in Section 8.

5.5.2 Interoperability Class II GA

Interoperability Class II is the classification of a GA which is intended to be primarily for a specific application use case, such as a fleet operation or a home system for a specific vehicle or vehicle family. An Interoperability Class II GA may operate over less than the full VA coil ground clearance range and output power range.

Full performance is expected from a specific set of VAs for which this GA was optimized to work with while limited performance is expected from other SAE J2954/2-compliant product VAs that are within the VA coil ground clearance range of the Interoperability Class II GA. There is an expectation of prevention of operation with a VA outside of these ranges. The performance requirements and the test configurations for an Interoperability Class II GA are covered in Section 8.

NOTE: For proprietary WPT systems not compliant to SAE J2954/2, reference safety considerations in this document, UL 2750, IEC 61980-1, and IEC 61980-3.

6. WIRELESS CHARGING SYSTEM FUNCTIONS AND OPERATION

A wireless charging system consists of several functional elements:

- A power transfer function.
- A communication function.
- Safety related functions required to:
 - Protect against damage from heating of metal foreign objects.
 - Protect humans from exposure to electromagnetic fields.

6.1 Power Transfer Functional Description

The WPT system consists of a grid interface, high frequency power inverter, filter, compensation network, power transfer coils, compensation network, filter, rectifier, optional regulator, and communications between the vehicle energy charging/storage system and the grid connected power inverter. The grid interface is similar to an existing EVSE connection for single or three-phase AC power. Figure 5 illustrates the major functional components of an example wireless power transfer system.

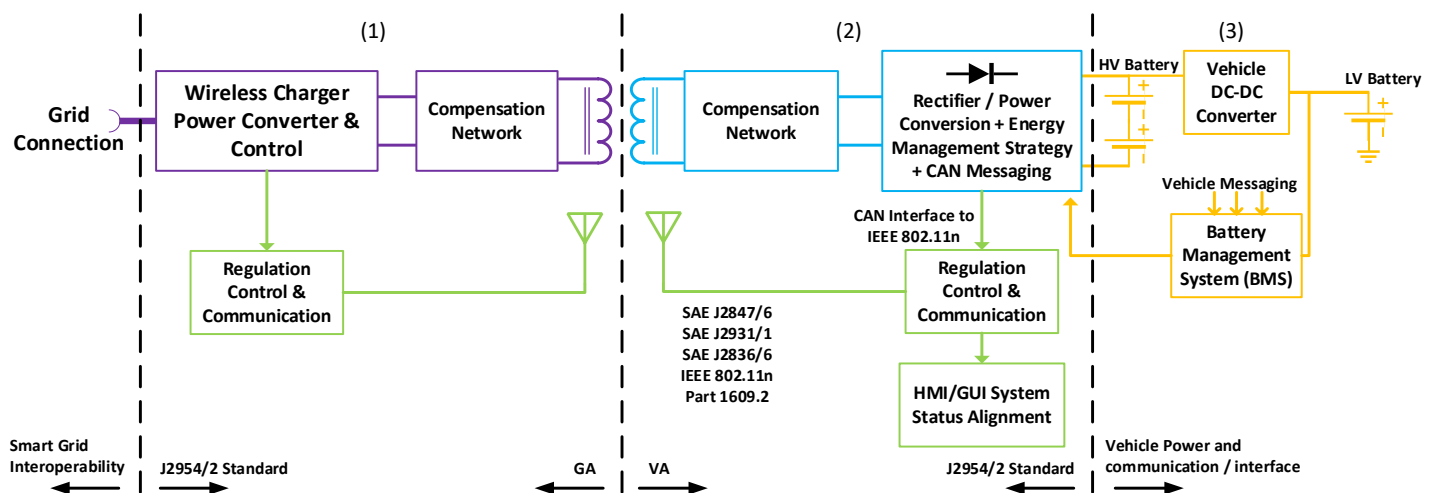


Figure 5 - Typical functional elements of a wireless charging system

6.1.1 Physical Partitions of the Power Transfer Function

Wireless power transfer technology for electric vehicles consists of three major partitions: (1) the grid-connected converter with its attendant GA coil for power coupling, with a communication link to the vehicle system (the GA); (2) the vehicle-mounted VA coil with rectification, filtering components, and charging control power electronics necessary for regulation/safety/shutdown when required, with a communications link to the infrastructure side (the VA); (3) the secondary energy storage system, battery management system components, and associated modules necessary for in-vehicle communications (CAN, LIN) required for battery SOC, charge rate, and other necessary information (the vehicle energy storage system). See Figure 5.

6.1.2 Main Functional Elements of the Power Transfer Function

Proceeding from left to right in Figure 5, the grid connected converter should be situated at a parking space. The function of this converter is to process grid supplied and metered electricity into a nominal frequency current suitable for magnetic coupling under resonance. This converter includes active front-end power electronics to control the power factor. The converter is matched to one (or more) GA coils located on or embedded in the garage floor or parking space.

The vehicle system functional elements consist of a VA coil operating under magnetic resonance with the GA coil and adhering to the requirements of this document, power conversion electronics to process the received energy or to shut down the system under a fault condition, and the interface to the vehicle energy storage system.

6.2 Communication Function

The communication system transfers information between the VA and the GA for the purpose of regulating the level of transmitted power and to communicate enable and inhibit signals depending on vehicle energy storage system status.

In addition to the communication that is mentioned above in support of safe power transfer, bidirectional communication between the GA and VA is utilized for guidance, alignment, positioning, position verification, compatibility verification, and other purposes prior to the start of power transfer. See Section 12 for additional details.

6.3 Safety Functions

Prior to and during power transfer, it is important to detect any objects which might be heated to a dangerous temperature during power transfer. See 16.2.1 for description and requirements regarding detection of foreign objects.

During power transfer, it is important to prevent humans from exposure to harmful electromagnetic fields. While general exposure is covered in Section 10 for accessible regions, exposure in the case of unusual circumstances, such as crawling under the vehicle while power is being transferred, need to be protected against. See 16.2.2 for live object protection (LOP) requirements.

Vehicle components in a WPT system should be designed according to functional safety in ISO 26262 related to possible hazards caused by malfunctioning behavior of safety-related electrical systems, including interaction of these systems. WPT system designs should avoid a single point failure wherever possible.

6.4 Description of Wireless Power Transfer Operation

6.4.1 General

During parking in a space that is equipped with an SAE J2954/2-compliant GA, the driver begins the guidance and alignment process. The GA and the VA exchange information to ascertain compatibility. If compatible, positioning information is exchanged. When the vehicle is within the alignment tolerance area and stopped, information is exchanged to confirm that it is allowable to start power transfer.

Unless the vehicle has confirmed that it is compatible with the GA and that it is within the allowable position tolerance area, the VA should not request power transfer, and the GA should not initiate power transfer.

Following confirmation that the VA coil is properly aligned with the GA coil, the VA should exchange information with the GA to activate and initiate power transfer according to the requests from the vehicle energy storage system. This information is relayed to the GA to set the power level for proper power transfer. Control over the power transfer process can be performed through the vehicle's dedicated charger or directly from the VA using messages provided over the wireless communication path between the GA and VA.

The GA and the VA should ensure their own safe operation with regard to parameters such as temperature, current and voltage. Should an unsafe condition develop, the system should take corrective action, including—if necessary—causing system shutdown and the safe cessation of power transfer.

6.4.2 Wireless Power Transfer Frequency

Since the power transfer systems in this document are based on principles of magnetic resonance, a common power transfer frequency between the GA and the VA should exist.

6.4.2.1 HD Static WPT Frequency

Due to the development nature of this document, there were two frequencies allowed for static HD WPT. The goal in future revisions of SAE J2954/2 to determine one common frequency for a given use-case application.

The static WPT SAE J2954/2 frequency ranges of 22 to 25 kHz or 79 to 90 kHz should be used for wireless power transfer.

6.4.2.2 DWPT Frequency

The DWPT SAE J2954/2 frequency range of 79 to 90 kHz should be used for dynamic wireless power transfer.

6.4.3 Centered Position, Natural Offset, and Module Array Offset

In order to be able to compare performance and determine interoperability, a centered position of the VA coil (or a set of VA coils in a module array) relative to the GA coil (or a set of GA coils in a module array) is described.

The centered position in the XY-plane of a VA with respect to any GA is specified by determining the position of the VA coil relative to the GA coil when the VA is placed in the middle of the defined X and Y alignment tolerance offsets.

In the case where the VA coil topology is the same as the GA coil topology, the centered position is typically the position where the geometric centers of the GA and the VA are aligned.

In the case where the VA coil topology is not the same as the GA coil topology, the centered position may require the use of a “natural offset” relative to the position that aligns the geometric centers of the VA and the GA.

In the case where an array of GA modules and/or VA modules is used to enable higher power levels of WPT, a “module array offset” may need to be applied if the GA and VA module array configurations do not match. In this case, the module array offset is given relative to the geometric centers of the VA and GA module arrays.

NOTE: For communications purposes, the “natural offset” and the “module array offset” can be combined into a single offset vector that is used for alignment.

7. PHYSICAL DIMENSIONS AND PARAMETERS

7.1 GA Coil Dimensions

The length of the GA coil is specified along the direction of travel of the vehicle; i.e., the X direction. The width of the GA coil is specified in the transverse direction of the vehicle, the Y direction.

The actual size of the assembly is determined by system requirements for interoperability and safety. Assembly sizes of future SAE J2954/2 test station devices for interoperability evaluations will be specified in future appendices.

7.2 GA Coil Mounted Height

For above ground mounted systems the GA coil mounted height is the distance from the ground surface to the top surface of the GA coil package outer case (see Figure 6).

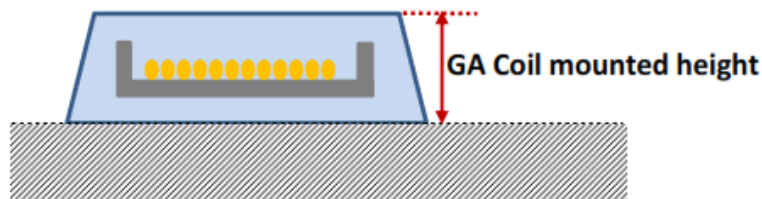


Figure 6 - Definition of GA coil mounted height

The maximum recommended allowable protrusion above the ground surface is 70 mm. This maximum protrusion height may be subject to local installation rules and may be more or less than the value recommended here.

7.3 GA Coil Location

The specified location of the GA coil within a parking space.

7.4 VA Coil Size

The size of a product VA coil is dependent on OEM considerations.

Sizes of the test station VA coils used for interoperability testing will be specified in future appendices.

7.5 VA Coil Ground Clearance

The installed product VA coil ground clearance is dependent on the specific vehicle and conditions such as the loading condition and tire pressure.

7.6 VA Coil Mounting Location

The mounting location of the VA coil on the vehicle is determined by the OEM. See Appendix A for examples of recommended locations.

The geometric center of the VA coil is recommended to be installed on the centerline of the vehicle in the Y direction.

The geometric center of the VA coil in the driving direction (X) is determined by the OEM and could be near the front of the vehicle for forward parking locations or near the rear for reverse parking locations.

8. PERFORMANCE, INTEROPERABILITY, AND SAFETY REQUIREMENTS

8.1 General

The requirements, test configurations, and tests described in this document ensure that the systems meet the interoperability and performance requirements and are safe to operate under normal conditions.

EMC requirements and recommended procedures are covered in Section 9; EMF and touch current requirements are covered in Section 10. Electrical safety requirements and tests are specified in UL 2750 (under development) (see Section 11). Communication and alignment requirements are referenced in Section 12.

The tests to verify conformance with the listed power transfer performance requirements are in Section 15; they ensure the correct degree of interoperability. Unless otherwise specified, they are intended to be test station tests, with one side being test station devices/communication module and the other side being product device candidates. Some tests are intended to be vehicle level tests and are so noted.

All systems, at the system level, require:

- Compatible communication method/sequence/messages.
- The necessary output power to be delivered within the expected operating conditions of the system (e.g., with a GA/VA pair at its centered position and at the specified offsets) while operating within thermal limits over the power transfer duration, and responding safely to any incidents (e.g., FOD/LOP detection).
- Compliance with EMC requirements.
- Compliance with EMF protection requirements.

An Interoperability Class I GA:

- Should meet all performance, safety and EMC requirements with all future application specific SAE J2954/2 normative test station VAs within its application and power class and over all three Z ground clearance ranges.
- Should follow the communications and the control protocols detailed in Sections 12 and 13.
- Should be verified by a national recognized testing lab to meet SAE J2954/2 requirements and should also meet UL 2750 (or equivalent) requirements.
- Should have an applicable “weights and measure” certification and test according to local and/or national regulations (e.g., NIST Handbook 44, PTB, etc.) or equivalent for deployment in a commercial environment.

An Interoperability Class II GA:

- Should meet all performance, safety and EMC requirements with all product VAs it is intended to work with and any future SAE J2954/2 normative test station VAs within its application and power class and over the specified GA ground clearance range.
- Should follow the communication, control, and alignment requirements detailed in Sections 12 and 13 and should use these protocols when operating with all SAE J2954/2-compliant VAs, including the test station VAs.
- Should be certified by a national recognized testing lab as meeting UL 2750 (or equivalent) requirements.

NOTE: A GA can use proprietary alignment, communications, and controls with a specific product VA it is intended to work with, in addition to the requirements listed above.

8.2 Power Transfer Performance Requirements

8.2.1 Test Configurations

Testing procedure is given in Section 15.

8.2.1.1 Product VA

A product VA is intended to be tested with all future SAE J2954/2 normative test station GA dedicated to its application and power class using a test station GA communication module.

8.2.1.2 Interoperability Class I Product GA

An Interoperability Class I GA is intended to be tested with all relevant future application and power class specific normative test station VAs along with a test station VA communication module. As a result, the performance of the Interoperability Class I GA will be verified over all three Z classes, at a full range of power levels, output voltages, and alignment tolerances specific to its application and power class.

8.2.1.3 Interoperability Class II Product GA

An Interoperability Class II GA is tested with the specific VAs it is intended to work with and to work with all application and power class specific normative test station VAs included in future versions of this document.

The Interoperability Class II GA is tested with only the future normative test station VAs which are specified to operate at the same VA coil ground clearance as the GA. Communication (Section 12) provides information to the GA about the VA coil ground clearance. The GA should not begin power transfer (for Interoperability Class II) if the VA is outside the GA's specified and tested VA coil ground clearance range.

8.2.2 Alignment Tolerance

The SAE J2954/2 WPT system (for any interoperability class) should operate safely over a range in X, Y, and Z to allow for parking misalignment and variations in vehicle height. The worst-case misalignment in the XY plane occurs when both X and Y are at a maximum distance from the centered position. For GA and VA WPT systems comprising more than one module within the designated packaging space (as indicated in Appendix A, Figure A5), the alignment and tolerances shown in the tables below are taken from geometric center of all of the VA and GA module packages and is called the "module array offset."

The alignment tolerance for HD applications depends on the application classes A-H as defined in 5.1 (see Table 1). Tolerances for applications G and H (semi dynamic and dynamic) are discussed in Section 18. Stationary power transfer applications without Z-movers within classes A, B, C, E, and F are expected to have similar alignment tolerances, roll, pitch and yaw. Application class D is for power transfer systems designed to provide power to the rear of a vehicle under docking application and may require different specifications for alignments, roll, pitch, and yaw.

8.2.2.1 SAE J2954/2 Alignment Tolerance for Product VAs under Stationary Power Transfer

Table 5 - X, Y, Z operating range requirements for product VAs

Application Classes A, B, C, E, F		Application Class D	
Offset Direction	Value (mm)	Offset Direction	Value (mm)
ΔX	± 100	ΔX	--
ΔY	± 100	ΔY	--
Z range	Specified by manufacturer	Z range	Specified by manufacturer