
Road vehicles — Interchange of digital information on electrical connections between towing and towed vehicles —

**Part 1:
Physical and data-link layers**

Véhicules routiers — Échange d'informations numériques sur les connexions électriques entre véhicules tracteurs et véhicules tractés —

Partie 1: Couche physique et couche de liaison de données

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 31, *Data communication*.

This third edition cancels and replaces the second edition (ISO 11992-1:2003) which has been technically revised.

The main changes compared to the previous edition are as follows:

- wording improvements and clarifications;
- introduction of requirement statements; and
- addition of informative [Annex A](#), *Implementation examples of the bus failure management*.

A list of all parts in the ISO 11992 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The ISO 11992 series specifies the interchange of digital information between road vehicles with a maximum authorised total mass greater than 3 500 kg. The series also specifies digital information interchange for towed vehicles, including communication between towed vehicles in terms of parameters and requirements of the lower OSI layers (physical and data link layer) of the electrical connection used to connect the electrical and electronic systems.

This document specifies the data link and physical layer requirements of the CAN communication bus between towing and towed vehicles.

This document has been structured according to the Open Systems Interconnection (OSI) Basic Reference Model, in accordance with ISO/IEC 7498-1 and ISO/IEC 10731, which structures communication systems into seven layers. When mapped on this model, the application protocol and data link layer framework requirements specified/referenced in a ISO 11992 series standard are structured according to [Figure 1](#).

[Figure 1](#) illustrates the following communication frameworks:

- normal vehicle communication framework;
- vehicle diagnostic communication framework;
- vehicle-specific use case framework; and
- vehicle lower-layers framework.

The normal vehicle communication framework is composed of ISO 11992-2 and ISO 11992-3.

The vehicle diagnostic communication framework is composed of ISO 14229-1^[3], ISO 14229-2^[12], ISO 14229-3^[13] and ISO 11992-4^[3].

The vehicle-specific use case framework is composed of ISO 11992-4, ISO 22901-1 or vehicle manufacturer-specific diagnostic data definition.

The vehicle lower-layers framework is composed of ISO 15765-2^[14], ISO 11898-1, 1, ISO 7638-1^[6] and ISO 12098^[10].

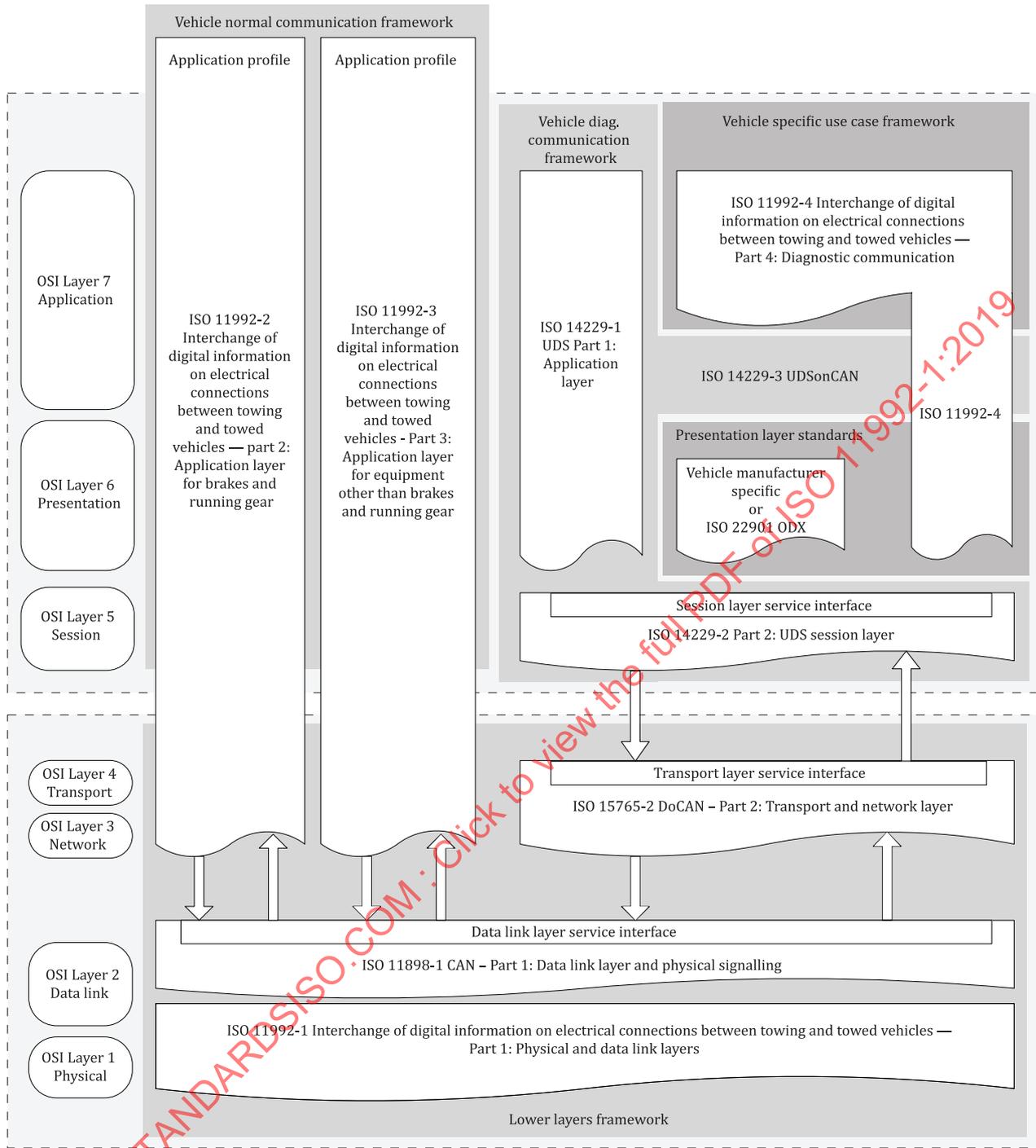


Figure 1 — Towing and towed vehicles framework documents reference according to the OSI model

Figure 2 shows the implementation example of the lower-layers block diagram.

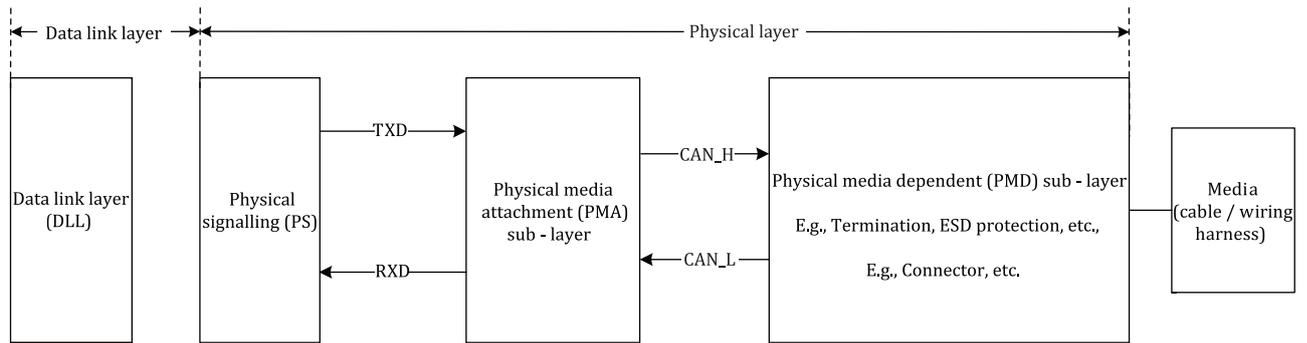


Figure 2 — Implementation example of lower-layers block diagram

The above requirements structure has been chosen to provide the following developers with relevant requirements:

- transceiver developers;
- device (e.g., electronic control unit) developers; and
- towing and towed vehicle network developers.

All requirements are numbered and headlined uniquely, so that each implementer can reference them.

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Road vehicles — Interchange of digital information on electrical connections between towing and towed vehicles —

Part 1: Physical and data-link layers

1 Scope

This document describes the data link layer (DLL) and physical layer (PHY) for the two CAN-based network interfaces specified in the 11992-series.

The DLL sub-clauses are composed of:

- DLL protocol entity requirements;
- DLL device interface requirements; and
- DLL network system requirements.

Normally, the physical signalling sub-layer is implemented in the CAN protocol controller. The physical medium attachment sub-layer is normally implemented in the CAN transceiver or the System Base Chip (SBC). Optionally, it can comprise also additional protection circuitry. The media-dependent sub-layer comprises the connectors and the cabling.

The physical signalling (PS) sub-clauses are composed of:

- PS entity requirements;
- PS device interface requirements; and
- PS network system requirements.

The physical medium attachment (PMA) sub-clauses are composed of:

- PMA protocol entity requirements; and
- PMA device interface requirements.

The physical medium dependent (PMD) sub-clauses are composed of:

- PMD entity requirements;
- PMD device interface requirements; and
- PMD network system requirements.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 4141-1, *Road vehicles — Multi-core connecting cables — Part 1: Test methods and requirements for basic performance sheathed cables*

ISO 11898-1, *Road vehicles — Controller area network (CAN) — Part 1: Data link layer and physical signalling*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

3.1
1-wire operation
communication on either CAN_L or CAN_H with reference to ground and V_s potential during fault-tolerant operation mode

3.2
2-wire operation
communication on CAN_L and CAN_H, with reference to ground and V_s potential, in nominal (non fault-tolerant) operation mode

3.3
bus
communication link between two communication entities

3.4
CAN_H
CAN_L
particular cable and/or contact of the communication connection

3.5
differential transmission
transmission of digital information carried by voltage between the two conductors of the electrical connections

3.6
maximum authorised total mass
vehicle mass determined as a maximum by the administrative authority for operating conditions laid down by that authority

Note 1 to entry: In some jurisdictions this will be known as the Gross Vehicle Weight Rating or the Gross Combination Weight Rating.

[SOURCE: ISO 1176:1990, 4.8, modified — NOTES 1 and 2 replaced by a new Note 1 to entry]

3.7
data link layer protocol entity
DLL protocol entity
functional part of the electronic component implementing the DLL protocol as standardised in ISO 11898-1

3.8
data link layer device interface
DLL device interface
electronic device interface compliant with ISO 11898-1 optionally with functional restrictions

EXAMPLE No transmission of remote frames or transmission of extended frame formatted messages only.

3.9**data link layer network system**
DLL network system

logical DLL system comprising two additional interoperable nodes compliant with ISO 11898-1

3.10**physical signalling entity**
PS entity

functional part of the electronic component implementing the DLL protocol as standardised in ISO 11898-1

3.11**physical signalling device interface**
PS device interface

electronic interface compliant with ISO 11898-1 and detailed bit-timing configuration including configured re-synchronisation capability

3.12**physical signalling network system**
PS network system

network with devices with an interoperable bit-timing and bit synchronisation compliant with ISO 11898-1

3.13**physical medium attachment entity**
PMA entity

electronic component (transceiver) or part of an electronic component (system base chip)

3.14**physical medium attachment device interface**
PMA device interface

electronic device interface comprising a PMA entity and optionally additional circuitry

3.15**physical medium attachment network system**
PMA network system

network system comprising two devices with physical media attachment interfaces compliant to this document

3.16**physical medium dependent entities**
PMD entities

connectors, cabling, and other electro-mechanical network components

3.17**physical medium dependent device interface**
PMD device interface

connectors, cabling, and other electro-mechanical components

3.18**physical medium dependent network system**
PMD network system

electro-mechanical interface of a single device

3.19**towed vehicle**

unpowered vehicle that is towed by a towing vehicle or another unpowered vehicle

[SOURCE: ISO 3833:1977, 3.2, modified — definition editorially revised]

3.20

towing vehicle

motor vehicle or unpowered vehicle, which tows a succeeding unpowered vehicle

4 Abbreviated terms

- AC alternating current
- CAN controller area network
- CEFF classical extended frame format
- DC direct current
- DLL data link layer
- ECU electronic control unit
- PHY physical layer
- PMA physical medium attachment
- PMD physical medium dependent
- PS physical signalling

5 Data link layer (DLL)

5.1 General

The data link layer provides the functional and procedural means to transfer data between network devices and provides the means to detect and possibly correct errors that can occur in the physical layer. The DLL is concerned with local delivery of frames (PDUs) between devices on the CAN network. The DLL endeavours to arbitrate between parties contending for access to a medium, without concern for their ultimate destination. When devices attempt to use a medium simultaneously, frame collisions occur. The data-link protocol specifies how devices detect and recover from such collisions and may provide mechanisms to reduce or prevent them.

5.2 DLL protocol entity requirements

The DLL protocol entity transfers data between network nodes on the CAN network. The following requirements are applicable.

REQ	2.1	DLL — ISO 11898-1
The DLL protocol entity shall comply with ISO 11898-1.		

5.3 DLL device interface requirements

REQ	2.2	DLL — Allowed data frame format
The DLL device interface shall transmit only data frames in CEFF (Classical Extended Frame Format).		

REQ	2.3	DLL — Remote frames
The DLL device interface shall not request remotely data frames by means of remote frames.		

6 Physical layer (PHY)

6.1 General

The PHY is divided in three sub-layers:

- physical signalling (PS),
- physical medium attachment (PMA), and
- physical medium dependent (PMD) sub-layers.

6.2 Physical signalling (PS) requirements

6.2.1 General

The physical signalling sub-layer, as specified in ISO 11898-1, determines the transmission speed and the recent re-synchronisation capability.

6.2.2 PS entity requirements

The physical signalling entity is normally part of the CAN controller implementation.

REQ	1.1	PHY — PS entity requirements — ISO 11898-1 conformance
The PS entity shall comply with ISO 11898-1.		

REQ	1.2	PHY — PS entity requirements — Fault confinement
The fault confinement entity used for the data link layer shall be in accordance with ISO 11898-1.		

6.2.3 PS device interface requirements

The bit-timing settings determine the transmission speed and the re-synchronisation capability. The programming of the bit time depends on the internal signal delay time and the capacitive load.

REQ	1.3	PHY — PS device interface requirements — Bit-rate
The PS device shall be configured that it transmits frames at a bit-rate of 125 kbit/s.		

REQ	1.4	PHY — PS device interface requirements — Oscillator frequency
The oscillator frequency from which the data rate is derived shall have a maximum relative tolerance of $\pm 0,01$ %.		

REQ	1.5	PHY — PS device interface requirements — Bit timing settings
To ensure proper operation under worst case conditions, the parameters specified in Table 1 shall apply and following requirements shall be fulfilled.		
— Only signal edges from recessive-to-dominant shall be used for synchronisation.		
— Single sampling shall be used.		

Table 1 — Bit timing parameters

Parameter	Notation	Unit	Value		
			Min.	Nominal	Max.
Bit time without synchronisation (logical)	t	μs	7,999 2	8,0	8,000 8
Internal signal delay time ^a	t_{del}	μs	—	—	0,4
Synchronisation jump width	t_{sjw}	ns	—	—	500
Sample point ^b	t	μs	$6 + t_{\text{sjw}}$	—	7

^a Period of time between transmit logic input signal and receive logic output signal at state transition, bus length = 0 m.
^b See ISO 11898-1.

6.3 Physical medium attachment (PMA) requirements

6.3.1 PMA entity requirements

REQ	1.6	PHY — PMA entity requirements — PMD interface
The PMA entity shall provide the differential voltage V_{diff} as specified in Equation (1) .		

REQ	1.7	PHY — PMA entity requirements — Dominant state
In the logical “dominant” state, the voltage levels of CAN_H and CAN_L shall be as specified in Equation (2) .		

REQ	1.8	PHY — PMA entity requirements — Recessive state
In the logical “recessive” state, the voltage levels of CAN_H and CAN_L shall be as specified in Equation (3) .		

Definition of [Equation \(1\)](#)

$$V_{\text{diff}} = V_{\text{CAN_L}} - V_{\text{CAN_H}} \tag{1}$$

This results in a value of:

$$V_{\text{diff}} = 1/3 \times V_s \text{ at recessive state, and}$$

$$V_{\text{diff}} = -1/3 \times V_s \text{ at dominant state.}$$

Definition of [Equation \(2\)](#)

$$V_{\text{CAN_H}} = \frac{2}{3} \times V_s \tag{2}$$

$$V_{\text{CAN_L}} = \frac{1}{3} \times V_s$$

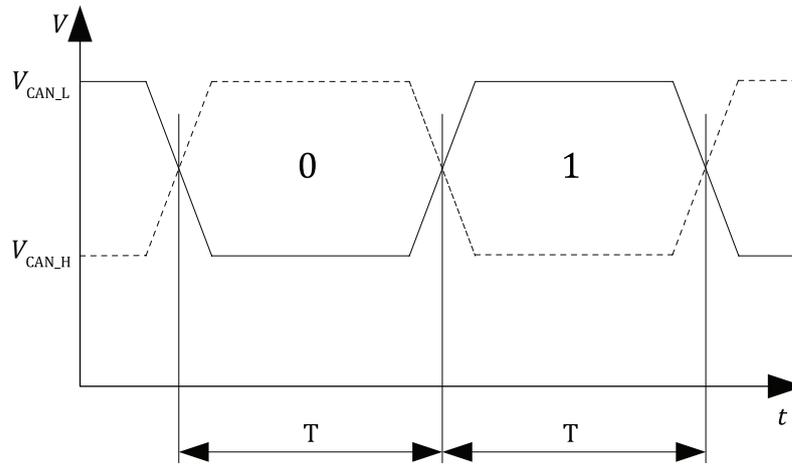
where V_s is the supply voltage of the device connected to the bus.

Definition of [Equation \(3\)](#)

$$V_{\text{CAN_H}} = \frac{1}{3} \times V_s \tag{3}$$

$$V_{\text{CAN_L}} = \frac{2}{3} \times V_s$$

[Figure 3](#) shows the dominant and recessive state of CAN_H and CAN_L.



Key

- 0 dominant: Logic "0"
- 1 recessive: Logic "1"

Figure 3 — Dominant and recessive state of CAN_H and CAN_L

REQ	1.8	PHY — PMA entity requirements — DC parameters
The DC parameter of a PMA entity shall be within the ranges specified in Table 2 and Table 3 , as appropriate. The parameters are valid for 2-wire operation, and for non-affected parts of the interface in the case of 1-wire operation.		

[Table 2](#) specifies the DC parameters for the recessive state with the two connectors mated.

Table 2 — DC parameters for the recessive state

Parameter	Notation	Unit	Value		
			min.	nominal	max.
Voltage level if TXD and RXD (see Figure 2) are in high-impedance state	V_{CAN_H}	V	$0,32 \times V_S$	$0,33 \times V_S$	$0,35 \times V_S$
	V_{CAN_L}		$0,65 \times V_S$	$0,67 \times V_S$	$0,68 \times V_S$
Differential voltage	V_{diff}		—	$0,33 \times V_S$	—
Threshold of differential voltage for receiving a recessive bit	$V_{diff-th}$	V	0	—	0,65

[Table 3](#) specifies the DC parameters for the dominant state.

Table 3 — DC parameters for the dominant state

Parameter	Notation	Unit	Value		
			min.	nominal	max.
Voltage level ^a	V_{CAN_H}	V	$0,64 \times V_S$	$0,67 \times V_S$	$0,70 \times V_S$
	V_{CAN_L}		$0,30 \times V_S$	$0,33 \times V_S$	$0,36 \times V_S$
Differential voltage	V_{diff}		—	$-0,33 \times V_S$	—
Threshold of differential voltage for receiving a dominant bit	$V_{diff-th}$	V	-0,65	—	0
Current for the entire range of V_S	I_{CAN_H}	mA	—	13,3 (6,6) ^b	—
	I_{CAN_L}				

^a Two interfaces coupled with the connector, only one transmits.

^b Two interfaces coupled. The values within brackets apply to nominal 12-V voltage systems; those without brackets apply to nominal 24-V voltage systems.

REQ	1.9	PHY — PMA entity requirements — Time constant t_F
The time constant t_F shall be in accordance to Equation (4) . See also REQ 1.21.		

Definition of [Equation \(4\)](#)

$$X = V_{CAN_L1} + 0,63 \times (V_{CAN_L2} - V_{CAN_L1}) \tag{4}$$

[Figure 4](#) shows an example of time constant t_F , which is the delay of voltage change between V_S and V_{CAN_H} or V_{CAN_L} in the case of any changes of V_S .

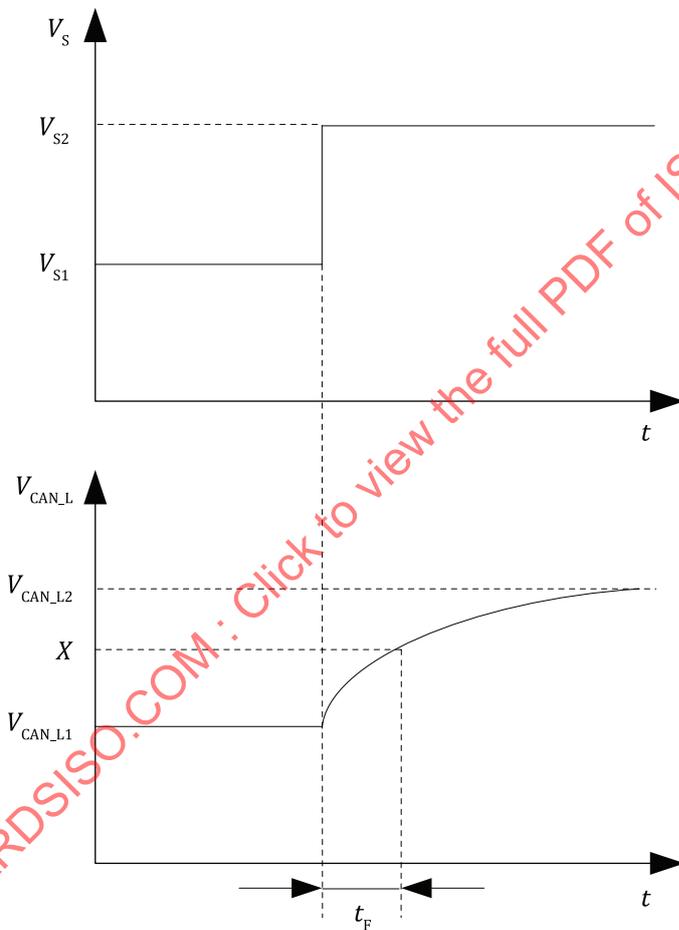


Figure 4 — Example of time constant t_F

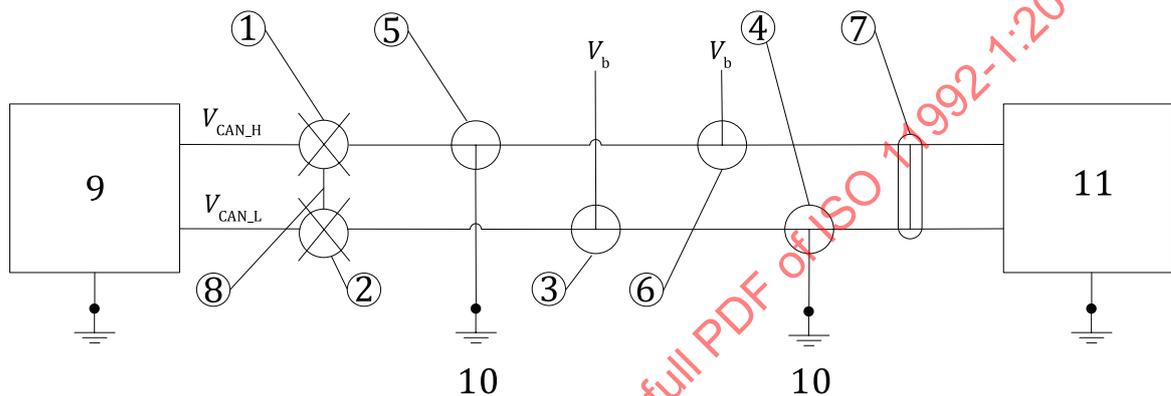
Transient errors (e.g. according ISO 7637-1[4] and ISO 7637-2[5]) are handled by the DLL entity (see ISO 11898-1).

REQ	1.10	PHY — PMA entity requirements — CAN bus-off state
When a node is set into the bus-off state it shall be immediately reset to resume communication. Failure handling depends on the repetition times, t_r , of the initialisation messages. Failures in the data transmission which are only present for less than $5 t_r$ shall not be indicated to the data link layer entity. In such case, the PMA interface shall remain in the 2-wire operation mode.		

Some bus faults as shown in [Figure 5](#) can impact the proper operation of the PMA entity.

REQ	1.11	PHY — PMA entity requirements — Electrical circuit
An electrical circuit shall be provided to avoid a total breakdown of the data transmission during bus failures. This circuit shall have the capability to transition from 2-wire-to 1-wire operation mode using only one of the two wires CAN_H or CAN_L.		

This allows data transmission to be maintained in the case of an interruption of CAN_H or CAN_L, or a short circuit of one cable to ground or to supply voltage, or a short circuit between CAN_H and CAN_L (see bus fault cases 1, 2, 3, 4, 5, 6 and 7 in [Figure 5](#)). Data transmission is no longer possible if both cables are affected by a short circuit (except a short circuit between CAN_H and CAN_L) or interruption (bus fault case 8). Implementation examples are given in [Annex A](#).



Key

- 1 bus fault case 1 — CAN_H broken wire
- 2 bus fault case 2 — CAN_L broken wire
- 3 bus fault case 3 — CAN_L short to V_b
- 4 bus fault case 4 — CAN_L short to *ground*
- 5 bus fault case 5 — CAN_H short to *ground*
- 6 bus fault case 6 — CAN_H short to V_b
- 7 bus fault case 7 — CAN_H and CAN_L shorted
- 8 bus fault case 8 — CAN_H and CAN_L broken wire
- 9 device towing vehicle
- 10 ground
- 11 device towed vehicle

Figure 5 — Bus fault cases

REQ	1.12	PHY — PMA entity requirements — Bus fault detection
If correct data transmission is not possible for longer than $5 t_r$ (data neither correctly received nor transmitted), then the fault handling logic shall indicate this and perform the bus fault handling procedure described in REQ 2.15 to REQ 2.16.		

NOTE 1 The bus fault detection and handling is realised either by hardware or software.

REQ	1.13	PHY — PMA entity requirements — 1-wire bus fault operation mode 1 handling (cases 1 to 6)
In the CAN_L-operation mode the dominant driver of CAN_H shall be switched off and the voltage at the receive-comparator for CAN_H shall be replaced by a reference voltage. This mode shall be used to cover bus fault case 1, bus fault case 5, and bus fault case 6 of Figure 5 .		

REQ	1.14	PHY — PMA entity requirements — 1-wire bus fault operation mode 2 handling (case 1 to case 6)
<p>In the CAN_H operation mode the dominant driver of CAN_L shall be switched off, the recessive source of CAN_L switched to a high impedance state, and the voltage at the receive-comparator for CAN_L shall be replaced by a reference voltage. This mode shall be used to cover bus fault cases 2, 3, and 4 of Figure 5.</p>		

REQ	1.15	PHY — PMA entity requirements — 1-wire bus fault handling case 7
<p>Bus fault case 7 of Figure 5 shall be covered by either CAN_L-operation mode or CAN_H-operation mode.</p>		

NOTE 2 The bus fault detection and handling can be a procedure realised either by hardware or software.

Depending on the bus fault case, one of the two operation modes allow successful data transmissions. This mode is called the "correct 1-wire operation mode". It could be necessary to try both 1-wire operation modes before identifying the correct 1-wire operation mode.

The fault handling procedure in the towing vehicle starts when data transmission is not possible for $5 t_r$.

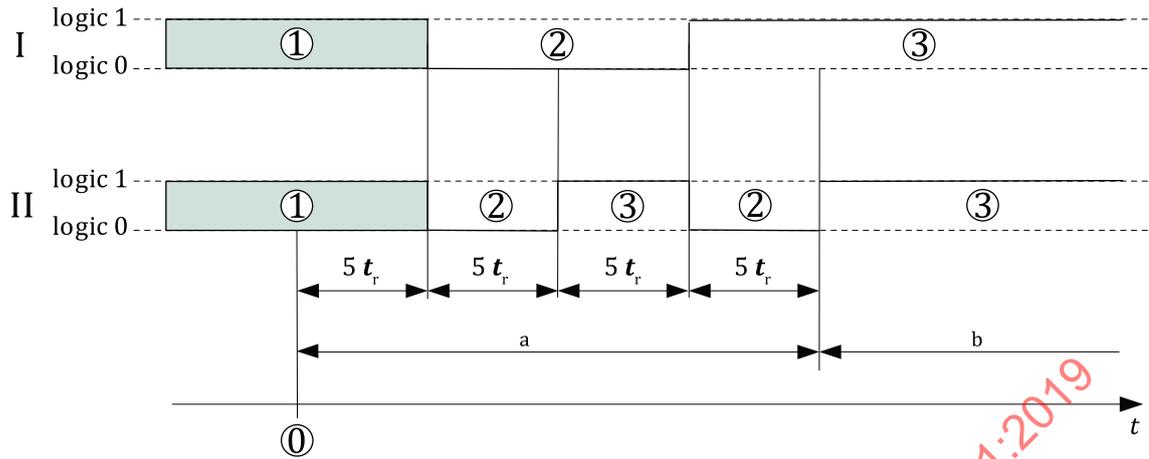
REQ	1.16	PHY — PMA entity requirements — Switch to 1-wire operation mode
<p>The fault handling procedure shall then switch to a 1-wire operation mode and try to work in this mode for $10 t_r$. If during this time no data transmission is successful, the interface shall switch to the other 1-wire operation mode and try to operate in this mode for $10 t_r$.</p> <p>If during this time data transmission is still not successful, the interface shall switch to the 2-wire operation mode and start the fault detection and handling procedure again with a $5 t_r$ observation period.</p>		

The fault handling procedure in the towed vehicles starts when data transmission is not possible for $5 t_r$.

REQ	1.17	PHY — PMA entity requirements — Switch to correct 1-wire operation mode
<p>The fault handling shall perform a procedure that guarantees that the towed vehicle switches to the correct 1-wire operation mode within $6 t_r$, after the interface of the towing vehicle switched to the correct 1-wire operation mode and that it then remains in that mode.</p> <p>If no data transmission is successful for $20 t_r$, the interface shall switch to the 2-wire operation mode and start that fault detection and handling procedure again with a $6 t_r$ observation period.</p>		

REQ	1.18	PHY — PMA entity requirements — Resume successful data transmission
<p>As soon as data transmission is successful again, the current operation mode shall be continued, and the fault detection and handling sequence shall be restarted with a $5 t_r$ observation period of the line or lines used.</p>		

An example of the timing diagram for bus failure, case 6 = CAN_H short to V_b , is shown in [Figure 6](#).



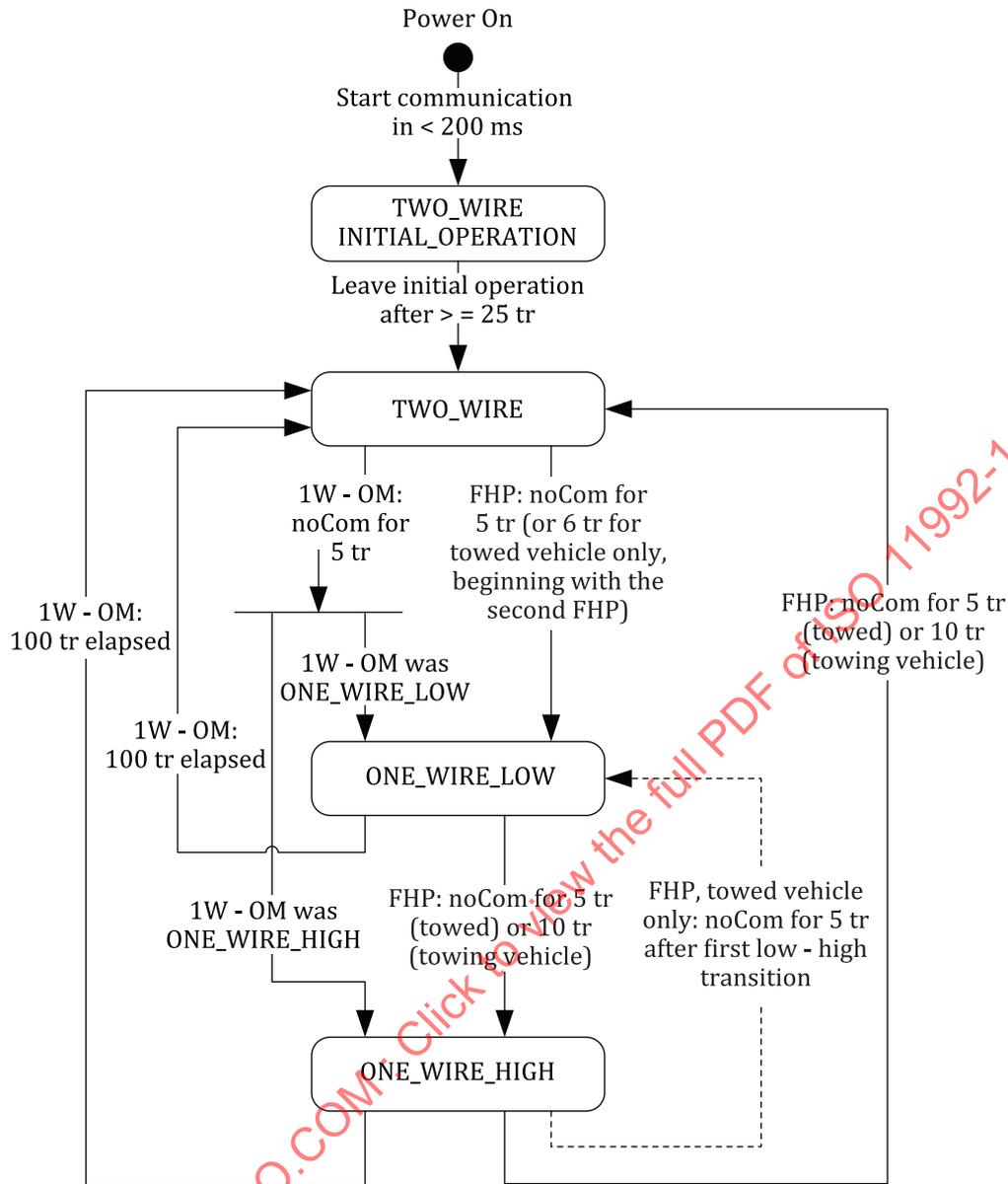
Key

- I operation mode in the towing vehicle
- II operation mode in the towed vehicle
- 0 bus fault occurs
- 1 2-wire operation mode
- 2 CAN_L operation mode
- 3 CAN_H operation mode
- a No transmission possible.
- b Transmission in the correct 1-wire operation mode.

Figure 6 — Example of timing diagram for bus fault case 6

[Figure 7](#) shows the CAN wire states detection and handling from the viewpoint of the towing vehicle.

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- Key**
- noCom communication interruption (data neither received nor transmitted)
 - FHP fault handling procedure (see REQ 2.15 to REQ 2.16)
 - 1W-OM 1-wire operation mode

Figure 7 — CAN wire states detection and handling from the viewpoint of the towing vehicle

REQ	1.19	PHY — PMA entity requirements — Bus fault recovery
When the PMA entity operates in a 1-wire operation mode for 100 t_r since the first correct data transmission in this mode, it shall switch back to the 2-wire operation mode for a test period of 5 t_r . If data transmission is successful during this test period, it shall remain in the 2-wire operation mode and restart the normal fault detection and handling procedure with another 5 t_r observation period. If during the test period data transmission is not successful, the interface shall switch back to the 1-wire operation mode that was in use before the test period.		

REQ	1.20	PHY — PMA entity requirements — Power-on procedure
The PMA entity shall start with transmission not later than 0,2 s after power is switched on for the interface. When transmission is started, the interface shall try to operate in the 2-wire operation mode for at least 30 t_r .		

6.3.2 PMA device interface requirements

REQ	1.21	PHY — PMA device interface requirements — AC parameters
The C_{bus} and t_F parameters of the PMA device interface shall be within the ranges as specified in Table 4 .		

Table 4 — AC parameters of PMA device interface

Parameter	Notation	Unit	Value		
			min.	nominal	max.
Input capacitance of one interface ^a	C_i	pF	—	400	—
Differential input capacitance ^b	C_d		—	100	—
Bus input capacitance ^c	C_{bus}		—	600	800
Time constant of supply filter ^d	t_F	ms	—	—	5

a Capacitance between CAN_H and ground, CAN_L and ground, with no connector connected.
b Capacitance between CAN_H and CAN_L with no connector connected.
c The capacitive load for the driving circuit resulting from the electronic unit is $C_{bus} = C_i + 2 \times C_d$ measured with no connector connected.
d See [Figure 4](#).

REQ	1.22	PHY — PMA device interface requirements — Voltage ranges
The voltage ranges of the PMA device interface shall be within the ranges specified in Table 5 and Table 6 .		

Table 5 — Voltage ranges for 24-V nominal voltage systems

Parameter	Notation	Unit	Value		
			min.	nominal	max.
Interface operating voltage	V_S^a	V	16	—	32
Voltage at bus connection	V_{CAN_H}	V	0	—	32
	V_{CAN_L}				
Interface supply current (nominal operation)	I_S^b	mA	—	—	60

a V_S see [Figure 10](#).
b I_S see [Figure 10](#).

Table 6 — Voltage ranges for 12-V nominal voltage systems

Parameter	Notation	Unit	Value		
			min.	nominal	max.
Interface operating voltage	V_s^a	V	9	—	16
Voltage at bus connection	V_{CAN_H}	V	0	—	16
	V_{CAN_L}				
Interface supply current (nominal operation)	I_s^b	mA	—	—	30

a V_s see Figure 10.
 b I_s see Figure 10.

6.4 Physical media dependent (PMD) sub-layer requirements

6.4.1 PMD entity requirements

The PMD entity consists of device connector contacts, termination resistor and other requirements which are not in scope of this document e.g., common mode chokes.

REQ	1.23	PHY — PMD entity requirements — Device connector contacts
The device connector contact parameters related to the contacts CAN_H and CAN_L shall be in accordance with Table 7.		

Table 7 — Device connector contact parameters

Parameter	Notation	Unit	Value		
			min.	nominal	max.
Device contact resistance	R_{con}	mΩ	—	—	10
Insulation resistance between CAN_H and CAN_L ^a	R_{i1}	MΩ	50	—	—
Differential capacitance between CAN_H and CAN_L	C_{cd}	pF	—	5	—
Insulation resistance between CAN_H/CAN_L and ground ^a	R_{i2}	MΩ	50	—	—
Input capacitance between CAN_H/CAN_L and ground	C_{ci}	pF	—	5	—
Capacitive load of the connector ^b	C_{con}	pF	—	—	20
Current through connector ^c	I_{CAN_H}	mA	—	0	—
	I_{CAN_L}				

a According to ISO 8092-2[7].
 b The capacitive load for the driving circuit resulting from the connector is $C_{con} = C_{ci} + 2 \times C_{cd}$.
 c With the two connectors mated.

6.4.2 PMD device interface requirements

REQ	1.24	PHY — PMD device interface requirements — Termination resistor
The termination resistors R_1 and R_2 shall be implemented according to the definition in Table 8 and Figure 8 for towing and towed vehicle networks.		

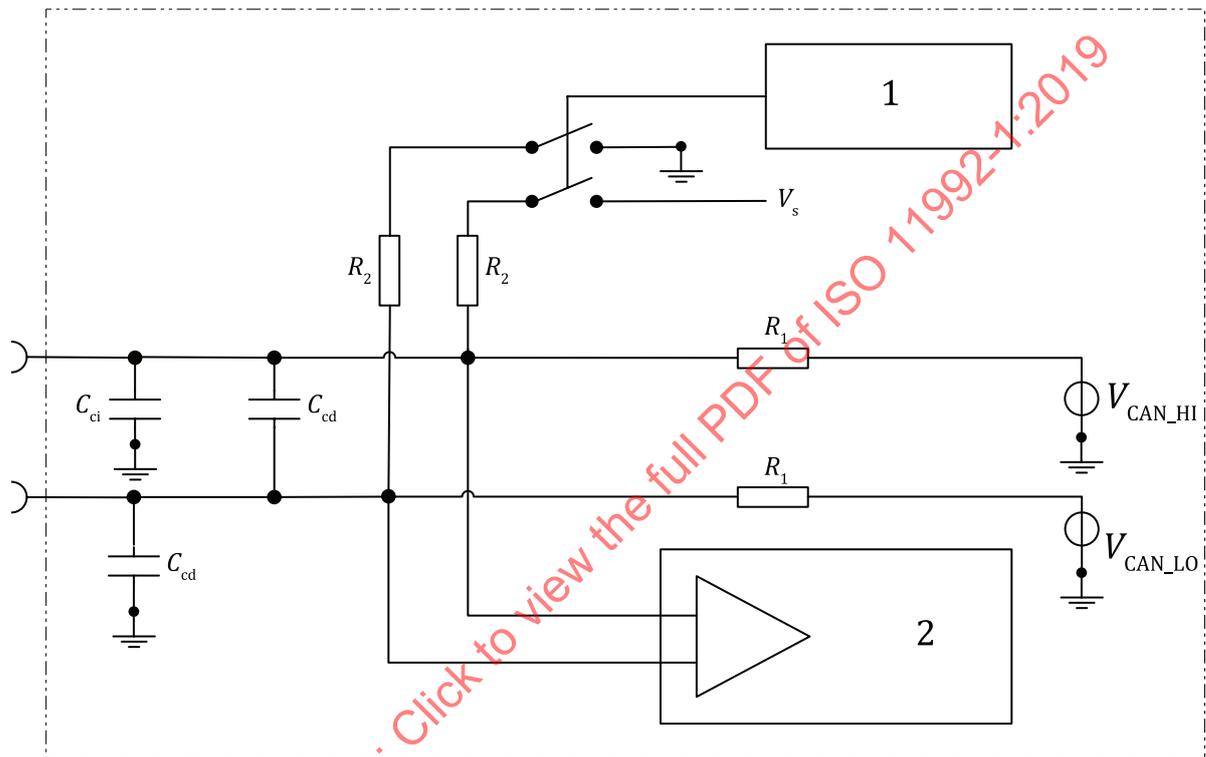
Table 8 specifies the termination resistors for the recessive and dominate state of CAN_H and CAN_L.

Table 8 — Termination resistors for the recessive and dominate state of CAN_H and CAN_L

Parameter	Notation	Unit	Value		
			min.	nominal	max.
Input resistance (recessive state)	R_1	Ω	570	600	630
Serial resistance (dominant state) ^a	R_2	Ω	285	300	315

^a Including the serial resistance of the switch (see [Figure 8](#)).

[Figure 8](#) shows the electrical equivalent circuit diagram of PMD device interface.



Key

- 1 transmit logic
- 2 receive and transmit logic
- V_{CAN_HI} voltage source of CAN_H for recessive state
- V_{CAN_LO} voltage source of CAN_L for recessive state

Figure 8 — Electrical equivalent circuit diagram of PMD device interface

REQ 1.25	PHY — PMD device interface requirements — Towing vehicle PMD parameters
The PMD parameters of the towing vehicle device shall comply with the values specified in Table 9 .	

Table 9 — Towing vehicle PMD parameters

Parameter	Notation	Unit	Value		
			min.	nominal	max.
Differential capacitance between CAN_H and CAN_L in towing vehicle ^a	C_{d1}	pF	—	750	—
Input capacitance between CAN_H and ground, CAN_L and ground in towing vehicle ^a	C_{i1}	pF	—	750	—
Bus capacitance in towing vehicle ^b	C_{bus1}	nF	—	—	2,4
Resistance of CAN_H and CAN_L in towing vehicle	R_{i1}	mΩ	—	—	600
Insulation resistance of each CAN_H and CAN_L to ground and V_S in towing vehicle ^c	R_{i11}	MΩ	15	—	—
Insulation resistance between CAN_H and CAN_L in towing vehicle ^d	R_{i21}	MΩ	15	—	—

^a Test method according to ISO 4141-1.
^b The capacitive load for the driving circuit resulting from the cable is $C_{busx} = C_{ix} + 2 \times C_{dx}$, where $x = 1, 2, 3$; including the connector capacitance, C_{con} .
^c Test method similar to that given in ISO 8092-2[7].

REQ	1.26	PHY — PMD device interface requirements — Towed vehicle PMD parameters
The PMD parameters of the towed vehicle device shall comply with the values specified in Table 10 .		

Table 10 — Towed vehicle PMD parameters

Parameter	Notation	Unit	Value		
			min.	nominal	max.
Differential capacitance between CAN_H and CAN_L in towed vehicle ^a	C_{d3}	pF	—	900	—
Input capacitance between CAN_H and ground, CAN_L and ground in towed vehicle ^a	C_{i3}	pF	—	900	—
Bus capacitance in towed vehicle ^b	C_{bus3}	nF	—	—	2,9
Resistance of each CAN_H and CAN_L in towed vehicle	R_{i3}	mΩ	—	—	700
Insulation resistance of each CAN_H and CAN_L to ground and V_S in towed vehicle ^c	R_{i13}	MΩ	12	—	—
Insulation resistance between CAN_H and CAN_L in towed vehicle ^c	R_{i23}	MΩ	12	—	—

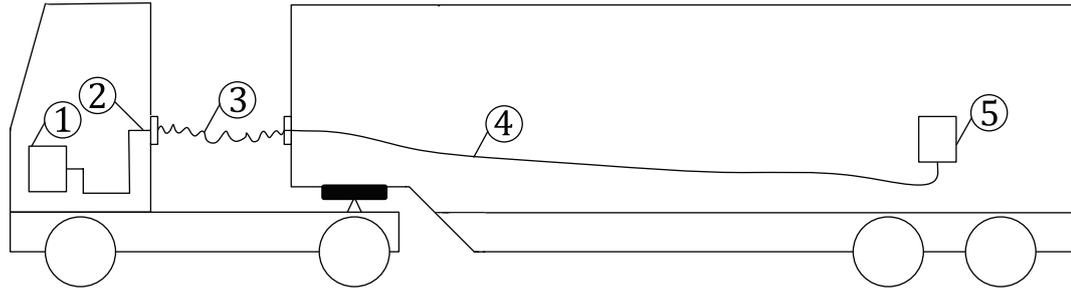
^a Test method according to ISO 4141-1.
^b The capacitive load for the driving circuit resulting from the cable is $C_{busx} = C_{ix} + 2 \times C_{dx}$, where $x = 1, 2, 3$; including the connector capacitance, C_{con} .
^c Test method similar to that given in ISO 8092-2[7].

6.5 Network wiring harness system requirements

The physical media is a cable, which may be part of a multi-core cable. For this physical media the characteristic impedance has no significant influence and is therefore left unspecified.

REQ	1.27	PHY — PMD network system requirements — Unshielded twisted pair bus lines
The network media shall be an unshielded twisted pair (CAN_H and CAN_L)		

The total length of the cable is normally split into three parts, l_1 , l_2 and l_3 , as shown in [Figure 9](#).



Key

- 1 device e.g. ECU in towing vehicle
- 2 cable of wiring harness in towing vehicle
- 3 cable between towing and towed vehicle
- 4 cable of wiring harness in towed vehicle
- 5 device e.g. ECU in towed vehicle

Figure 9 — Cable lengths

REQ	1.28	PHY — PMD network system requirements — Cable parameters
The cable parameters shall comply with the values specified in Table 11 .		

[Table 11](#) defines the cable parameters according to [Figure 9](#).

Table 11 — Cable parameters

Parameter	Notation	Unit	Value		
			min.	nominal	max.
Overall cable length ^a	l	m	—	—	40
Cable length between towing and towed vehicle	l_2	m	—	—	7
Differential capacitance between CAN_H and CAN_L in cable between towing and towed vehicle ^b	C_{d2}	pF	—	560	—
Input capacitance between CAN_H and ground, CAN_L and ground in cable between towing and towed vehicle ^b	C_{i2}	pF	—	700	—
Bus capacitance in cable between towing and towed vehicle ^c	C_{bus2}	nF	—	—	1,9
Resistance of each CAN_H and CAN_L in cable between towing and towed vehicle	R_{i2}	mΩ	—	—	300
Insulation resistance of each CAN_H and CAN_L to ground and V_S in cable between towing and towed vehicle ^d	R_{i12}	MΩ	30	—	—
Insulation resistance between CAN_H and CAN_L in cable between towing and towed vehicle ^d	R_{i22}	MΩ	30	—	—
Cable length in towed vehicle	l_3	m	—	—	18
Differential capacitance between CAN_H and CAN_L in towed vehicle ^b	C_{d3}	pF	—	900	—

^a $l = l_1 + l_2 + l_3$.

^b Test method according to ISO 4141-1.

^c The capacitive load for the driving circuit resulting from the cable is $C_{busx} = C_{IX} + 2 \times C_{dx}$, where $x = 1, 2, 3$; including the connector capacitance, C_{con} .

^d Test method similar to that given in ISO 8092-2[2].