SURFACE VEHICLE STANDARD

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(R) Wireless Power Transfer for Light-Duty Plug-in/Electric Vehicles and Alignment Methodology

RATIONALE

Electrified powertrains, specifically battery electric and plug-in electric (BEV/PHEV) vehicles, are projected to become more prevalent in production internationally due to environmental factors (such as GHG, CO_2 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 benefits of electrified powertrains are eliminating or significantly reducing local emissions while increasing the overall well-to-wheels efficiency. In addition, automated 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 BEV/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 automated vehicles enabling autonomous parking with alignment assistance and automated charging (in all weather conditions, such as rain or snow).

This standard is an evolution of SAE J2954, which is based on actual bench testing and vehicle interoperable data taken around the world. SAE J2954 is meant to harmonize with standards developing organizations in order to make a world-wide WPT standard to 11.1 kVA, useful for commercial applications. The SAE Task Force (TF) harmonized with numerous standard organizations (AAMI, ANSI, CISPR, GB, ISO, IEC, UL, VDA) towards these goals and specifically the documents produced in ISO and IEC. The SAE J2954 TF has worked directly with government agencies to gain feedback (U.S. DOE, U.S. FCC, U.S. FDA) and testing actual systems both in government laboratories and private. The SAE J2954 TF has documented the lessons learned from the first stage of testing with real OEM systems in accompanying SAE technical data reports (see Section 2). It is essential that data-based standards are used as a basis for commercialization of this technology.

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
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SAE WEB ADDRESS:

For more information on this standard, visit
ds/content/J2954_202010

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1. SCOPE

The SAE J2954 standard establishes an industry-wide specification that defines acceptable criteria for interoperability, electromagnetic compatibility, EMF, minimum performance, safety, and testing for wireless power transfer (WPT) of light-duty plug-in electric vehicles. The specification defines various charging levels that are based on the levels defined for SAE J1772 conductive AC charge levels 1, 2, and 3, with some variations. A standard for WPT based on these charge levels enables selection of a charging rate based on vehicle requirements, thus allowing for better vehicle packaging and ease of customer use. The specification supports home (private) charging and public wireless charging.

In the near term, vehicles that are able to be charged wirelessly under SAE J2954 should also be able to be charged conductively by SAE J1772 plug-in chargers.

SAE J2954 addresses unidirectional charging, from grid to vehicle; bidirectional energy transfer may be evaluated for a future standard. This standard is intended to be used in stationary applications (charging while vehicle is not in motion); dynamic applications may be considered in the future. In this version, only above-ground (surface mounted) installations are covered; flush mounted installations have been discussed but are not yet ready for inclusion.

SAE J2954 contains requirements for safety, performance, and interoperability. It also contains recommended methods for evaluating electromagnetic emissions, but the requirements and test procedures are controlled by regulatory bodies. Development of the interoperability requirements in this standard employed a performance-based evaluation of candidate designs using a standardized test station and procedures, resulting in defining reference devices which are used to determine acceptable performance of products.

1.1 Wireless Power Transfer General System Description

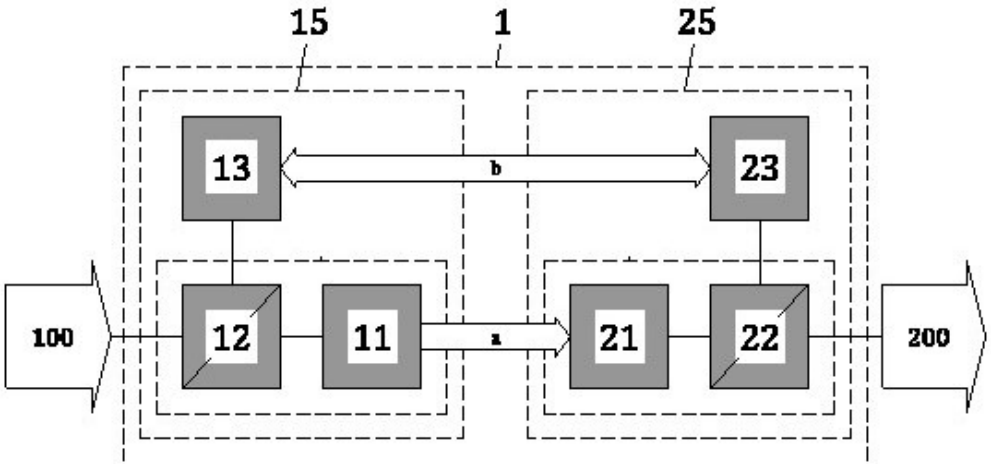
WPT systems consist of a Ground Assembly (GA) Subsystem and a Vehicle Assembly (VA) Subsystem as depicted in Figure 1. The GA broadly consists of a mains-connected Power Factor Correction (PFC) converter, followed by a DC-AC inverter, a filter, and Impedance Matching Network (IMN) that is connected to 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 charging 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 VA (25), the power desired to charge the battery is determined.
- 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 charges the batteries.
- This process continues until the VA signals a different power level requirement, including no power required, as would be the case when the batteries are adequately charged.



KEY			
1	WPT system	21	VA coil
11	GA coil	22	VA electronics
12	GA electronics	23	Vehicle communication controller
13	Base communication controller	25	VA - vehicle subsystem
15	GA - ground subsystem	200	Power to battery
100	Power from grid	b	Communication
a	Wireless power flow		

Figure 1 - SAE J2954 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 J1211	Handbook for Robustness Validation of Automotive Electrical/Electronic Modules
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 between Wireless Charged Vehicles and Wireless EV Chargers
SAE J2931/6	Signaling Communication for Wirelessly Charged Electric Vehicles
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 http://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 CISPR Publications

Available online at https://www.iec.ch/dyn/www/f?p=103:30:27264173884763::::FSP_ORG_ID,FSP_LANG_ID:1412,25.

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

2.1.4 IEC Publications

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

IEC 60204-1 Safety of Machinery - Electrical Equipment of Machines - General Requirements

IEC 60990 Methods of Measurement of Touch Current and Protective Conductor Current

IEC 61000-3-2 Electromagnetic Compatibility (EMC) - Part 3-2: Limits for Harmonic Current Emissions (Equipment Input Current = 16 A per Phase)

IEC 61000-3-3 Electromagnetic Compatibility (EMC) - Part 3-3: Limits - Limitation of Voltage Changes, Voltage Fluctuations and Flicker in Public Low-Voltage Supply Systems, for Equipment with Rated Current ≤16 A per Phase and not Subject to Conditional Connection

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 61000-3-11 Electromagnetic Compatibility (EMC) - Part 3-11: Limits - Limitation of Voltage Changes, Voltage Fluctuations and Flicker in Public Low-Voltage Supply Systems - Equipment with Rated Current ≤75 A and Subject to Conditional Connection

IEC 61000-3-12 Electromagnetic Compatibility (EMC) - Part 3-12: Limits - Limits for Harmonic Currents Produced by Equipment Connected to Public Low-Voltage Systems with Input Current >16 A and ≤75 A per Phase

IEC 61000-4-2 Electromagnetic Immunity - Testing and Measurement - Electrostatic Discharge

IEC 61000-4-3 Electromagnetic Immunity - Testing and Measurement - Radiated EM Immunity

IEC 61000-4-4 Electromagnetic Compatibility (EMC) - Part 4-4: Testing and Measurement Techniques - Electrical Fast Transient/Burst Immunity Test

IEC 61000-4-5 Electromagnetic Compatibility (EMC) - Part 4-5: Testing and Measurement Techniques - Surge Immunity Test

IEC 61000-4-6 Electromagnetic Compatibility (EMC) - Part 4-6: Testing and Measurement Techniques - Immunity to Conducted Disturbances, Induced by Radio-Frequency Fields

IEC 61000-4-8 Electromagnetic Compatibility (EMC) - Part 4-8: Testing and Measurement Techniques - Power Frequency Magnetic Field Immunity Test

IEC 61000-4-11 Electromagnetic Compatibility (EMC) - Part 4-11: Testing and Measurement Techniques - Voltage Dips, Short Interruptions and Voltage Variations Immunity Tests

IEC 61000-4-34 Electromagnetic Compatibility (EMC) - Part 4-34: Testing and Measurement Techniques - Voltage Dips, Short Interruptions and Voltage Variations Immunity Tests for Equipment with Mains Current More Than 16 A per Phase

IEC 61000-6-2 Electromagnetic Compatibility (EMC) - Part 6-2: Generic Standards - Immunity for Industrial Environments

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 Standard for Measurements

IEC 61980 -1/-2/-3 Electric Vehicle Wireless Power (WPT) Systems - Part 1: General Requirements, Part 2: Specific Requirements for Communication between Electric Road Vehicle (EV) and Infrastructure, Part 3: Specific requirements for the Magnetic Field Wireless Power Transfer 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

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

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

ICNIRP 1998 Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic and ElectroMagnetic Fields (up to 300 GHz)

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)

2.1.6 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

2.1.7 ISO Publications

Copies of these documents are available online at http://webstore.ansi.org/.

ISO 4130 Road Vehicles - Three-Dimensional Reference System and Fiducial Marks - Definitions

ISO 23374 Intelligent Transport Systems - Automated Valet Parking Systems (AVPS) - System Framework, Communication Interface, and Vehicle Operation

ISO 7637-2 Road Vehicles - Electrical Disturbances from Conduction and Coupling - Part 2: Electrical Transient Conduction Along Supply Lines Only