



SURFACE VEHICLE RECOMMENDED PRACTICE

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Electric Power Take-Off Interface for Commercial Vehicles

RATIONALE

Emerging all-electric and electric hybrid commercial vehicle technologies have created an opportunity for accessory and body builder equipment to connect to and operate from the chassis stored energy. The standardization of the connection and operation methods benefits the industry for interoperability, service, and safety.

1. SCOPE

This SAE Recommended Practice (RP) covers the general guidelines for conductive power transfer of high voltage Direct Current (DC) between OEM commercial truck chassis electrical systems and electrically powered body accessory equipment. The OEM chassis can have an EV drive train or be a hybrid chassis with or without a connection for traditional mechanical Power Take-Off (PTO). The chassis can include use of range extension systems. Voltage levels are defined as greater than 60 VDC and include typical EV chassis voltage ranges up to and including 1500 VDC based on selected component capabilities. It also covers limited functional requirements for the connection systems, body builder communication modes, and suggested operational modes. The scope of the Electric Power Take-Off (ePTO) physical electrical connection will be limited to a recommendation of the interface concept, space claim, and service features and will leave connector features and design open for future definition.

Although many of the elements defined here may apply, including addendum, the scope does not include sufficient content to define a connector for linking a Class 8 tractor to a semi-trailer or truck to trailer in any class using functional voltages as defined below. The scope does not include high-cycle connections or other applications where the connections to ePTO are separated daily or outside of annual maintenance inspections. Requirements for bidirectional power flow on the ePTO connection are out of scope in this document but could be accommodated within the future definition of ePTO applications. These application scope limits were reviewed by the Task Force and tabled for future development.

1.1 Purpose

The purpose of this new RP is to define and provide guidance for high voltage DC accessory equipment connections between commercial electric truck OEMs providing the connections and Body Builders installing electrically powered equipment. This equipment was traditionally self-powered by secondary combustion engines or powered off of the vehicle mechanical PTO. Use of the vehicle or hybrid system battery for integrated body builder equipment use is preferred over addition of multiple or secondary stored energy power sources. The RP also allows for the ability for the chassis and the body service providers to disconnect and service the body equipment separate from the chassis for individual service needs.

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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 J1455_201703	Recommended Environmental Practices for Electronic Equipment Design in Heavy-Duty Vehicle Applications
SAE J1742	Connections for High Voltage On-Board Vehicle Electrical Wiring Harnesses - Test Methods and General Performance Requirements
SAE J1766	Recommended Practice for Electric, Fuel Cell and Hybrid Electric Vehicle Crash Integrity Testing
SAE J1939	Serial Control and Communications Heavy-Duty Vehicle Network - Top-Level Document
SAE J1939-76	SAE J1939 Functional Safety Communications Protocol
SAE J1939DA	J1939 Digital Annex
SAE J1960	Accelerated Exposure of Automotive Exterior Materials Using a Controlled Irradiance Water-Cooled Xenon Arc Apparatus
SAE J2527	Performance Based Standard for Accelerated Exposure of Automotive Exterior Materials Using a Controlled Irradiance Xenon-Arc Apparatus
SAE J3176	Cable Marking for Circuit Identification in Multi-Voltage Power Distribution Systems

2.1.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM B117	Standard Practice for Operating Salt Spray (Fog) Apparatus
ASTM G155-05a	Standard Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials

2.1.3 DIN Publications

Copies of these documents are available online at <https://www.din.de/en/>.

DIN 40050-9	Road Vehicles; Degrees of Protection (IP-Code); Protection Against Foreign Objects; Water and Contact; Electrical Equipment
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2.1.4 Federal Motor Vehicle Safety Standards (FMVSS)

Available from U.S. Department of Transportation, National Highway Traffic Safety Administration, Safety Assurance, Office of Vehicle Safety Compliance, 400 7th Street, SW, Room 6111, Mail Code NSA-30, Washington, DC 20590, www.nhtsa.gov.

FMVSS 305 Electric Powered Vehicles: Electrolyte Spillage and Electrical Shock Protection

2.1.5 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 60068-2-52 Salt Mist Testing

IEC 60529 Degrees of protection provided by enclosures (IP Code)

IEC 61508 Functional safety of electrical/electronic/programmable electronic safety-related systems (E/E/PE, or E/E/PES)

2.1.6 ISO Publications

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

ISO 6469-3:2021 Electrically propelled road vehicles - Safety specifications - Part 3: Electrical safety

ISO 19642 Road vehicles - Automotive cables

ISO 20653 Road vehicles - Degrees of protection (IP code) - Protection of electrical equipment against foreign objects, water and access

ISO 23316-2 Tractors and machinery for agriculture and forestry - Electrical high-power interface 700 V DC / 480 V AC - Part 2: Physical interface

ISO 26262 Road vehicles - Functional safety

2.1.7 UL Publications

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

UL 94 Standard for Safety of Flammability of Plastic Materials for Parts in Devices and Appliances

2.1.8 Other Publications

LV 123 Electrical Characteristics and Safety of High-Voltage Components in Road Vehicles

LV 215 Motor Vehicle High-Voltage Contacts

2.2 Related Publications

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

2.2.1 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 J1127	Low Voltage Battery Cable
SAE J1654	Unshielded High Voltage Primary Cable
SAE J1908	Electrical Grounding Practice
SAE J2202	Heavy-Duty Wiring Systems for On-Highway Trucks
SAE J2840	High Voltage Shielded and Jacketed Cable
SAE/USCAR-2	Performance Standard for Automotive Electrical Connector Systems
SAE/USCAR12-5	Electrical Connector Design Criteria

2.2.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM B700	Standard Specification for Electrodeposited Coatings of Silver for Engineering Use
ASTM G153	Standard Practice for Operating Enclosed Carbon Arc Light Apparatus for Exposure of Nonmetallic Materials
ASTM G154	Standard Practice for Operating Fluorescent Ultraviolet (UV) Lamp Apparatus for Exposure of Nonmetallic Materials

2.2.3 ATA Technology Maintenance Council (TMC) Publications

Available from ATA/TMC, 950 N Glebe Road, Suite 210 Arlington, VA 22203, Tel: 703-838-1763, <https://tmc.trucking.org/>.

RP 170	Chassis to Body Electrical Interface Guidelines for Refuse Trucks
RP 173	Design Guidelines for ECM Harness and Connectors
RP 1427	Standard Body-To-Chassis Connector

2.2.4 CSA Group Publications

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

CSA C22.2	Adhesive Labels
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2.2.5 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 62477-1 Edition 2.0 2022-05 Safety requirements for power electronic converter systems and equipment

2.2.6 ISO Publications

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

ISO 1456 Metallic and other inorganic coatings

ISO 2081 Metallic and other inorganic coatings - Electroplated

ISO 2093 Electroplated coatings of tin

ISO 9227 Corrosion tests in artificial atmospheres - Salt spray tests

2.2.7 UL Publications

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

UL 969 Standard for Marking and Labeling Systems – Label Durability

3. DEFINITIONS

3.1 ACTIVE DISCHARGE EVENT

Reduction of DC bus voltage to less than 60 VDC within 5 seconds when high voltage DC bus is disabled. This can be for the entire chassis or, if enabled by design, isolated accessory or body equipment subsystems. Active discharge should be triggered in any ePTO fault conditions defined as Critical by the Chassis or Body Original Equipment Manufacturer, including the loss of Low Voltage and/or messaging communications.

3.2 AUXILIARY ePTO POWER CONNECTIONS

Refers to the vehicle chassis connection system, equipment cables, and body builder connection system that provides High Voltage DC power to the high voltage auxiliary devices on the truck or trailer and includes, at a minimum, low voltage conductors for a high voltage interlock (HVIL) signal. This is intended to be a dedicated connection, implemented with off-the-shelf or dedicated components that are aligned with the recommendations in this document. In the transitional time period, connectors with Main Power connections and HVIL only may be used for ePTO, or in some cases, terminal connections within the chassis PDU may be utilized. Signal and low voltage connections other than HVIL are defined as Auxiliary functions of the ePTO connection.

3.3 AUXILIARY ePTO BODY BUILDER SIGNALS CONNECTION

As used in this document, it refers to the chassis to body builder connection for low voltage power and chassis signals. These signals include SAE J1939 and other functional and safety signals as recommended in this document.

3.4 BODY

The Body consists of the box, bed, utility components, accessory and auxiliary systems, or any other structures or equipment added to the Chassis subsystem as manufactured by the Chassis Original Manufacturer.

3.5 BODY DISCONNECT REQUEST (BDR)

The Body Disconnect Request is a function initiated by the Body equipment or accessory power unit connected to the Chassis ePTO. The BDR initiates a high voltage disconnect between the Chassis ePTO output and the Body equipment ePTO input. The result is that the Chassis can continue to have power to the drivetrain if possible while the Body equipment remains disconnected and any voltage present on the Body system is actively discharged to below 50 VDC.

3.6 CABLE PLUG

The cable plug is part of the cable assembly. This may include a mating connector or terminal connections to be mated to the chassis ePTO connections or a header or in-line assembly as determined by the chassis manufacturer.

3.7 CHASSIS

The frame, powertrain, and cab subsystems that are part of a completed vehicle assembly when combined with a Body and associated accessory or auxiliary power subsystems and functions.

3.8 COUPLING CYCLE

One coupling cycle is coupling and uncoupling a plug and receptacle.

3.9 CONNECTOR POSITION ASSURANCE (CPA)

Connector Position Assurance is a feature of an electrical connector that includes a secondary latch or locking system that can only be actuated when the connector is fully engaged to the mating connector. It acts to retain the mated components and assure that un-mating can only occur when the specified release mechanism is activated.

3.10 CRASH EVENT

A Crash Event is typically detected by the Chassis through sensors and systems resulting in a vehicle response, activation of safety systems, and in some cases, event recording and data capture.

3.11 ePTO

The term “ePTO” shall be defined as an Electric Power Take-Off function of the EV chassis power system. This connection is typically a direct connection to the vehicle DC bus power distribution system. The ePTO is the DC connection. The ePTO application can range from direct power conversion to mechanical systems or exported energy. This is not a hydraulic or rotational function as a general definition.

3.12 ePTO APPLICATIONS

These are the many applications of ePTO including pumping, hydraulic power, transport refrigeration, motor and actuator functions, and the power conversion equipment required for exported power beyond the vehicle boundary.

3.13 EXPORTED POWER APPLICATION

Exported power is typically defined as power conversion from the vehicle high voltage battery to an outlet or function supplied as off-board/ex-vehicle for power tools, job site power, or as a backup generator for temporary power transfer. These functions and applications are outside of the boundary of the vehicle chassis and body.

3.14 HIGH VOLTAGE INTERLOCK LOOP (HVIL)

The HVIL function is a feature of the high voltage system controls on a Chassis and any connected Body ePTO-powered equipment as well as other integrated and accessory features connected to battery power systems associated with hazardous voltages. The feature is implemented on connector systems designed for high voltage power transfer and is generally implemented in a manner where disconnection of the high voltage connector results in an independent low voltage signal being broken. This broken signal results in a system response that can include a high voltage system shutdown and an active discharge of residual voltage.

3.15 MANUFACTURER IDENTIFICATION

Devices conforming to this document shall be identified with the manufacturer's identification. The device may include the model or part number.

3.16 PASSIVE DISCHARGE EVENT

Reduction of DC bus voltage to less than 60 VDC within 120 seconds when high voltage DC bus is disabled typically without a fault condition present. This can be for the entire chassis or, if enabled by design, isolated accessory or body equipment subsystems.

3.17 RECEPTACLE

The receptacle consists of the connector socket, its housing, and a cover which latches the cable plug in place.

3.18 REVISION AND STANDARD ALIGNMENT LABEL

Label Format to be used if suppliers add standards to which the device conforms to product identification common to SAE:

XYZ Corp.
SAE J3253
Month/year

3.19 SERVICEABLE

A serviceable part is one that can be removed with reasonable force and reinstalled without visible damage.

3.20 SAE DESIGNATION

Devices conforming to this document shall be visually differentiated by connector type.

3.21 SAE ePTO LEVEL

This is defined as "SAE ePTO Level" 1-3 (new to this document) and is defined by the maximum current capacity of the connection or total power at maximum current and voltage.

3.22 TERMINAL POSITION ASSURANCE (TPA)

Terminal Position Assurance is a feature of a wire terminal or contact design incorporated into a connector housing that includes a secondary lock mechanism that can only be engaged when the terminal or contact is properly inserted and seated within the connector housing. If the terminal is not properly inserted, the lock mechanism will not engage fully and will indicate to the assembler that the terminals are out of place and need to be inspected and re-seated.

4. DESIGN INTENT, LIFE CYCLE, CONTACT, AND SIGNAL DEFINITION

4.1 Design Intent

Cable plugs, bulkheads, and receptacles to be associated with ePTO functions within a fixed-chassis design as in a rigid or straight truck or tractor chassis are recommended to be designed to conform to the performance requirements of this document. It is anticipated that future development may align to create a standardized connector or connectors for this functionality. At this time, connector topology and other features may be defined by the connector manufacturer. This document provides guidance and best practices in a forward-looking manner. Applications that span tractor to trailer or that are high frequency mate/un-mate applications are considered for some design elements but are out of scope for environment and design durability definitions in this document.

4.2 Design Life Cycle

Cable plugs utilized for ePTO connections should be designed to mate to a compatible component in either a bulkhead or in-line connection. This connection, as applied in a chassis application, shall support no fewer than 50 lifetime cycles without plating wear-through of top finish plating. This limited duty cycle count is based on one to two yearly mating cycles focused on maintenance and inspection. The latch mechanism shall be constructed to latch and release without interference. When mated, the connector set shall meet the required environmental standards listed under the connector design requirements. If a connector is used for daily connection sequencing between the chassis and body components, much higher cycle life (5000 to 10000+) will be required and is currently out of scope of this document.

4.3 Indexing

The cable plugs and receptacles used for ePTO shall be designed with an indexing feature. Indexing is required to ensure proper electrical mating and provide Poka Yoke, mistake-resistant, connection system. Force required to overcome mismatched indexing features in a connector pair shall exceed 120 N.

4.4 Terminal Materials and Finish

Current-carrying components of terminals shall be constructed of copper or copper alloy. Contact finish depends on current rating. Circuits intended to carry less than 2 A shall have gold finish. Circuits carrying between 2 and 20 A shall have tin finish. Circuits carrying greater than 20 A and up to 50 A should be evaluated for finish based on application and manufacturer's recommendations. Circuits carrying 50 A or above shall have silver finish. Connector design should follow best practices for the minimization of intermetallics. Plating shall not exhibit wear through of top finish prior to the lifetime connection cycle count.

4.5 Wiring Circuits and Power Rating Levels

The function and color code of each circuit is shown in Table 1. The location of each circuit is shown in Figures A1 and A4. The wire color code refers to the color of the insulation on the conductors. The receptacle and cable plug shall be constructed so that the terminals can accommodate the following energy requirements and/or listed wire sizes:

4.5.1 Main Power: 2 Pins

Main power connection between vehicle chassis DC bus and body builder accessory equipment on straight truck chassis or as a connection between tractor and on-board accessory equipment or to a semi-trailer. Voltage between 60 and 1500 VDC. The three suggested levels of connection ampacity based on applications surveyed include 50 A, 100 A, and 200 A DC. A Blade-style terminal is suitable for 50 A connection. 100 A and 200 A should consider round pin terminals.

4.5.2 Auxiliary Power: 2 Pins

Connection to vehicle DC power for controls. Voltage less than 60 V, typically 12 V or 24 V nominal. Will be rated to 48 V nominal to align with SAE Multi-voltage definition. 12 AWG minimum wire gauge. This connection may include constant power or power upon request/wake/activation by body or chassis.

4.5.3 Control Area Network (CAN): 2 Pins

ePTO Functionality shall include bidirectional communication between the chassis and body systems. SAE J1939 is to be utilized. Wiring shall follow SAE J1939 physical layer standard. Accommodates both shielded and unshielded networks, but no shield pin or shield pass-through will be provided at the connector.

4.5.4 High Voltage Interlock (HVIL): 2 Pins

The High Voltage Interlock pins signal that the high voltage connectors are properly mated. The HVIL pins can be configured as a pass-through cable or as a shunt. Power will be applied to the high voltage pins only after the HVIL loop is connected and confirmed by the system controller. The connector contacts will be last to mate, first to break in the coupling sequence. When the HVIL circuit is disconnected, the result can be that the complete vehicle or an isolated circuit is disabled. A broken HVIL loop signals all affected high voltage contactors to open and to initiate active discharge of the DC bus. Active discharge should bring the DC bus to less than 60 V in under 5 seconds.