Draft technical supplement 0.1.0

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1 Document History

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

2 Introduction

The technical supplement is used for explanation of the technical specification of the signals and the connection between electric vehicles and trailer / semitrailer for voltage class B ePTO's.
In the document you will find use cases and examples for the operation of ePTO's.

2.1 Abbreviations

Abbreviation	Description
ePTO	Electric Power Take-Off
OEM	Original Equipment Manufacturer
EPBC	Equipotential Bonding Conductor
PE	Protective Earth
HV	High Voltage class B
LV	Low Voltage
AC	Alternating Current
DC	Direct Current
IMD	Insulation Monitoring Device
ECU	Electronic Control Unit
BEV	Battery Electric Vehicle
EB	Electronic Bonding
FD	Flexible Data
HVIL	High-Voltage Interlock Loop
EMC	Electromagnetic Compatibility
BDR	Body Down Request
SOC	State Of Charge
CAN	Controller Area Network
GND	Ground

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
ECE R100
IEC 60664
ISO 11992
ISO 12098
Draft ePTO Signalling Specification V.0.1.0
Draft ePTO Connection Specification V.0.1.0

3 General remarks

The ePTO interface gives the opportunity for body builders to power their equipment from the energy storage of an electrified vehicle propulsion system. The application here is a pluggable power supply for HV consumers on a trailer/semitrailer.

Currently out of scope at the moment is the implementation of HV energy sources (batteries, e-axles, etc.) at the trailer/semitrailer (only unidirectional power transmission from truck to trailer).

The HV power is supplied at a dedicated HV connector and is described in the ePTO Connection specification ("draft ePTO Specification Connection V.0.1.0.pdf"). The HV connector specification describes hardware requirements needed to fulfill operational and safety functionality for transferring power from truck to trailer.

The LV connector is described physically as well in the ePTO Connection specification ("draft ePTO Specification Connection V.0.1.0.pdf").

The ePTO Signalling specification ("draft ePTO Specification Signalling V0.1.0.pdf") defines the signal interface (bidirectional communication) between truck and trailer/body ECUs and also covers safety requirements.

The ePTO Signalling Specification defines the logical interface requirements that provide interoperability and cross compatibility for systems and equipment.
The communication is based on SAE J1939 and ISO 11992.

Out of scope is the support of AC-ePTO and of more than one DC-ePTO from vehicle side.

4 Legal aspects

4.1 Extract of ECE R100 (2021/2190)

Chap. 5.1 Protection against electrical shock

These electrical safety requirements apply to high voltage buses of electric power train and electrical components which are galvanically connected to the high voltage bus of electric power train under conditions where they are not connected to external high voltage power supplies.

4.2 Comment

1. The ECE comprises HV components which are galvanically connected to the HV bus in the sense of a permanent (non-pluggable) connection (HV heaters, HV AC compressors, HV power train etc.).
2. The ECE deals with vehicles of category M, N and O but not with a combination of N and O. So, the trailer/semitrailer (as well as a BEV truck) as an independent vehicle with HV consumers is within the scope of the ECE. The system of both the truck and the trailer galvanically coupling their HV intermediate circuits is not.
3. A pluggable and galvanically **not** separated connection would mean that every time e.g., a trailer/semitrailer of any brand or model series is connected to a truck of any brand or model series, a revised or new homologation acc. to ECE R 100 must be conducted for this system.
   => Obviously not a practicable solution
4. Currently the only way out is to implement a galvanic separation in power supply of truck to trailer/semitrailer. Consequently, the device for galvanic separation itself will be part of the homologation. The HV consumer at the trailer/semitrailer (matching to the HV supply of the truck) is not within this homologation.

5 Proposal for a concept (left and right of the connector)

5.1 Technical concept including safety aspects

Figure 1 is an example how to possibly set up an HV supply from truck to trailer. The dashed red line shall depict the HV connection interface.

An important condition is that Chassis Ground (equipotential bonding connection) of the truck and Chassis Ground of the trailer cannot be separated since terminal 31 of the LV supply from truck is forwarded to the trailer. Terminal 31 is also bonded to Chassis Ground. Trailer hitch and pneumatic couplings also contribute to the connection of both Chassis Grounds. Eventually the shielding of LV and HV cable connection also has to be considered.

In order to easily find out whether there is an insulation resistance issue within the HV intermediate circuit of the trailer it is recommended to integrate an IMD on trailer side. If there is interference of the IMD truck with the IMD trailer, then the trailer IMD has to be synchronized/switched off during operation of the IMD truck. The concept at both HV intermediate circuits of truck and trailer/semitrailer shall be maintained as IT net.

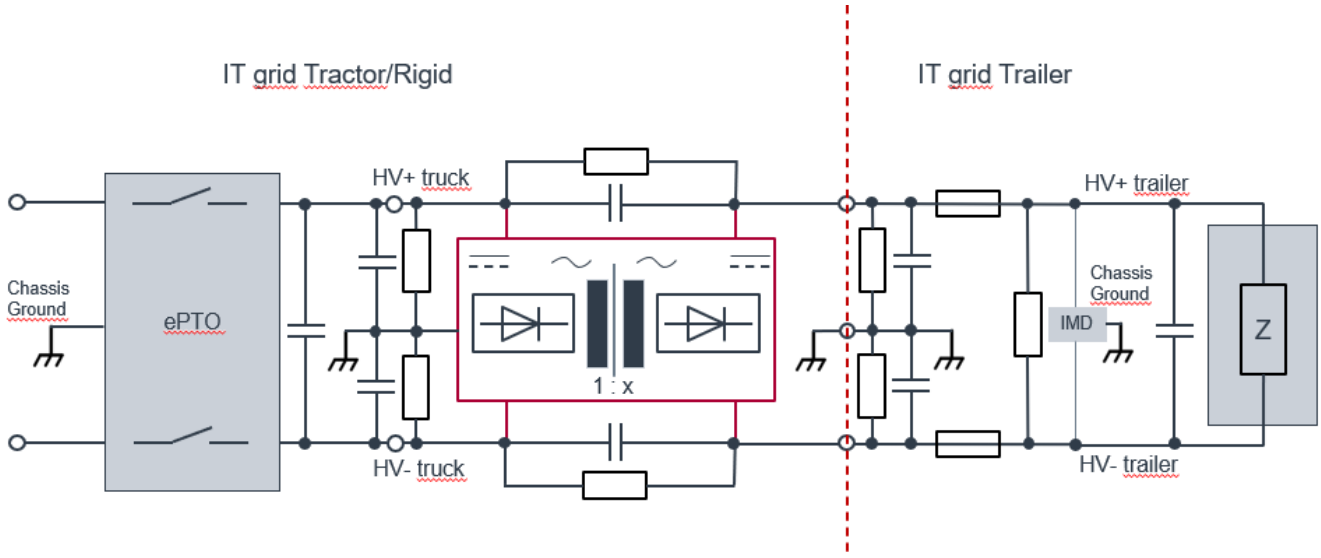

Figure 1 Wiring diagram for HV galvanic separation of truck and trailer

In principle the issue is the same like with commercial AC or DC chargers: A galvanic separation must be provided in order to be allowed connecting an AC or DC charger of any supplier to the grid (incl. Powertrain, acc. ECE R 100).

Some aspects:

- Galvanic separation Truck – Trailer (HV rails)
- Common Chassis Ground Truck – Trailer
  At first fault HV+ truck to Chassis Ground:
  => HV+ truck on Chassis Ground Trailer
  => Surveillance of EB connection truck – trailer necessary (scenario of second fault HV- trailer on Chassis Ground)
- Dedicated IMD Trailer necessary
  => Synchronization with IMD truck is mandatory (common Chassis Ground will possibly interfere with the functionality of IMD truck)
- Isolating transformer with double isolation (flashover resistance)
- Definition of performance classes necessary
- LV supply Trailer possible by Truck
- Bidirectional power transmission:
  Recuperation power is depending on transmission performance of the transformer
  => Recuperation at Trailer shall mostly be covered by the Trailer itself

5.2 Surveillance of EB connection truck-trailer

5.2.1 Rational

- The Equipotential Bonding connection between truck and trailer must be monitored since in case of a first fault of truck HV+ at Chassis Ground the same HV+ (or a share of it) will be present at the trailer resulting in a hazardous potential difference between Chassis Ground truck and trailer (violation of ECE R 100).
- Surveillance of EB connection truck – trailer is necessary because a bad connection will lead to parasitic (balancing) currents and thus to potential shifts at terminal 31.
- Since shield and screens of HV and LV harnesses are also bonded to Chassis Ground it must be made sure that excessive over- and short currents are not forwarded via these conductors but are mainly conducted by the equipotential bonding.

5.2.2 How does it work

The functionality is based on the so-called Kelvin measurement. There is a current loop which is driven by a current source delivering a constant current i.e., 1 A. Also, a pulsed current source with a duty cycle of i.e., 10% is possible in order to reduce power loss (see also section Nr. truck-trailer HV/LV interface).
A second loop is measuring the voltage drop at the relevant line section. In our case this is the section between the defined Chassis Ground point at truck side and the defined Chassis Ground point at trailer side.

The constant current source will generate a voltage drop at the relevant line section i.e., 1 A x 0.1 Ω = 0.1 V. This voltage drop can be measured high ohmic with a voltmeter at 10 MΩ. If the voltage drop goes beyond a limit (i.e., 0.2 V which means 0.2Ω) then the EB connection shall be considered as „bad ".

The EB monitoring does not have to be in continuous mode. Depending upon the safety concept, each time the HV power supply for the trailer is switched on a check shall be performed.

5.2 Truck – trailer HV/LV interface

In order to avoid EMC interferences of HV and LV lines between truck and trailer there shall be two individual connectors for HV power supply and LV signalling.
Figure 2 shows the principle of the connector interface.

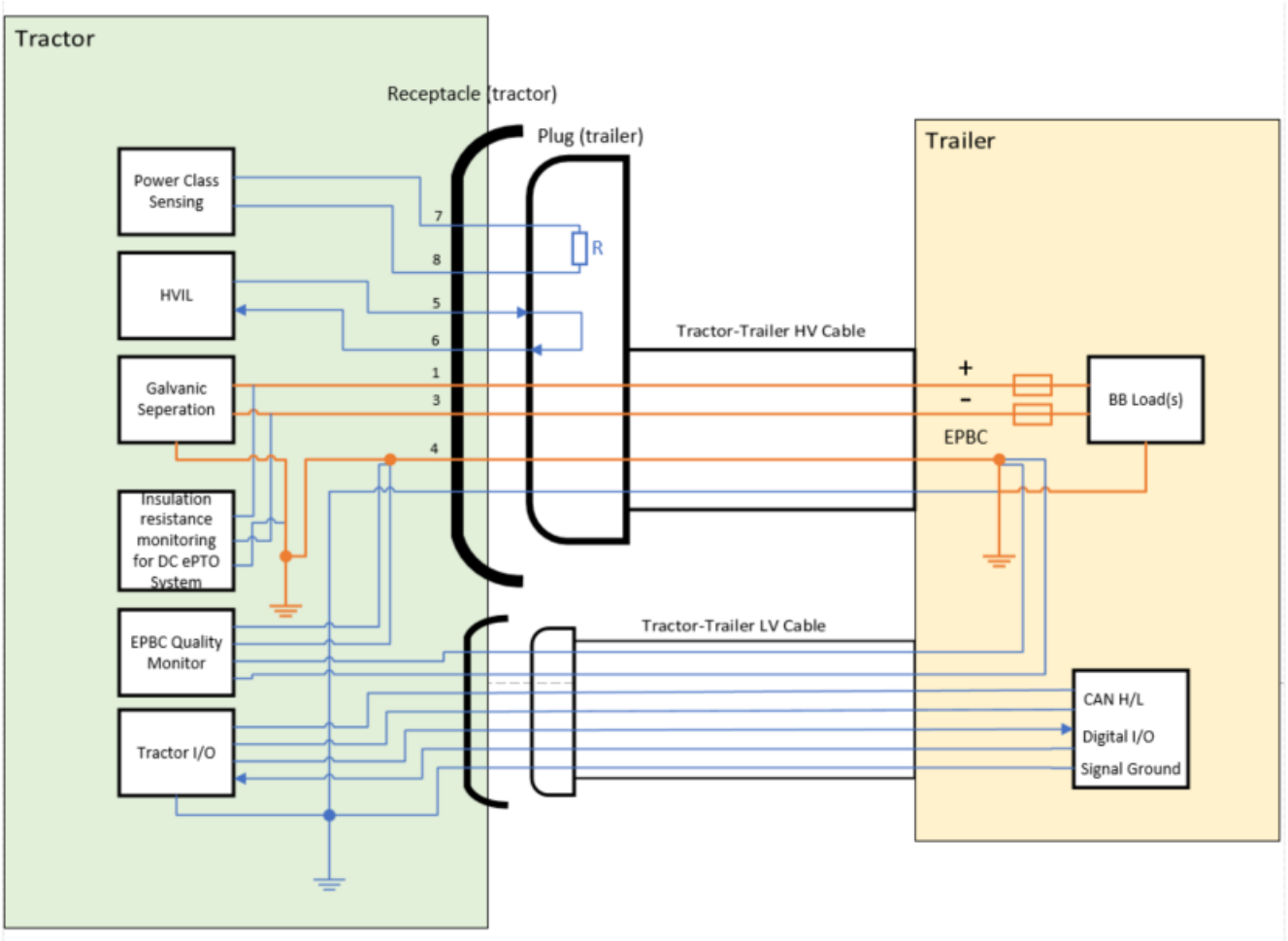

Figure 2 HV and LV connectors

Description:

- HV+/HV- / EPBC:
  members of the IT net
- Surveillance of EB connection truck-trailer:
  This requirement is addressed by two LV lines within the LV connector (lower lines of „PE Quality Monitor", EB current, EB voltage) bonded together at a defined ground connection at trailer side. The other two lines shall be bonded at a defined ground connection at truck side (Kelvin measurement).
- Power class definition:
  This requirement is addressed by evaluation of the power class sensor. The easiest way will be to include a resistor to the HV plug.
- Detection of mated and unmated HV plug:
  This requirement is addressed by evaluation of the status of the HVIL lines of the HV plug. It shall support the protection from arcing when DC current is interrupted by un-intentional physical disconnection.
- Monitoring the insulation resistances of the HV consumer on trailer side:
  A possibility is to include an IMD for the trailer at truck side in order to ease the synchronization with the other IMDs in the truck system. Careful design is necessary here to avoid a short to the primary side of the galvanic separation.
- A CAN Highspeed or FD interface shall be included to the LV connector.
- At least two binary I/O lines shall be included for the Crash Signal (from truck to trailer) and the Body Down Request (from trailer to truck).
- There are additional lines provided by the LV connector (see technical specification connection).
- Rational for splitting up to a HV and LV connector:
  In order not to force all LV lines to fulfil the requirements of IEC 60664-1 (dielectric strength).
  Only HV dedicated low voltage lines are within the HV connector.
  Minimizing possible EMC interferences.

6 What does the signalling support (concept)

The ePTO Signalling specification defines the signal interface (bidirectional communication) between vehicle and trailer/body ECUs.

The communication is based on SAE J1939 and ISO 11992.
The ePTO Signalling specification defines those signals which are needed for ePTO's only. For application specific definitions the ISO 11992-3 is applicable.

Out of scope is the support of more than one ePTO and AC-ePTO from vehicle side.

For some body builder applications a wake-up functionality is necessary. In this case wake-up of vehicle to ensure power supply must be triggered by the body builder via pin or CAN network management.

7 Some use cases with examples

7.1 Normal start

7.1.1 Preconditions, Application, situation

- Connections are correct for HV and LV
- HV System is operational
- Communication is operational (LV)
- All system tests are ok

7.1.2 Sequence

- ePTO Control Status from the vehicle is not ready and checking the system
- ePTO Control Status from the vehicle is ready (good case)
- ePTO Activation from the body is Request activation
- ePTO Control Status from vehicle is On/Initiation
- ePTO Control Status from vehicle is On/Active (=power available)

7.1.3 Additional comments

This use case is independent whether the vehicle is moving or not.

How to keep the HV system and communication on (during park, charging, etc.) is OEM specific.

This behavior should at least be configurable with parameters or from driver action before leaving the vehicle.

7.1.4 Example

Vehicle parked without driver or operator present.

Typical application is fridge truck parked overnight. The ePTO keeps its state (as long as there is enough power available by the vehicle)

7.2 Normal Stop

Stop sequence is started either by the vehicle or the body system.

7.2.1 Preconditions, Application, situation

- ePTO is active
- HV system and communication is operational
- No active faults in the fault memory entries

7.2.2 Sequence

- ePTO Status signal from vehicle is On/Active
- Either vehicle wants to deactivate, or the body system sets the ePTO Activation to "no activation"
- ePTO Status signal from vehicle is deactivating
- ePTO Status signal from vehicle is Ready or not ready depending on the situation at the vehicle (e.g., no more power left/operator has deactivated)

7.2.3 Additional comments / Concerns

The Deactivation by the vehicle might be caused due to less power available (indicated by ePTO Energy Status) or by the body system by the ePTO Activation signal set to "not requested".

The behavior for the status after deactivation is OEM specific (e.g., whether an activation is possible when Level 2 of the ePTO Energy Status has reached)

7.2.4 Example

The available power of the vehicle has reached level 0 then the vehicle systems initiates a deactivation.

The ePTO Status is set to "not ready".

The body system initiates a deactivation then the ePTO Status is set to "Ready" if all conditions for providing power are fulfilled (e.g., enough power available, all system tests are ok).

7.3 Stop on Error

Stop sequence is started due to an error on the vehicle (stated e.g., by the ePTO Error Status, interlock) or by the BDR signal from the Body.

7.3.1 Preconditions, Application, situation

- ePTO Status is Active

7.3.2 Sequence

- ePTO Error Status is set to the error case definition
- ePTO Status is set to "System Failure"

7.3.3 Additional comments / Concerns

The reset of the ePTO Status "System Failure" is OEM specific.

7.3.4 Example

The interlock of the HV connector is broken due to an unwanted disconnection then the ePTO Error status is set to "system failure" and the power supply is immediately interrupted by the vehicle. The reaction time is dependent on the error (critical/not critical) and maybe OEM specific.

The body indicates an "ePTO emergency deactivation request" due to a malfunction of the body system. The ePTO Error Status is set to "Body system error". The power supply is subsequently interrupted by the vehicle. After that, the ePTO Status is set to "Ready". The body has to make sure that there is no error in the body system and have the ePTO Activation set to "not requested".

This may also apply for crash situation (critical).

7.4 Trailer connection established

There is a trailer connection established by the driver for HV and LV. The trailer can be an already known trailer or a not known trailer (check of the Trailer ID).

7.4.1 Preconditions, Application, situation

- ePTO is not active
- The HV connection and LV connection is established correctly
- LV communication is active

Some reason to check compatibility has occurred. This can be when a trailer is connected, when ePTO is being activated or as a routine or similar thing. This is only needed if different BB equipment are used by a vehicle with different capabilities, mainly for connecting new standardized trailers which could be used by any tractor. Could be replaced by a standardization where all BB applications are required to meet some requirements that make them compatible with all tractors.

7.4.2 Sequence

- ePTO Status is "not ready"
- The vehicle system test are done:
    - Check the interlock
    - Check the "Body equipment acceptable voltage (min/max)"
    - Check the "Body equipment current class"
    - Check the Power class sensor (resistor) in the cable/plug
    - Check the galvanic separation
    - Check the I/O signals
- After successful tests the ePTO Status is set to "ready"
- The Body Application send all configuration signals continuously (low rate). The configuration parameters right now are these, but it can change moving forward.
    - ePTO Adequate Voltage Range
    - ePTO Needed Power - normal mode

The vehicle uses the information in the configuration parameters to check if the Body Load is compatible. It can use this information to deny activation requests but also to show information about this in the cluster or offboard.

It's possible that the compatibility check comes to different conclusions in different situations (depending on Traction Voltage on vehicle side for example), this needs to be handled by the vehicle side.

7.4.3 Additional comments / Concerns

There can be a configuration on vehicle to say if it needs to check the configuration parameters or not. For fixed installation, these signals are not needed and could be ignored. If multiple frames are desired these signals could be put in a separate frame or only sent if needed.

7.5 Disconnect trailer

7.5.1 Preconditions, Application, situation

- ePTO is active
- The HV connection and LV connection is established correctly
- LV communication is active

7.5.2 Sequence

Example:

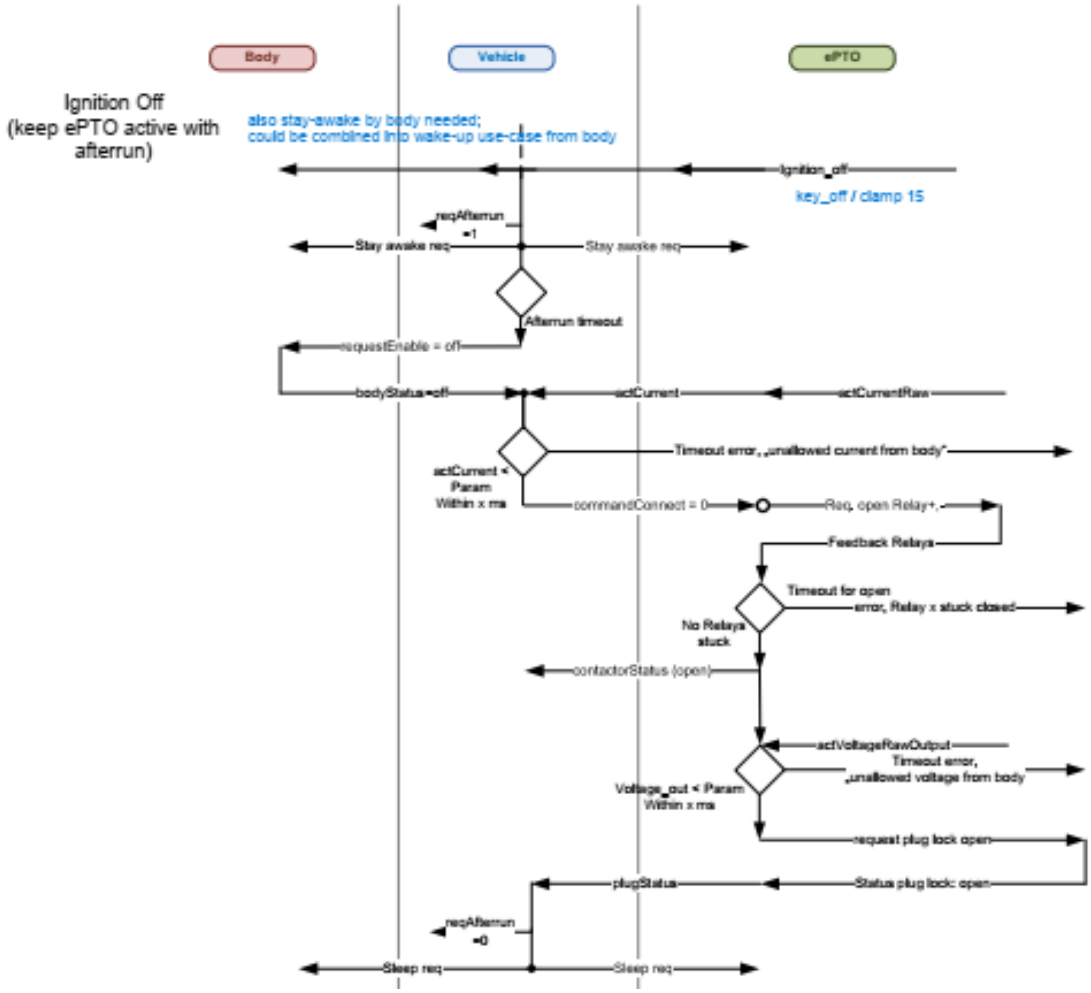

Figure 3 Disconnect trailer

7.5.3 Additional comments / Concerns

Disconnection initiated manually (by driver) or automatic (low SOC) or safety (foreseeable misuse e.g., remove plug under load).

7.6 Limit power from vehicle side

ePTO is running. Vehicle has some sort of power management function that can allocate a certain power budget for the Body load.

7.6.1 Preconditions, Application, situation

- ePTO is active
- HV system and communication is operational

7.6.2 Sequence

- ePTO is active/on
- "ePTO available power" is set and transmitted by the vehicle
- Body gives feedback on the actual power via the signal "ePTO actual power"

The behavior of the vehicle/body depends on the following conditions:

- Vehicle calculates the available power for the body and transmits it via the signal "ePTO Available Power"
- If the value of the available power is equal or higher than the "ePTO actual power", the body can operate without restrictions.
- If the value of the available power is lower than the "ePTO actual power", the body has to restrict its power consumption.
- If the value of the available power is higher than the "ePTO actual power", the body has to restrict its power consumption. If the body doesn't restrict its power, the vehicle has to decide at which given time or overload the ePTO will shut down.

7.6.3 Additional comments / Concerns

The value of "ePTO available power" and the logic when to shut down the ePTO at which specific power difference or after which specific time is OEM specific due to different vehicle architectures.

7.7 Safety features

7.7.1 Example: Remove trailer connection during operation (hot unplugging, misuse)

If HV connector and/or LV connector is unmated
-> the trailer shall go in a safe state
-> the truck shall stop power supply

7.7.2 Example: LV communication brake down at truck or trailer side

If LV communication brake down
-> the trailer shall go in a safe state
-> the truck shall stop power supply

8 Drawings

8.1 Truck – Trailer HV/LV interface

In order to avoid EMC interferences of HV and LV lines between truck and trailer there shall be two individual connectors for HV power supply and LV signalling.
Figure 4 shows the principle of the connector interface.

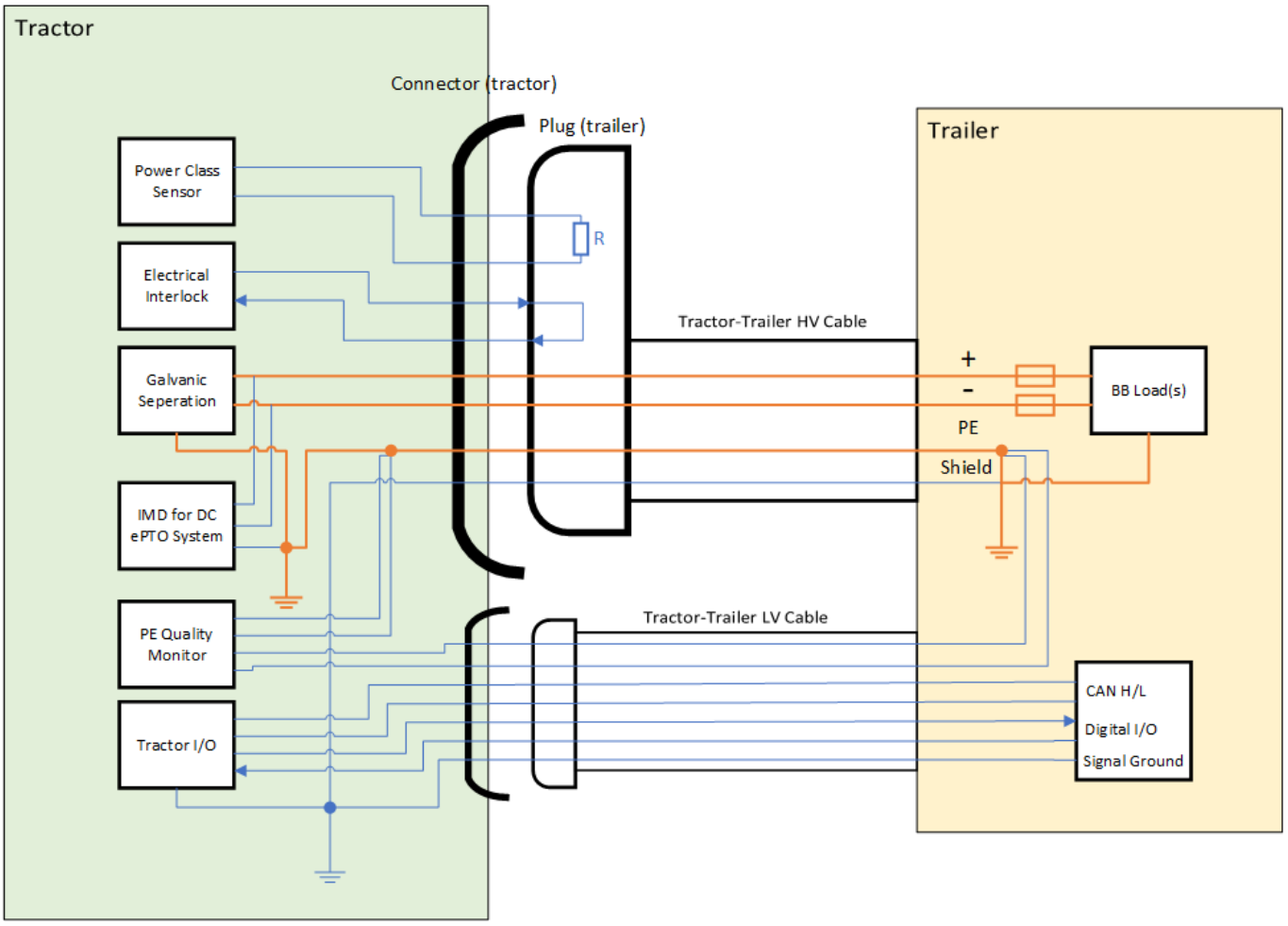

Figure 4 HV and LV connectors

Description:

- Surveillance of EB connection truck-trailer:
  This requirement is addressed by two LV lines within the LV connector (lower lines of „PE Quality Monitor, EB current, EB voltage) bonded together at a defined ground connection at trailer side.
  The other two lines shall be bonded at a defined ground connection at truck side (Kelvin measurement).
- Power class definition:
  This requirement is addressed by evaluation of the power class sensor. The easiest way will be to include a resistor to the HV plug.
- Detection of mated and unmated HV plug:
  This requirement is addressed by evaluation of the status of the HVIL lines of the HV plug. It protects against arcing when DC current is interrupted by un-intentional physical disconnection.
- Monitoring the insulation resistances of the HV consumer on trailer side:
  A possibility is to include an IMD for the trailer at truck side in order to ease the synchronization with the other IMDs in the truck system. Careful design is necessary here to avoid a short to the primary side of the galvanic separation.
- Signalling:
  A CAN Highspeed or FD interface shall be included to the LV connector.
  At least two binary I/O lines shall be included for the Crash Signal (from truck to trailer) and the Body Down Request (from trailer to truck).

8.2 Proposals

8.2.1 HV Connector

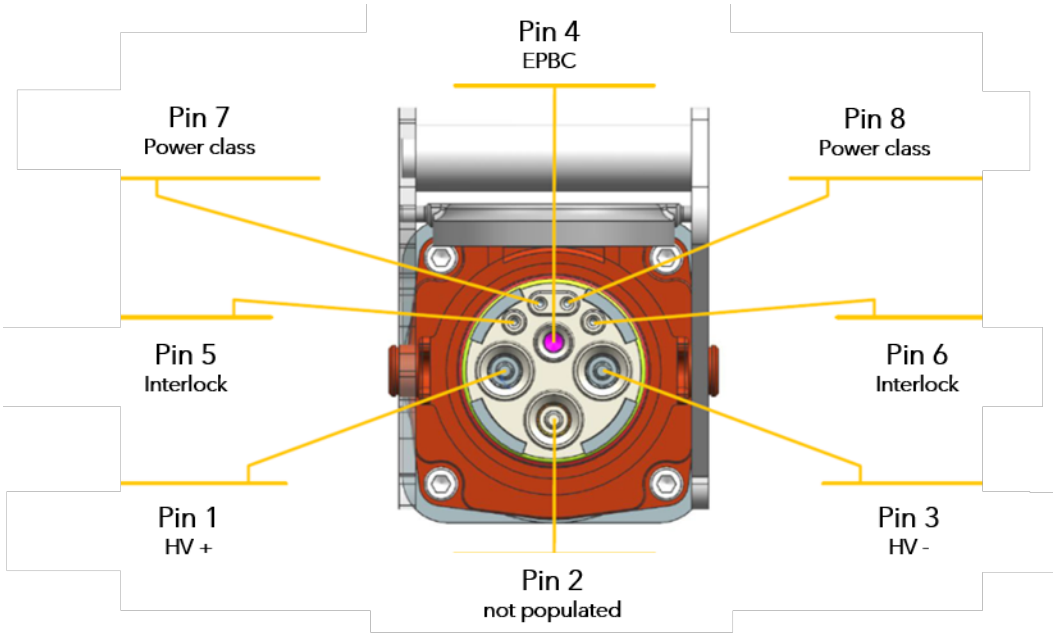

Figure 5 HV Connector acc. AEF

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

8.2.2 LV Connector

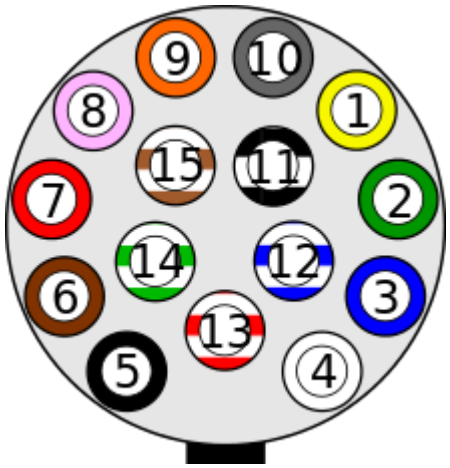

Figure 6: LV Connector acc. ISO 12098

Remark: In order to avoid mismatch with the existing connector acc. ISO 12098, a different hardware coding (positioning unit) is mandatory. A different color of the LV connector is recommended.

Pinout table:

Pin	Signal
1	EB current
2	EB voltage
3	Crash
4	BDR (Body Down Signal)
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