Draft ePTO specification Connection 0.1.0

Table of Contents

Table of Figures

Table of Tables

1 Document History

Date	Changes/Additions	Version
2022-07-04	Creation of document	0.0.1
2023-05-20	Review of the document	0.0.2
2023-07-31	Review of the document	0.0.3
2023-10-10	Final draft	0.1.0

2 Introduction

2.1 Abbreviations

Abbreviation	Description
ePTO	Electric Power Take-Off
OEM	Original Equipment Manufacturer
EPBC	Equipotential Bonding Conductor
HPI	High Power Interface
HV	High Voltage (class B)
REESS	Rechargeable Electrical Energy Storage System
BEV	Battery Electric Vehicle
PE	Protective Earth
AC	Alternating Current
DC	Direct Current
REESS	Rechargeable Energy Storage System
HVIL	High-Voltage Interlock Loop
IMD	Insulation Monitoring Device
LV	Low Voltage
BDR	Body Down Request
GND	Ground
CAN	Controller Area Network
EMC	Electromagnetic Compatibility

2.2 Definitions

Abbreviation	Term	Description
M	Mandatory	It is a must
O	Optional	It is up to each OEM to decide if they want to implement this information or not

2.3 References

Document name
SAE J1939DA
UN ECE R 10
UN ECE R 100
IEC 60269
IEC 60664-1
IEC 62196-3
ISO 6469-3
ISO 6722-1
ISO 12098
ISO 16750-3
ISO 20653
ISO 23316-1
ISO 23316-2
Draft ePTO Signalling Specification V.0.1.0
Draft Technical Supplement V 0.1.0

3 General remarks

ePTO gives the opportunity for external body builders to power their equipment from the energy storage of an electrified vehicle propulsion system. The vehicles can be i.e., hybrids, battery electric or fuel cell vehicles.

There are three main types of ePTO: Electrical DC connection, electrical AC connection and mechanical power from an electrical machine.

The ePTO Specification specifies physical and logical interface requirements that provide interoperability and cross compatibility for systems and equipment.

This specification is focusing on a customer pluggable DC connection between truck and trailer/semitrailer.

Currently out of scope is the implementation of HV energy sources (batteries, e-axles, etc.) at the trailer/semitrailer.

As of today, the prerequisite for using HV consumers within a trailer/semitrailer supplied by the REESS of a BEV-truck is a galvanic separation of the HV rails of the truck and the trailer/semitrailer (see UN ECE R 100). General remarks will be given in order to support HV safety in a separate document ("draft technical supplement V 0.1.0).

The OEMs (Body and Truck manufactures) have to carry out safety investigations according to the valid standards for their individual HV architectures.

4 Physical interface

4.1 HV Connector

The ISO 23316-2 defines a physical interface which is the base for this specification.
Any forces of the mating and unmating process for the operator shall not exceed 100 N over lifetime.

The connector shall be mated and unmated without additional tools.

In the plugged state the connector shall be retained by a mechanical locking device (latch).

There shall be two distinguished actions necessary to mate and unmate.

Remark:

During unmating the handle or lever shall make the connector move in a way that by the time the HVIL is opened the connector still shall be mechanically guided and retained by the lever. Only moving the lever fully to the end position for open, it shall allow taking out the connector from the header.

Additional requirements for insulation coordination and dielectric withstand voltage need to be added to enable voltages up to 1500 VDC.

The HV connector shall support all defined power classes. There is only one layout supported and cross sections of the contacts (HV Pins) are defined according to the maximum amperage.

The physical interface has to comply with ISO 6469-3.

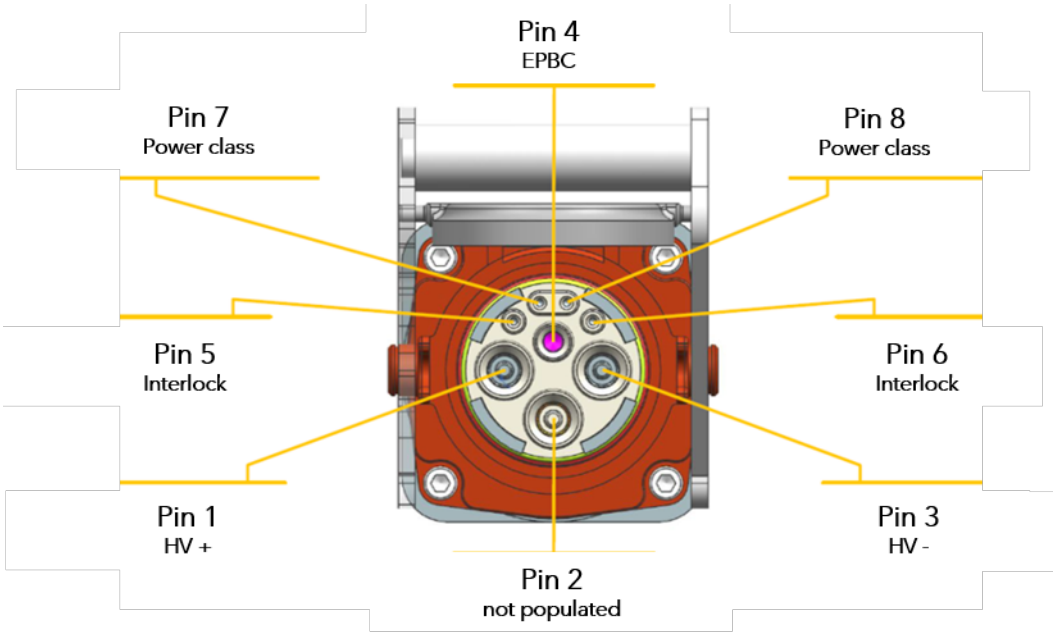

Figure 1: Example based on the ISO 23316-1

Revised pinning table:

Pin	Mandatory signal
1	HV +
2	Shall be not populated
3	HV -
4	EPBC
5	HVIL
6	HVIL
7	Power class
8	Power class

Table 1: Pinning of the HV connector

Pull-out force of crimped pins (LV contacts) shall be 150 N for 1.5 mm^2 (acc. ISO 6722-1).
Other cross section accordingly.

Figure 2: Example for plug (left side – trailer) – receptacle (right side – truck)

A parking position for the plug is recommended.

The ePTO Connector shall be mechanically different to the AEF connector to avoid misuse and mismatch (e.g., with agriculture machinery).

4.1.1 Connector requirements

The maximum weight of the plug (without cable) is 10kg.

Pin 1 is HV-plus, Pin 3 is HV-minus, Pin 2 shall not be populated.

The high voltage power connection between truck and trailer/semitrailer shall consist of a header connector located at the truck and a mating plug physically connected to the trailer/semitrailer.

The following requirements, features and descriptions in this document shall be valid for both items where applicable.

The receptacle should be screwed to a connection box at the truck side.

4.1.2 General function description

The connector is not part of the electric drive system of the vehicle due to restriction of ECE R100. For further details see the document "draft technical supplement V 0.1.0.pdf".

It shall support easy and safe customer pluggable HV power supply for trailer/semitrailer consumers.

4.1.3 Detailed function description

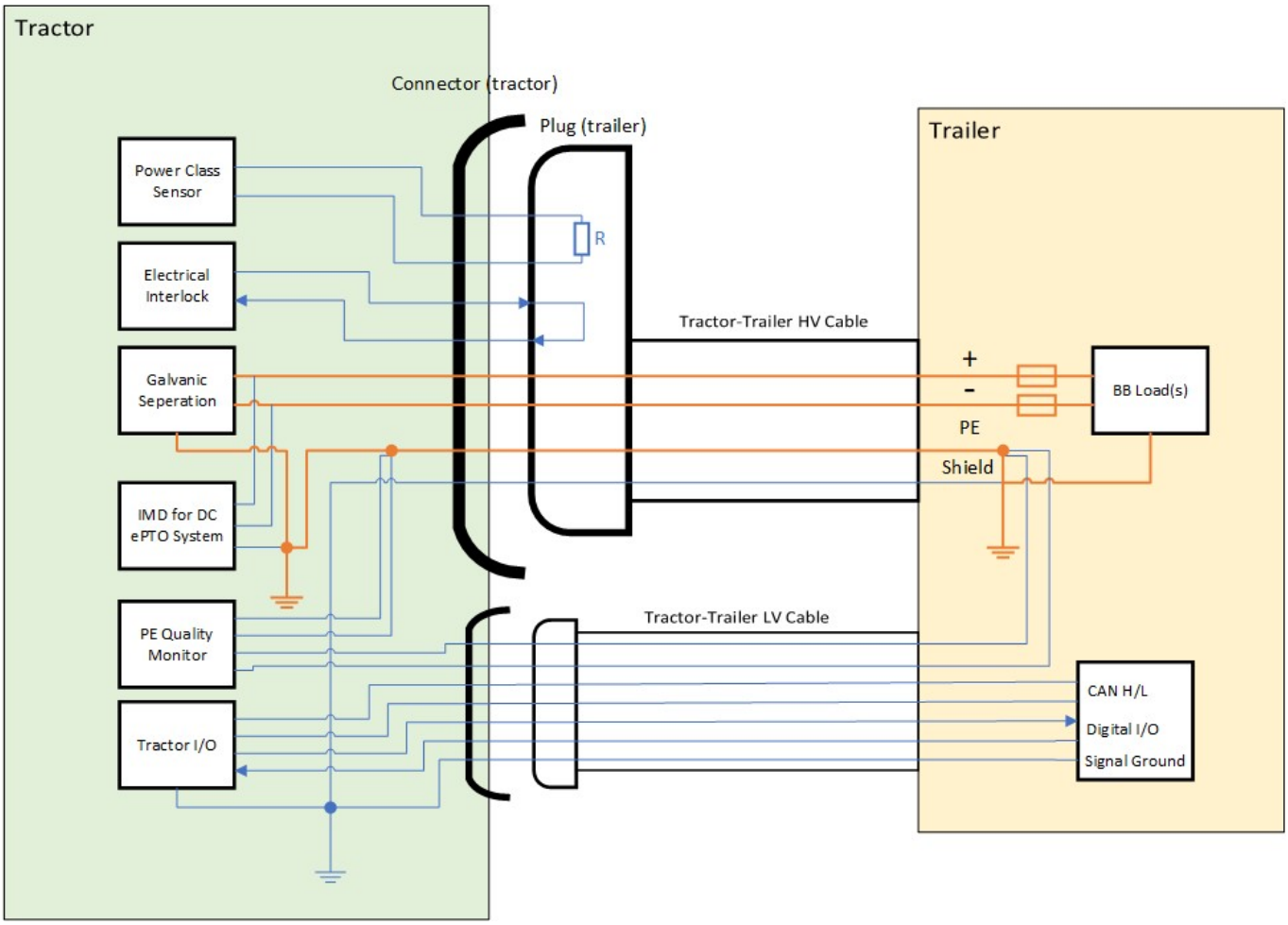

Figure 3: Detailed function description

For details of the LV connector functionalities see LV Connector chapter.

The HV connection shall have the following features:

- incorporate a housing providing shielding (e.g., complete metal housing or conductive layer inside a plastic housing).
- The current classes for max. 100kW defined by resistor value are:
  - class A: 0 – 50A (corresponding to the power class 25 kW)
  - class B: 0 – 100A (corresponding to the power class 50 kW)
  - class C: 0 – 200A (corresponding to the power class 100 kW)
- Power class resistor definition:
  - Class A: 100 Ω
  - Class B: 1000 Ω
  - Class C: 10000 Ω

Remark:

The correlation is that 100kW at the lowest operating voltage of 500VDC leads to a maximum amperage of 200A.

- Both receptacle and plug shall provide means for feeding through shielding.
- The OEMs have to carry out investigations whether shielding of the HV power supply on a system view truck – trailer is necessary. Reference is UN ECE R 10.
- HV interlock to ensure correct mating/unmating ("mate first/break last", see mating sequence chapter)
- EPBC is present to connect chassis ground truck and chassis ground trailer to the same potential.
- HV DC plus and minus for power supply.

4.1.4 Geometric requirements

The HV plug shall provide cable strain relief.

The HV contacts should "float" within the connector body to avoid pin/socket misalignment.

Remark: The HV receptacle cable strain relief is OEM specific.

There shall be solid insulation between the HV poles which covers the entire length of pins. This will prevent arcing between poles inside the connector in case of a fault. The insulation shall provide dielectric strength withstand voltage between both HV poles and LV contacts.

The housing of the plug shall comprise a kink protection for the HV cable.

The plug housing shall provide the possibility to have a sealed HV cable attachment.

Receptacle and plug shall provide a positioning device.

Ingress protection shall be ensured (see chapter Ingress protection level of components).

Easy mating and unmating shall be ensured (e.g., by means of a handle or lever).

Remark:

The clearance area for mating and unmating should be reduced to a minimum.

4.1.5 HV contacts

4.1.5.1 Overcurrent

In order to ensure continuous operability, the OEM has to define a degrading concept in case of exceeding the maximum continuous current of 200A.

The connector is intended to address different power classes However, amongst the various

ratings, their geometric properties, particularly the contact diameters, and the ampacity shall be the same (one type of connector system for all power classes).

4.1.5.2 Short current

The OEMs shall introduce a fuse concept which complies to IEC 60269.

4.1.5.3 DC voltage definition

The maximum working DC voltage is 1500V according to the definitions in ISO 6469-3:2021(E) class B.

Remark: The OEMs have to state the DC voltage for normal operation within Class B.

4.1.5.4 Withstand voltage

Withstand test voltage for test location at 4000m above sea level shall be according to Clause 5.1

IEC 60664-1.

Rated working voltage is 1500 VDC.

Withstand voltage can be calculated by IEC 60664-1:2007, 5.3.3.2.3.

4.1.5.5 Contact resistance

In order to avoid a temperature sensor within the plug/receptacle the contact resistance per HV contact shall be lower than 100 μΩ over lifetime.

Remark:

Special plating material might be necessary.

4.1.6 Clearance and creepage distances

Pollution degree 3 according to IEC 60664-1 shall be applied.

The clearance and creepage distances shall meet the requirements for double or

reinforced insulation as defined in clause 5.1 and 5.2 of IEC 60664-1.

The clearance can be calculated by table F.2 in IEC 60664-1.

The creepage for solid insulation required for a rated voltage of 1500 VDC can be calculated by table F.5 in IEC 60664-1.

An example calculation can be found in the "draft technical supplement V 0.1.0.pdf".

For clearance the condition is for inhomogeneous field.

4.1.7 Protection against direct access to live parts

The HV contacts shall be finger proof acc. to IPXXB / IP2X (ISO 20653) in terms of both the receptacle and the plug when unmated.

The protection class shall be IPXXD in terms of both the receptacle and the plug when mated.

4.1.8 Ingress protection level of components

The plug shall have a sealing in order to prevent intruding liquid and dust at the interface of the cable and the plug.

The plug shall be tight against dust, liquids and be corrosion resistant.

The plug shall fulfil IP6K9K and IP6K7 in accordance with ISO 20653 in following state:

- Mated condition (sealing at the interface of the housings of plug and receptacle)

For the unmated condition, a fixed mounted plug parking device should be provided ensuring at least IP44. The plug should be fixed in a way, so no force is introduced to the cable.

The receptacle shall be equipped with a cover flap in order to be

- corrosion resistant and tight against dust and liquids
- fulfilling IP6K9K and IP6K7 in accordance ISO 20653

when unmated and with the cover flap closed.

The cover flap shall be of orange color.

4.1.9 Equipotential bonding

Both the receptacle and the plug shall incorporate an EPBC.

- Depending on the cross section of the HV lines, the EPBC cross section shall have a minimum of 16 mm² and a maximum of 25 mm².
- Contact resistance of the EPBC shall be lower than 200 µΩ over lifetime.
- The EPBC shall mate before the HV lines and unmate after the HV lines (see mating and unmating sequence).

4.1.10 Insulation resistance

The connector insulation resistance shall be at least 10 GΩ over lifetime.

4.1.11 HV interlock

The connector shall incorporate two contacts to detect the status of the connector as being properly mated. As long as the signal at these contacts is not active the status of the plug shall be considered as not mated. Hence in this state HV must not be activated (compare mating and unmating sequence).

- Maximum voltage shall be 60 V.
- Maximum current shall be 100 mA.
- Contact resistance shall be lower than 5 mΩ over lifetime.
- Conductor cross section shall be max 1.5 mm²
- During the mating process the interlock shall connect as last contact. During the unmating process it shall disconnect as first contact

4.1.12 Mating and unmating Sequence

The complete sequence for mating is:
1. EPBC
2. HV lines + shielding
3. Power class pins
4. HV interlock

The complete sequence for unmating is:
1. HV interlock
2. Power class pins
3. HV lines + shielding
4. EPBC

4.2 LV Connector

To make the design easier, the ePTO connector group has decided for a separate connector for the communication and binary signals.

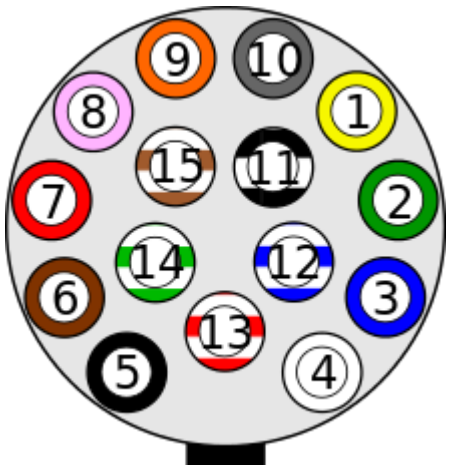

Figure 4: LV Connector acc. ISO 12098

This connector is physically based on the ISO 12098 connector.

The changes are the pinout and a different positioning device in order to avoid mismatch with an already present connector.

Different coding and color to the existing connector (ISO 12098) is mandatory.

Pinout table:

Pin	Signal
1	EB current
2	EB voltage
3	Crash
4	BDR (Body Down Request)
5	CAN high.
6	CAN shield (optional)
7	Terminal 31 (optional)
8	reserved for ePTO group, e.g., wake-up, etc.
9	Terminal 15 (optional)
10	Terminal 30 (optional)
11	Signal GND
12	reserved for ePTO group, e.g., wake-up, etc.
13	CAN GND (optional)
14	CAN low
15	reserved for ePTO group, e.g., wake-up, etc.

Table 2: Pinning of the LV connector

Pin 1 and Pin 2 are used for monitoring of the equipotential bonding (concept to be found in the "draft technical supplement V 0.1.0.pdf").

Pin 3 for the crash signal is coming from the truck in the event of a detected crash.

Pin 4 is for the body down request coming from the trailer and is intended in the event the trailer consumer is not able to power down (e.g., due to an internal fault).

Pin 5 is CAN high line.

Pin 6 is the CAN shield and shall ensure CAN high speed communication. The CAN shield shall support in terms of EMC.

Pin 8, 12, 15 are spare and maybe optional (reserved for ePTO group, e.g., wake-up, etc.).

Pin 11 is the signal ground for Pin 3 and Pin 4 and for possible additional signals (Pin 8, 12, 15).

Pin 13 is the CAN ground and shall ensure CAN high speed communication.

Pin 14 is CAN low line.

The messages for information exchange (acc. SAE J1939) between truck and trailer can be found in the document "draft ePTO Specification Signalling V 0.1.0.pdf".

The cross section for all lines shall be at least 1.5 mm^2.

4.3 HV Connector mechanical robustness

The receptacle has a break-away feature which shall be also part of this requirements (see ISO 23316-2 Chapter 4.14).

Key features are:

- Break-away until a max. angle of 22.5° after which can inspection is required.
- break-away of the receptacle in the direction of the connector cable shall work at a force of 500 N to 800 N.
- Pulling at the cable attached to the plug at a force of 1 kN shall not damage the connector.

The connector shall handle the rated voltage and the rated current during the break-away event. The sealing shall be protected against mechanical influences. Sealing shall not slip or be otherwise dislocated unintentionally.

4.4 HV Connector environmental conditions

The following test specifications are only examples for environmental test procedures.

Pre-condition is that both plug and receptacle are located at the outside of the truck/trailer (fixed to the chassis).

- Shock and vibration test according to ISO16750-3, chap. 4
- Corrosion requirement and temperature cycle according to e.g., VDA 233-102
- surface temperature for the parts of the interface that are possible to touch (refer to IEC 62196-3-1 clause 16.5)
  - Touch temperature at ambient temperature 35 °C(?):
  - Plastic housing max 75 °C
  - Metal housing max 55 °C
  - Contact temperature:
    Max. temperature rise 50 °C above environmental temperature
- Humid and heat cyclic test acc. ISO 16750-4 chapter 5.6

4.5 HV Connector Durability

- Design for daily use => 5000 cycles minimum over lifetime
- rough environment: construction machinery, gravel pit, mining
- 100% outdoor use, UV exposure

Remark: This shall be valid for all parts of the connector (electrical contacts, shielding, housing, etc.).

4.6 HV Connector Marking

The HV connector shall have hazardous voltage marking (raised) according to ISO 6469-3.

The color of the plug housing should be orange.

The flap of the receptacle shall have hazardous voltage marking (raised) according to ISO 6469-3 and shall be of orange color.

5 Communication Signals

For communication, please see documents:

- "draft ePTO Specification Signalling V 0.1.0.pdf "and
- "draft technical supplement V 0.1.0.pdf"

6 Safety aspects

The safety concept of a HV truck/trailer connection is in the responsibility of the OEM/trailer manufacturer.

An example how it should work with the proposed pinouts of the HV/LV connectors and simultaneously addressing legal aspects can be found in the document "draft technical supplement V 0.1.0.pdf".