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ISO 11783-2

Third edition
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Tractors and machinery for agriculture and forestry — Serial control and communications data network —

Part 2: **Physical layer**

Tracteurs et matériels agricoles et forestiers — Réseaux de commande et de communication de données en série —

Partie 2: Couche physique

Reference number
ISO 11783-2:2019(E)

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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. 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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on 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 the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 23, *Tractors and machinery for agriculture and forestry*, Subcommittee SC 19, *Agricultural electronics*.

This third edition cancels and replaces the second edition (ISO 11783-2:2012), which has been technically revised. It also incorporates the Technical Corrigendum ISO 11783-2:2012/Cor 1:2012. The main changes compared to the previous edition are as follows:

— inclusion of physical layer aspects previously listed in other documents of the ISO 11783 series;

— addition of a twisted pair physical layer;

— updates to parameters of the physical layer components to reflect the current state of art;

— updates to test criteria to verify the conformance of implementations to this document.

A list of all the parts in the ISO 11783 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

ISO 11783-1 to ISO 11783-14 specify a communications system for agricultural equipment based on the ISO 11898[1] protocol. SAE J1939 documents, on which parts of ISO 11783 are based, were developed jointly for use in truck and bus applications and for construction and agricultural applications. Joint documents were completed to allow electronic units that meet the truck and bus SAE J1939 specifications to be used by agricultural and forestry equipment with minimal changes. General information on the ISO 11783 series is to be found in ISO 11783-1.

Tractors and machinery for agriculture and forestry — Serial control and communications data network —

Part 2: Physical layer

1 Scope

ISO 11783 specifies a serial data network for control and communications on forestry or agricultural tractors and mounted, semi-mounted, towed or self-propelled implements. Its purpose is to standardize the method and format of transfer of data between sensors, actuators, control elements, and information-storage and -display units, whether mounted on, or part of, the tractor or implement. ISO 11783 also provides an open interconnect system for on-board electronic systems used by agriculture and forestry equipment. It is intended to enable electronic control units (ECUs) to communicate with each other, providing a standardized system.

This document defines and describes the network's 250 kbit/s, twisted, non-shielded, quad-cable physical layer and an alternative cable and architecture named twisted pair physical layer (TPPL) based on a 250 kbit/s, un-shielded, twisted pair cable network layer which is fully backward compatible to twisted quad based machines and devices.

NOTE Where not differently specified, requirements are valid for both twisted quad and TPPL.

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 1724, *Road vehicles — Connectors for the electrical connection of towing and towed vehicles — 7-pole connector type 12 N (normal) for vehicles with 12 V nominal supply voltage*

ISO 11783-1, *Tractors and machinery for agriculture and forestry — Serial control and communications data network — Part 1: General standard for mobile data communication*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 11783-1 and the following 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
ECU Type I
electronic control unit without internal termination

3.2
ECU Type I WEAK
electronic control unit with a weak split termination centrally coupled to ECU_GND with a capacitor and that can be used for stubs only

Note 1 to entry: See 5.5.3.

3.3
ECU Type II
electronic control unit with internal bus termination that can be used only at one or each end of the bus

Note 1 to entry: See 5.4.3.2.

3.4
twisted pair physical layer
TPPL
250 kbit/s, unshielded, twisted pair cable-based network layer intended to be used as an alternate to the twisted quad physical layer and that is backward compatible with machines based on a twisted quad physical layer

3.5
machine
forestry or agricultural tractor or mounted, semi-mounted, towed or self-propelled implement

3.6
twisted quad physical layer
TQPL
250 kbit/s, unshielded, twisted quad cable-based network layer

4 Abbreviated terms

IBBC Implement Bus Breakaway Connector

IBBP Implement Bus Breakaway Plug

5 General requirements

5.1 Network physical layer

The physical layer of a network is the realization of the electrical connection of several electronic control units (ECUs) to a bus segment of the network. The total number of ECUs connected is limited by the electrical loads on the bus segment. In accordance with the electrical parameters specified by this document, the limit shall be 30 ECUs per segment.

5.2 Physical media

This document defines two types of physical media.

a) TQPL: composed by four conductors, two of them, designated CAN_H and CAN_L, are driven with the communications signals. The names of the ECU pins corresponding to these conductors are also designated CAN_H and CAN_L. The third and fourth conductors, designated TBC_PWR and TBC_RTN, provide power for the terminating bias circuits (TBCs) on the bus segments.

b) TPPL: physical media of twisted pair cable as described in SAE J1939-15. The conductors, designated CAN_H and CAN_L, are driven with the communications signals. The names of the ECU pins corresponding to these conductors are also designated CAN_H and CAN_L.

5.3 Differential voltage

The voltages of CAN_H and CAN_L relative to the ECU_GND of each ECU are denoted by V_{CAN_H} and V_{CAN_L}. The differential voltage, V_{diff}, between V_{CAN_H} and V_{CAN_L} is defined by Formula (1):

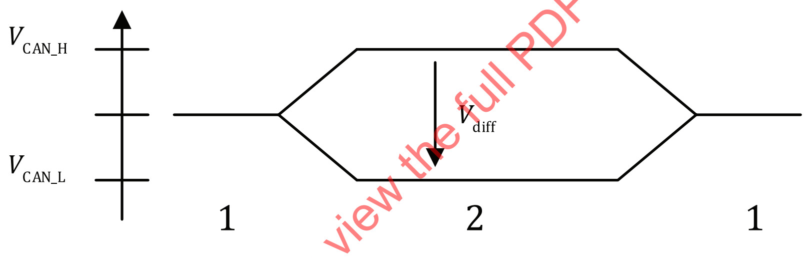
$$V_{diff} = V_{CAN\_H} - V_{CAN\_L} \tag{1}$$

5.4 Bus

5.4.1 Levels

5.4.1.1 General

The bus signal lines can be at one of two levels, and in one or the other of the two logical states, recessive or dominant (see Figure 1). In the recessive state, V_{CAN_H} and V_{CAN_L} are fixed at a bias voltage level. V_{diff} is approximately zero on a terminated bus. The recessive state is transmitted during bus idle when all the nodes CAN drivers are off. The dominant state is transmitted when any of the node CAN drivers is on. The dominate state is represented by a differential voltage greater than a minimum threshold which is detected by the nodes CAN receiver circuits. The dominant state overwrites the recessive state and is transmitted when there is a dominant bit. (See also Clause 6).



Key

1 recessive

2 dominant

Figure 1 — Physical bit representation of recessive and dominant levels or states

5.4.1.2 During arbitration

During arbitration, a recessive and a dominant bit imposed on the bus signal lines during a given bit time by two or more ECUs results in a dominant bit.

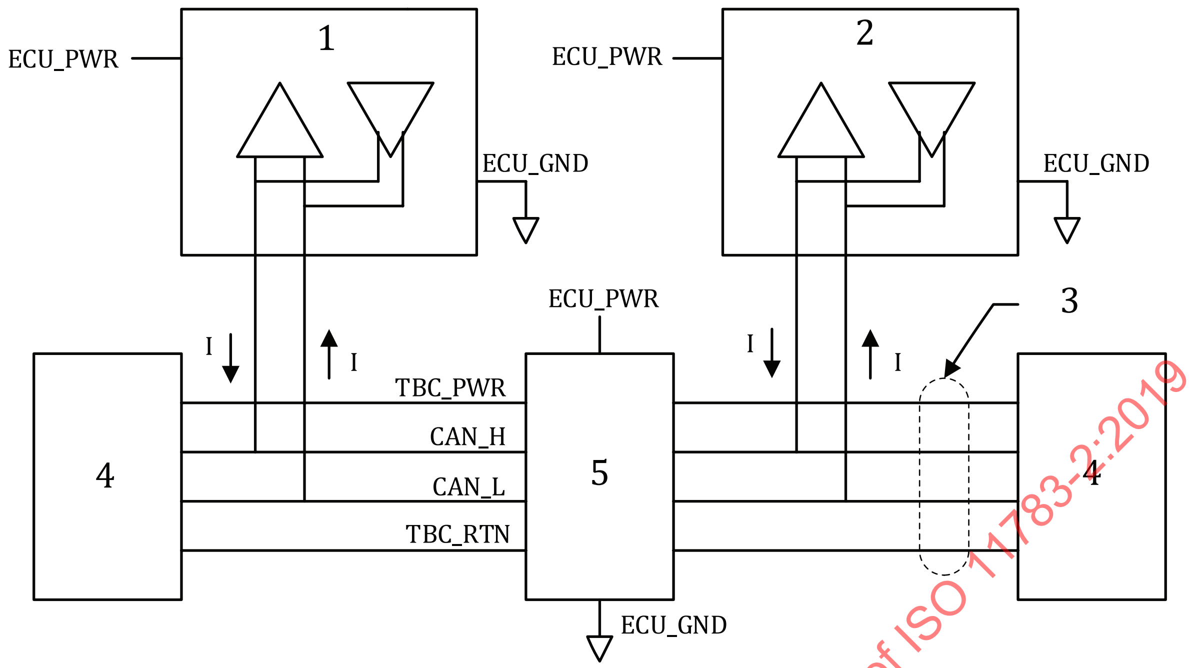
5.4.2 Voltage range

The bus voltage range is defined by the maximum and minimum acceptable voltage levels of CAN_H and CAN_L, measured with respect to the ECU_GND of each ECU, for which proper operation is guaranteed when all ECUs are connected to bus signal lines.

5.4.3 Bus termination

5.4.3.1 Twisted quad bus segment

The bus signal lines of a twisted quad bus segment are electrically terminated at each end by a terminating bias circuit. When a nodes CAN driver is on, a current (I) flow is induced that is either sunk by the CAN_H termination or is sourced by the CAN_L termination. This TBC shall be located externally from the ECU, to ensure bus bias and termination when the ECU is disconnected (see Figure 2).



Key

1 ECU No. 1

2 ECU No. *n*

3 twisted quad cable

4 terminating bias circuit (TBC)

5 power for TBC_PWR and TBC_RTN

Figure 2 — Physical layer functional diagram

5.4.3.2 Twisted pair physical layer bus segment

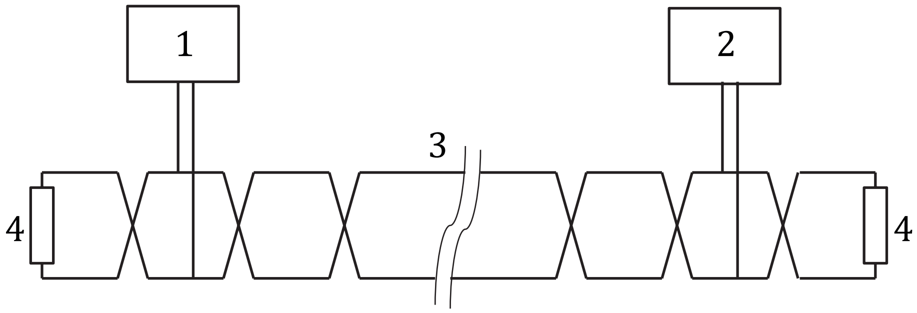
The bus signal lines of a TPPL bus segment are electrically terminated at each end with a passive load resistor denoted by R_L where R_L = 120 Ω.

This document recommends that R_L be located external to ECUs.

If a Type II ECU is used for terminating the bus segment, that ECU shall contain the bus termination resistor (see Figure 5) and shall be located at one or both ends of an ISO 11783-2 bus system only. Type II ECUs shall be clearly marked. A Type II ECU shall only be used at an end of the bus, even when the machine is attached to another machine by an IBBC.

Type II ECUs shall only be powered by ECU_PWR/ECU_GND.

See Figures 3 and 4.



Key

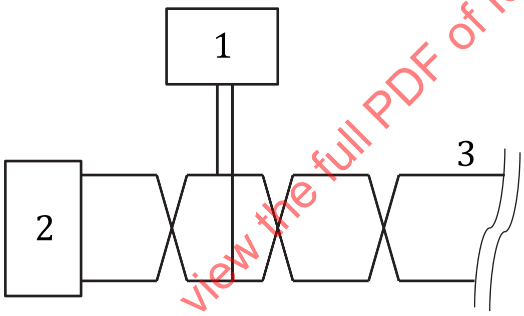
1 ECU Type I No. 1

2 ECU Type I No. *n*

3 unshielded twisted pair

4 terminating resistors R_L

Figure 3 — TPPL functional diagram



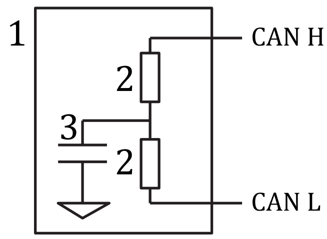
Key

1 ECU Type I

2 ECU Type II with internal R_L

3 unshielded twisted pair

Figure 4 — Physical layer functional diagram (one side) with ECU Type II as a termination



Key

1 ECU Type II

2 60 Ω resistors $R_L/2$

3 coupling capacitor C

Figure 5 — Split termination

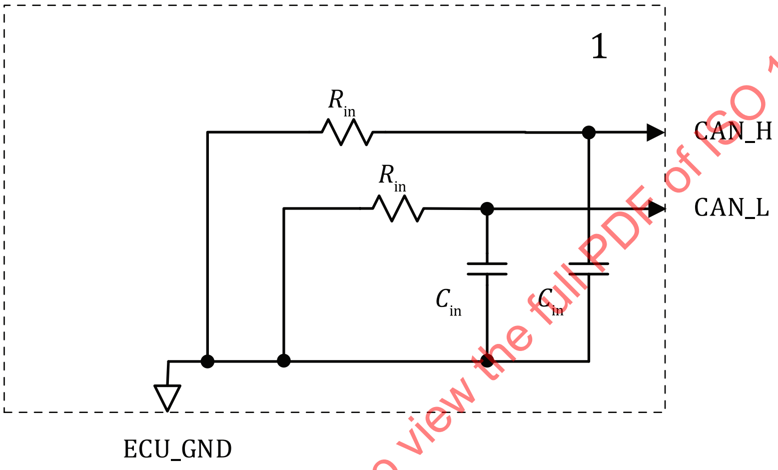
5.5 Resistance and capacitance

5.5.1 Internal resistance (R_{in}), capacitance (C_{in})

The internal resistance, R_{in}, of an ECU is defined as the resistance between CAN_H or CAN_L and ground (ECU_GND) in the recessive state, with the ECU disconnected from the bus signal line. The measurement shall be made with the ECU both powered and unpowered, and the minimum value used to confirm compliance.

The internal capacitance, C_{in}, of an ECU is defined as the capacitance between CAN_H or CAN_L and ECU_GND during the recessive state, with the ECU disconnected from the bus signal line. The measurement shall be made with the ECU both powered and unpowered, and the maximum value used to confirm compliance.

ECU internal resistance and capacitance are illustrated by Figure 6.



Key

1 ECU

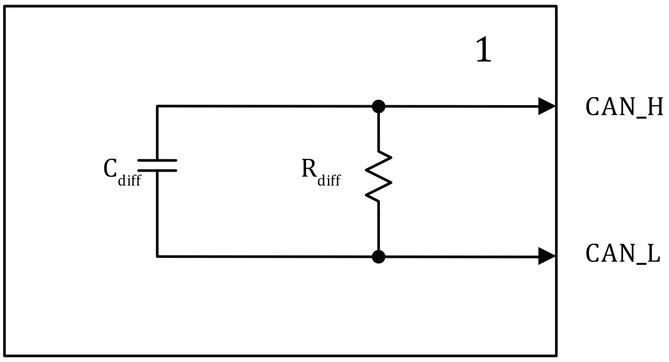
Figure 6 — Internal resistance and capacitance of ECU in recessive state

5.5.2 Differential internal resistance (R_{diff}), capacitance (C_{diff})

The differential internal resistance, R_{diff}, is defined as the resistance seen between CAN_H and CAN_L in the recessive state, with the ECU disconnected from the bus signal line. The measurement shall be made with the ECU both powered and unpowered, and the minimum value used to confirm compliance.

The differential internal capacitance, C_{diff}, of an ECU is defined as the capacitance seen between CAN_H and CAN_L during the recessive state, with the ECU disconnected from the bus signal lines (see Figure 7). The measurement shall be made with the ECU both powered and unpowered, and the maximum value used to confirm compliance.

ECU differential internal resistance and capacitance are illustrated by Figure 7.



Key

1 ECU

Figure 7 — Differential internal resistance and capacitance of ECU in recessive state

5.5.3 Weak termination for stubs

For higher immunity and better EMC performance, TPPL nodes which are connected to the bus can optionally be realized by using ECU Type I WEAK equipped with a split-termination configuration. Where an ECU Type I WEAK is used, this document recommends the termination is realized by a split-termination of minimum 750 Ω + 750 Ω with a 47 nF capacitor coupled with ECU_GND. The total number of Type I WEAK ECUs used on a single machine shall not exceed 3 units.

With reference to 7.6.3.7, where an ECU is powered by the PWR/GND circuit, the split termination of an ECU Type I WEAK shall be coupled with GND.

5.6 Bit time

The bit time, t_B, is defined as the duration of one bit. Bus management functions executed within this duration, such as protocol controller synchronization, network transmission delay compensation and sample point positioning, are defined by the programmable bit timing logic of the CAN protocol-controller integrated circuit (IC). Bit time conforming to this document is 4 µs, which corresponds to a data rate of 250 kbit/s. Bit time selection generally demands the use of crystal oscillators at all nodes so that the clock tolerance given in Table 1 can be achieved.

A reliable ISO 11783 network shall be able to be constructed with ECUs from different suppliers. ECUs from different suppliers cannot properly receive and interpret valid messages without timing restrictions achieved by specific timing requirements for the bit timing registers in each protocol controller. Moreover, there are substantial differences between the bit segments used by protocol-controller IC manufacturers.

The physical signalling sub-layer entity shall be configured to support a bit rate of 250 kbit/s. Additionally, the following settings shall be configured:

— single sample point method as defined in ISO 11898-1;

— sample point at 80 % ± 3 % of the bit time.

See Annex A for more information on protocol timing and naming, and a detailed description of bit timing.

5.7 AC parameters

Table 1 defines the AC parameters for an ECU disconnected from the bus. The timing parameters also apply for an ECU connected to a bus segment.

Table 1 — AC parameters of a node disconnected from the bus

Parameter	Symbol	Min.	Nom.	Max.	Unit	Condition
Bit time	t_B	3,998	4,000	4,002	µs	250 kbit/s[a]
Transition time	t_T	—	—	500	ns	Measured from 10 % to 90 % of the voltage of the prevailing state[b]
Internal delay time	t_{ECU}	0,0	—	0,9	µs	[c]
Internal capacitance	C_{in}	0	—	200	pF	250 kbit/s for CAN_H and CAN_L relative to ground[d]
Differential internal capacitance	C_{diff}	0	—	100	pF	[d]
Common mode rejection	CMR	40	—	—	dB	DC. to 50 kHz
	CMR_{5MHz}	10	—	—	dB	5 MHz may linearly decrease between 50 kHz and 5 MHz
Available time	t_{avail}	2,5	—	—	µs	with 40 m bus length[e]

[a] Including initial tolerance, temperature and ageing.

[b] The match between the drive voltages and impedances (or currents) on the CAN_H and CAN_L lines are equally important in determining emissions, owing to the spectra presented being determined by the actual wave shape.

[c] The value of t_{ECU} is guaranteed for a differential voltage of V_{diff} = 1,0 V for a transition from recessive to dominant, V_{diff} = 0,5 V for a transition from dominant to recessive. With the bit timing given in this table, a CAN-interface delay of 500 ns is nominal possible (controller not included), with a reserve of about 300 ns. This allows slower transmitter slopes and input filtering. Delay values are for the implement bus and are at the discretion of the original equipment manufacturer (OEM) for the tractor bus.

The minimal internal delay time can be zero. The maximum tolerable value is determined by the bit timing and the bus delay time.

Total time delay when arbitrating is $t_T(\text{rise}_1) + t_T(\text{rise}_R) + t_T(\text{repeater}) + t_T(\text{rise}_R) + t_T(\text{repeater}) + 2t_T(\text{line}) + t_T(\text{node}_2)$. If there is 0 delay for the line, repeater and the loop back in node_2, and the transition time is > = 1/4 bit time, the transition times still consume all available bit time.

[d] In addition to the internal capacitance restrictions, a bus connection should also have as low as possible series inductance. The minimum values of C_{in} and C_{diff} can be 0, while the maximum tolerable values shall be determined by the bit timing and the topology parameters *L* and *d* (see Table 15). Proper functionality is guaranteed if cable resonant waves, if occurring, do not suppress the dominant differential voltage level below V_{diff} = 1 V, nor increase the recessive differential voltage level above V_{diff} = 0,5 V, at each individual ECU (see Table 7 and Table 8).

[e] The available time results from the bit timing unit of the CAN controller protocol IC. For example, as shown in Annex A, this time in most CAN controller ICs corresponds to tTSEG1. Due to poor synchronization it is possible to lose the length of two synchronization jump widths (SJW), so that t_{avail} with one instance of this poor synchronization is tTSEG1−SJW. A time quantum (*tq*) of 250 ns with SJW = 2 *tq*, tTSEG1 = 12 *tq*, tTSEG2 = 3 *tq*, results in t_{avail} = 2,5 µs.

6 Bus segment specifications

6.1 Twisted quad bus segment

A linear twisted quad bus segment shall be terminated at each end by a TBC (see Figure 2), which provides the electrical bias and common mode termination needed to suppress reflections.

The bus is in the recessive state if the bus transmitters of all nodes on the bus are switched off, with the mean bus voltage being generated by the TBCs on a particular bus segment (Figure 2). A dominant bit is sent to the bus signal lines if the bus transmitter of at least one of the nodes is switched on. This induces a current through each side of the TBCs, with the consequence that a differential voltage is produced between the CAN_H and CAN_L lines.

The dominant and recessive bus levels are passed into a comparator input in the receiving circuitry to be detected as the recessive and dominant states.

6.2 TPPL bus segment

A linear TPPL bus segment shall be terminated at each end by a resistive termination (see 5.4.3.2) to suppress reflections.

The bus is in the recessive state if the bus transmitters of all nodes on the bus are switched off on a particular bus segment. A dominant bit is sent to the bus signal lines if the bus transmitter of at least one of the nodes is switched on so that a differential voltage is produced between the CAN_H and CAN_L lines.

The dominant and recessive bus levels are passed into a comparator input in the receiving circuitry to be detected as the recessive and dominant states.

7 Electrical specifications

7.1 Electrical data

7.1.1 General

The parameters specified in Table 1, Table 2 and Table 7 to Table 10 shall be complied with throughout the operating temperature range of each ECU. These parameters allow a maximum of 30 ECUs to be connected to a 40 m bus segment. Any stub may have its ECU unplugged, but an unplugged ECU still counts towards the maximum ECU limitation. The limits given in Table 1, Table 2 and Table 7 to Table 9 apply to the CAN_H and CAN_L pins of each ECU, with the ECU disconnected from the bus signal lines (see Clause 8).

7.1.2 Absolute maximum ratings

Table 2 specifies the absolute maximum DC voltages which can be connected to the bus signal lines without damage to transceiver circuits. Although the connection is not guaranteed to operate at these conditions, there is no time limit (operating CAN controllers go “error passive” after a period of time).

Table 2 — Limits of V_{CAN_H} and V_{CAN_L} of bus-disconnected ECU

Parameter	Symbol	Minimum	Maximum	Unit
Maximum DC voltage[a] **Conditions** 12 V nominal supply voltage	V_{CAN_H} V_{CAN_L}	−16,0	16,0	V
NOTE 1 Operation of the connection cannot be guaranteed under these conditions.				
NOTE 2 No time limit (although operating CAN controllers go “error passive” after a period).				
[a] Separately (only CAN_H or CAN_L is connected) or common mode. No damage may occur to the transceiver circuitry.				

Relative to ECU_GND pin of ECU (transceiver shall handle wider range if there is voltage drop along the lines internal to ECU).

7.1.3 DC parameters

7.1.3.1 Power supply operating ranges

Table 3 — Limits of power supply operating ranges

Parameter	Symbol	Minimum	Maximum	Unit
Operating range 12 V nominal supply voltage	PWR ECU_PWR	10,0	16,0	V

7.1.3.2 Power supply minimum current

The minimum current capacity available from the implement bus ECU_PWR shall be 15 A.

The minimum current capacity available from the implement bus PWR shall be 50 A.

7.1.3.3 Requirements for DC voltage supplied by tractor through the IBBC

Electrical power on the tractor is supplied by the 12 V supply and alternator system to various electrical loads on the tractor and implement. While the system voltage is regulated at the alternator terminals, electrical loads that are connected through long electrical leads will experience a voltage drop due to resistance of the supply and return leads. If this voltage drop becomes excessive, the electrical load can function improperly. To ensure that the tractor can adequately supply electrical power to the implement, the following voltage requirements apply at the IBBC/TPPL-BC electrical supply terminals.

The minimum current capacity available from the tractor implement bus ECU_PWR/ECU_GND circuit shall be 15 A under conditions reported in Table 4.

Table 4 — ECU_PWR limits at tractor IBBC/TPPL-BCs

Quantity	Min	Max	Units
V(ECU_PWR) – V(ECU_GND)	10,5	16,0	V
Conditions for measurement: — Measured at all tractor IBBC/TPPL-BC terminals — 15 A DC electrical load — Engine at normal operating min^{-1} range (as defined by manufacturer) — Tractor electrical loads on (lights, fans, etc.)			

The minimum current capacity available from the tractor implement bus PWR/GND circuit shall be 50 A under the conditions reported in Table 5.

Table 5 — PWR limits at tractor IBBC/TPPL-BCs

Quantity	Min	Max	Units
V(PWR) – V(GND)	10,5	16,0	V
Conditions for measurement: — Measured at all tractor IBBC/TPPL-BC terminals — 50 A DC electrical load — Engine at normal operating min^{-1} range (as defined by manufacturer) — Tractor electrical loads on (lights, fans, etc.)			

To prolong component life and to prevent damage, the maximum simultaneous combined current supplied from a single IBBC through ECU_PWR/ECU_GND and PWR/GND circuits shall be a continuous current of 55 A.

7.1.3.4 Requirements for DC voltage drop on implements

Electrical power on an implement is supplied by the PWR and ECU_PWR circuits through the IBBC.

The implement may provide a rear IBBC receptacle to allow daisy chain connection of additional implements that acts like electrical loads.

In case of a daisy chain connection, if the voltage drops due to the resistance of supply and return leads on an implement is too high, the following implement may experience an insufficient operating voltage for correct operation. To avoid such a situation, and to ensure that an implement can adequately supply electrical power to the following one, the maximum allowed voltage drop on an implement shall be in accordance to Table 6.

The maximum current sink of an implement shall be reported in the operator manual.

Table 6 — Maximum allowed voltage drop in an implement

Quantity	Min	Max	Units
Implement voltage drop on ECU_PWR/ECU_GND circuit[a]	—	1,5	V
Implement voltage drop on PWR/GND circuit[b]	—	1,5	V

[a] 15 A provided at the implement rear IBBC.

[b] 50 A provided at the implement rear IBBC.

Conditions for measurement (see Figure 8):

— Measured between implement plug and implement rear IBBC

— Any load on the implement under test shall be disconnected

— 1,5 V is the total drop of both power supply and return path

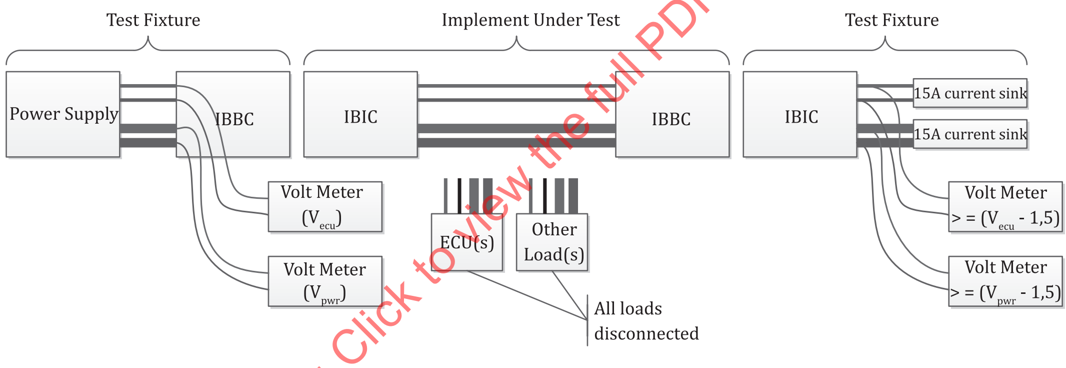


Figure 8 — Voltage drop measurement

7.1.3.5 Bus-disconnected ECU

Table 7 and Table 8 define, respectively, the DC parameters for the recessive and dominant states of an ECU disconnected from the bus.

Table 7 — DC parameters for recessive state of bus-disconnected ECU

Parameter	Symbol	Min.	Nom.	Max.	Unit	Conditions
Bus voltage output behaviour	V_{CAN_H} V_{CAN_L}	2,0	2,5	3,0	V	a,b
Differential output voltage behaviour	V_{diff_OR}	−1 200	—	50	mV	
Differential internal resistance [g]	R_{diff}	2	—	100	kΩ	f
Internal resistance [g]	R_{in}	5	—	50	kΩ	f
Internal resistance match	—	−5	—	5	%	d,f
Input differential voltage detected as recessive	V_{diff_IR}	−1,0	—	0,5	V	a,c,e

[a] The ECU is powered.

[b] The Thévenin equivalent resistance of the input biasing circuit appear in series from both the CAN_H and CAN_L terminals to the input bias source. This input bias is required to provide a known state for the network signals of an ECU disconnected from its bus segment.

[c] Reception shall be ensured within the common mode voltage range defined in Table 9 and Table 10.

[d] The physical layer utilizes field cancellation techniques. The match between the drive voltages and impedances (or currents) on the CAN_H and CAN_L lines are equally important in determining emissions, owing to the spectra presented being determined by the actual wave shape.

[e] Although $V_{diff} < -1{,}0$ V is only possible during fault conditions, it should be interpreted as recessive for compliance with fault requirements.

[f] The minimum of the value with the ECU powered or unpowered per 5.5.1 and 5.5.2.

[g] Only for Type I ECUs.

Table 8 — DC parameters for dominant state of bus-disconnected ECU

Parameter	Symbol	Min.	Nom.	Max.	Unit	Conditions
Bus voltage	V_{CAN_H}	3,0	3,5	5,0	V	a,c
	V_{CAN_L}	0,0	1,5	2,0		
Differential voltage output	V_{diff_OD}	1,5	2,0	3,0		a,c
Differential voltage detected as dominant	V_{diff_ID}	1,0	—	5,0		a,b,c

[a] 60 Ω is connected between CAN_H and CAN_L.

[b] Reception shall be ensured within the common mode voltage range defined in Table 9 or Table 10.

[c] An ECU Type I (normal or weak) has a 60 Ω across CAN_H, CAN_L externally to the ECU. An ECU Type II has a 120 Ω resistor across CAN_H, CAN_L externally to the ECU.

7.1.3.6 Bus-connected ECU

Table 9 and Table 10 define, respectively, the DC parameters for the recessive and dominant states of an ECU connected to a bus segment and other ECUs.

Table 9 — DC parameters (bus voltage) for all bus-connected ECUs in recessive state, without faults

Parameter	Symbol	Min.	Nom.	Max.	Unit	Conditions
Bus voltage	V_{CAN_H} V_{CAN_L}	0,1	2,5	4,5	V	Measured with respect to ground of each ECU[a]
Differential bus voltage	V_{diff_R}	−400	0	12	mV	Measured at each ECU connected to bus signal lines[b,c]

[a] The maximum recessive value of 3,0 V (see Table 7) plus the maximum ground offset of 2,0 V.

[b] The differential bus voltage is determined by the output behaviour of all ECUs during the recessive state. Therefore, V_{diff} is approximately zero (see Table 7).

[c] Although $V_{diff} < -1{,}0$ V is only possible during fault conditions, it should be interpreted as recessive for compliance with fault requirements.

Table 10 — DC parameters (bus voltage) for all bus-connected ECUs in dominant state, without faults

Parameter	Symbol	Min.	Nom.	Max.	Unit	Conditions
Bus voltage	V_{CAN_H}	—	3,5	7,0	V	Measured with respect to ground of each ECU[a]
	V_{CAN_L}	−2,0	1,5	—		
Differential bus voltage	V_{diff_D}	1,2	2,0	3,0	V	Measured at each ECU connected to bus signal lines[b]
				5,0		During arbitration

[a] The minimum value of V_{CAN_H} is determined by the minimum value of V_{CAN_L} plus the minimum value of V_{diff}. The maximum value of V_{CAN_L} is determined by the maximum value of V_{CAN_H} minus the value of V_{diff}.

[b] The loading on the bus signal lines as ECUs are added to a given bus segment of any network is due to R_{diff} and R_{in} of each of the ECUs. Consequently, V_{diff} can decrease. The minimum value of V_{diff} typically limits the number of ECUs allowed on the bus. The maximum value of V_{diff} occurs during arbitration when multiple ECUs are driving the bus signal lines. This maximum value of V_{diff} affects single-ended operation and shall not exceed 3 V.

7.1.4 Bus voltages (operational)

The bus voltage parameters specified in Table 10 apply when all ECUs (from 2 to 30) are connected to a correctly terminated bus segment (see 5.4.3). The maximum allowable ground offset between ECUs or ECUs and TBCs on the bus is 2 V. The voltage extremes associated with this offset can occur in either the dominant or recessive state.

7.1.5 Electrostatic discharge (ESD)

The CAN_H and CAN_L signals shall be tested for ESD while disconnected from the CAN bus, in accordance with ISO 10605 and using a maximum test level of 15 kV for both the component packaging and handling (unpowered) and component immunity (powered) test methods.

For the component packaging and handling test, a minimum of three pulses of each polarity and voltage shall be applied to the CAN_H and CAN_L pins (disconnected from the CAN bus signal lines) of the unpowered ECU using a 150 pF/2 kΩ discharge network with the following sequence: ±4 kV contact, ±8 kV contact, and ±15 kV contact.

For the component immunity test, a minimum of three pulses of each polarity and voltage shall be applied to the CAN_H and CAN_L pins (disconnected from the CAN bus signal lines) of the powered ECU at the contacts of the diagnostic connector. The cable length between the device and the diagnostic connector shall be 1,5 m to 2,5 m.

150 pF/330 Ω shall be used as the discharge network with the following sequence: ±4 kV contact, ±8 kV contact, and ±15 kV contact.

After ESD testing, the ECU shall be tested to confirm that it still conforms to the DC and AC parameters in Table 1, Table 7, and Table 8 for a node disconnected from the bus.

NOTE Usually contact discharges are applied to conductive parts (e.g. pins), air discharges are applied to non-conductive parts (e.g. cable insulation). Air discharges can be applied to conductive parts according to test plan but are less reproducible and are hard to be coupled to single pins, especially if a connector is installed.

7.2 Physical media parameters

7.2.1 Unshielded twisted quad cable

The parameters for the twisted quad cable (see Figure 9)shall be as specified in Table 11.

Table 11 — Physical media parameters for twisted quad cable

Parameter	Symbol	Min.	Nom.	Max.	Unit	Conditions
Impedance	Z_H Z_L	70	75	80	Ω	Measured at 1 MHz between either signal line and ground with TBC_PWR and TBC_RTN grounded
Specific resistance	R_b	0	25	50	mΩ/m	[a] Measured at 20 °C
Specific line delay	T_p	—	5,0	—	ns/m	[b]
Specific capacitance	C_b C_a	0 0	40 70	75 110	pF/m pF/m	Between CAN_H and CAN_L Between adjacent conductors
Conductor size	A_c	—	0,5	—	mm^2	Cross-section to be formed from 16 or greater strands of 32 AWG tinned or bare copper.
Conductor insulation diameter	D_{ci}	2,0	2,11	3,05	mm	Select the correct sealing type; N, T or E for Implement Breakaway connector plug (see Figure 10)
Conductor twist	—	48	50	52	mm/turn	Left-hand lay sequence TBC_PWR, CAN_H, TBC_RTN, CAN_L
Jacket size	T_j	—	0,5	—	mm	—
Cable diameter	D_c	6,0	6,2	8,5	mm	—
Temperature range	T	−40	—	+85	°C	[c] Continuous operation without degradation

[a] The differential voltage on the bus segment sensed by a receiving ECU depends on the line resistance between it and the transmitting ECU. Therefore, the total resistance of the signal conductors is limited by the bus level parameters of each ECU.

[b] The minimum delay time between two points on a bus segment can be zero. The maximum value is determined by the bit time and the delay times of the transmitting and receiving circuitry.

[c] Higher temperature range could be required in areas where the ambient temperature exceeds +85 °C.

Table 12 reports the recommended colours for the insulation of the wires in the cable. A detailed description of the wires colour shall be included in the manufacturer's instruction handbook

Table 12 — Recommended colours for conductor insulation

Colour of conductor insulation	Red	TBC_PWR
	Yellow	CAN_H
	Black	TBC_RTN
	Green	CAN_L

7.2.2 Unshielded twisted pair

The parameters for the unshielded twisted pair cable shall be as specified in Table 13.

Table 13 — Physical media parameters for twisted pair cable

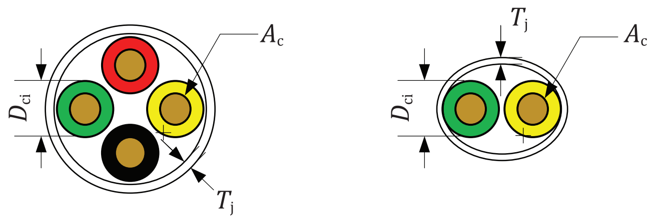
Parameter	Symbol	Min.	Nom.	Max.	Unit	Conditions
Impedance	Z	108	120	132	Ω	Three-meter sample length measured at 1 MHz between the two signal wires, using open/short method.
Specific resistance	R_b	—	25	50	mΩ/m	[a] Measured at 20 °C
Specific line delay	T_p	—	5,0	—	ns/m	[b]
Specific capacitance	C_b	—	40	75	pF/m	Between CAN_H and CAN_L
Conductor size	A_c	—	0,5	—	mm^2	Cross-section to be formed from 7 or more strands of tinned or bare copper. Conductor construction depends on the use case.
Conductor insulation diameter	D_{ci}	2,0	2,11	3,05	mm	Depends on the environmental sealing application, the used connectors and its contact-sealing. Design engineers should ensure compatibility between cables/wires, connectors and contacts.
Conductor twist	—	24	—	52	mm/turn	
Jacket size	T_j	—	—	—	mm	[d]
Temperature range	T	−40	—	+85	°C	[c]

[a] The differential voltage on the bus segment sensed by a receiving ECU depends on the line resistance between it and the transmitting ECU. Therefore, the total resistance of the signal conductors is limited by the bus level parameters of each ECU.

[b] The minimum delay time between two points on a bus segment can be zero. The maximum value is determined by the bit time and the delay times of the transmitting and receiving circuitry.

[c] Higher temperature range could be required in areas where the ambient temperature exceeds +85 °C.

[d] A jacket is not required if the communication channel characteristics are maintained for the product lifetime.



1 2

Key

1 unshielded twisted quad

2 unshielded twisted pair

A_c conductor size

D_{ci} conductor insulation diameter

T_j jacket size

Figure 9 — Cable cross-section

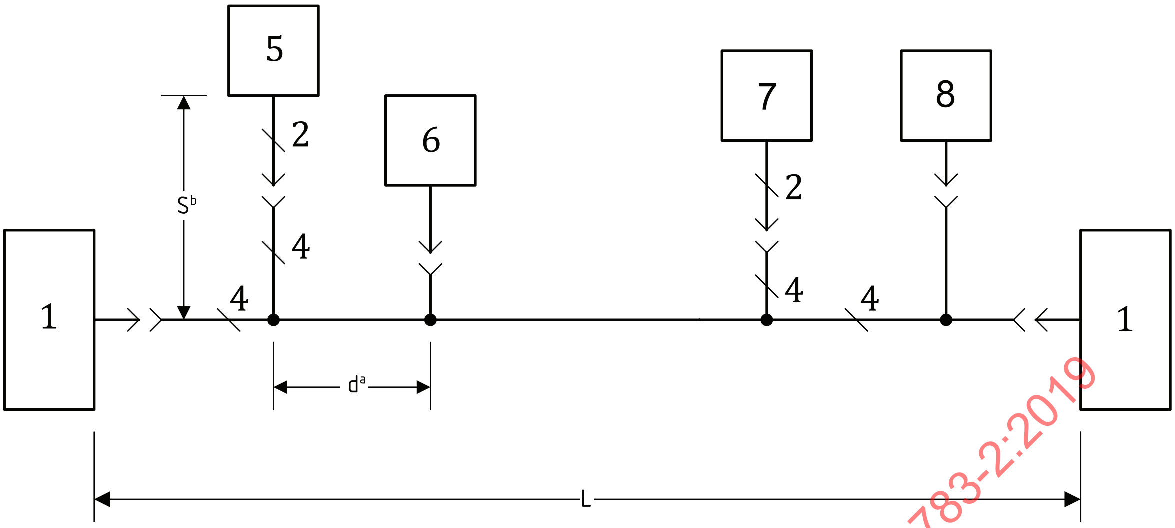
The bus line consists of CAN_H and CAN_L conductors. It is recommended the CAN_H conductor wire jacket is yellow while the CAN_L conductor wire jacket is green (see Figure 9 and Table 14).

Table 14 — Recommended colours for conductor insulation

Colour of conductor insulation	Yellow	CAN_H
	Green	CAN_L

7.3 Topology of twisted quad physical layers

To avoid cable reflections, the wiring topology of a bus segment shall have, as nearly as possible, a linear structure. In practice, it is necessary to connect short stubs to a main backbone cable, as shown in Figure 9. To minimize standing waves, nodes should not be equally spaced on the bus segment and stub lengths should not all be of the same length. The dimensional parameters of this topology as shown in Figure 10 shall be as given in Table 17.



Key

1 terminating bias circuit (TBC)

2 2 wires, CAN_H and CAN_L

4 twisted quad cable

5 ECU 1

6 ECU 2

7 ECU *n*-1

8 ECU *n*

a Distance *d* should be random, but not less than 0,1 m.

b 2 wire length shall be less than 0,15 m.

Figure 10 — Topology of bus-segment wiring

Table 15 — Topology dimensional parameters

Parameter	Symbol	Min.	Max	Unit	Conditions
Bus length	L	0	40	m	Not including stubs
Stub length	S	0	1	m	—
Node distance	d	0,1	40	m	—

7.3.1 ECU connection to TBC_PWR and TBC_RTN

To sense the status of the network, each ECU on the bus may provide a pin for TBC_PWR and TBC_RTN. Loading limits shall be those given in Table 16.

Table 16 — ECU loading of TBC_PWR and TBC_RTN

Parameter	Symbol	Min.	Max.	Unit	Conditions
DC resistance	R_{TBC_PWR}	30	—	kΩ	Measured between TBC_PWR and any other signal in ECU
	R_{TBC_RTN}	30	—	kΩ	Measured between TBC_RTN and any other signal in ECU
Capacitance	C_{TBC_PWR}	—	200	nF	Measured at 1 MHz between TBC_PWR and any other signal in ECU
	C_{TBC_RTN}	—	200	nF	Measured at 1 MHz between TBC_RTN and any other signal in ECU

7.3.2 Power for TBC_PWR and TBC_RTN

TBC_PWR and TBC_RTN for a given bus segment shall be supplied at only one point. This single connection point shall be selected to meet the requirements in Table 17. Filtering and regulation may be provided within the module providing this interconnection (see Annex B).

7.4 Topology of twisted pair physical layer

7.4.1 General

The main topology is the same as the TQPL with the following exceptions in order to give to designers more flexibility. The ECUs shall be connected to the bus either by:

— simple stub;

— compound stub;

— multiple splice.

The minimum distance between two stubs/splices shall be 50 cm.

7.4.2 Simple stub

The simple stub is intended to connect one single ECU to the bus. The maximum allowed length is 3,0 m.

A simple stub located close to the bus termination shall have a length 50 cm lower than the distance from the stub junction to the termination.

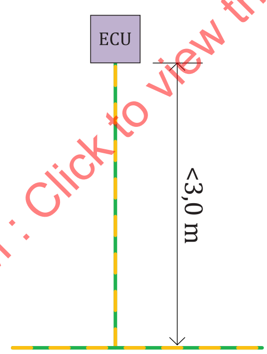
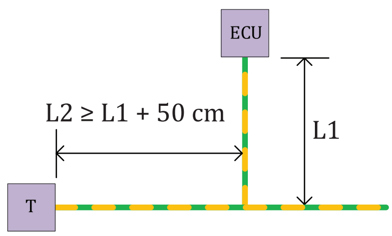


Figure 11 — Simple stub



Key

T termination

L1 length of stub

L2 length of stub junction to termination

Figure 12 — Simple stub close to bus termination

7.4.3 Compound stub

A compound stub is made by a common stub spliced at the end. The maximum number of splices is three and each one shall have a different length. The maximum length of the main stub is 1,5 m. The minimum length of a splice is 0,2 m and the maximum length is 0,5 m.

A compound stub located close to the bus termination shall have the longest branch in the splice at least 50 cm less than the distance from the stub junction to the termination.

There shall be only one compound stub on a machine.

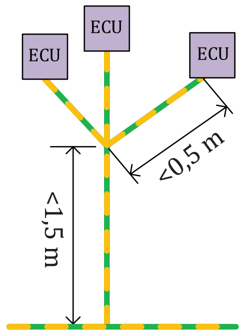
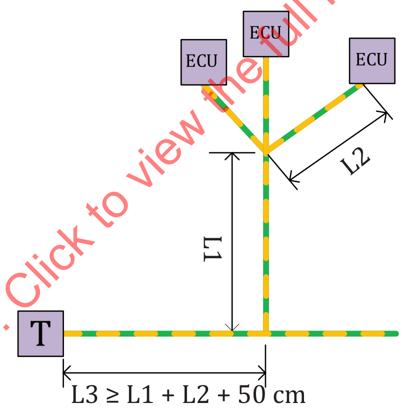


Figure 13 — Compound stub



Key

T termination

L1 length of main stub

L2 length of longest spliced stub

L3 length of stub junction to termination

Figure 14 — Compound stub close to bus termination

7.4.4 Multiple splice

A multiple splice is the connection of more than one stub to a single joint point on the bus. The maximum number of stubs from a single splice is three. The stubs shall have different length with a minimum value of 0,5 m up to a maximum of 1,5 m.

A splice located close the bus termination shall have the longer stub length at least 50 cm lower than the distance from the stub junction to the termination.

There shall be only one multiple splice on a machine.

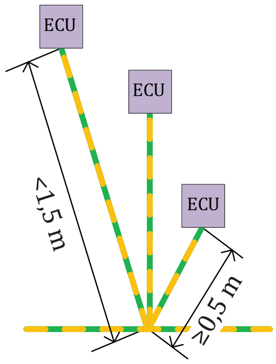
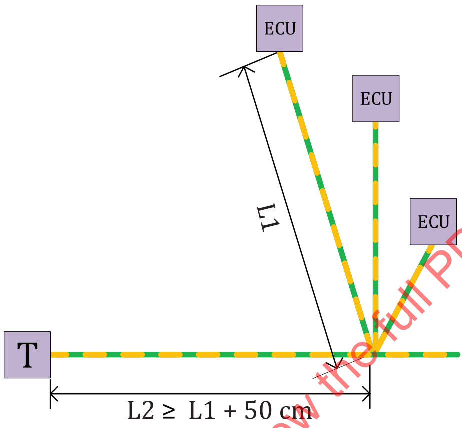


Figure 15 — Multiple splice



Key

T termination

L1 length of the longest splice

L2 length of stub junction to termination

Figure 16 — Multiple splice close to bus termination

7.5 TBC parameters

The terminating bias circuit for twisted quad physical layers connects all four conductors of the twisted quad cable, not only providing the bias for the CAN_H and CAN_L signals but also the common mode resistive termination for the respective conductors. Figure 17 illustrates the Thévenin-equivalent circuit required by the TBC, of which there shall be one for each end of every bus segment in the network (see Annex B). The TBC shall comply with the parameters specified in Table 17.

Table 17 — Terminating bias circuit (TBC) parameters

Parameter	Symbol	Min.	Nom.	Max.	Unit	Conditions
CAN_H bias voltage	U_H	2,25	2,5	2,75	V	U_H shall be capable of sourcing 5 mA and sinking 90 mA to GND
CAN_L bias voltage	U_L	2,25	2,5	2,75	V	U_L shall be capable of sourcing 90 mA and sinking 500 µA
CAN bias tracking	U_L-U_H	−0,1	—	0,1	V	—
CAN_H terminating resistance	R_{tH}	70	75	80	Ω	Thévenin equivalent of TBC
CAN_L terminating resistance	R_{tL}	70	75	80	Ω	Thévenin equivalent of TBC

[a] Resistance tracking is specified as $R_{tH}/((1/2)(R_{tH} + R_{tL}))$ and $R_{tL}/((1/2)(R_{tH} + R_{tL}))$.

Table 17 *(continued)*

Parameter		Symbol	Min.	Nom.	Max.	Unit	Conditions
Resistance matching		[a]	0,98	—	1,02	—	—
Parallel capacitance		C_{pL}	—	—	15	pF	CAN_H or CAN_L to ground
Series inductance		L_{sL}	—	—	0,1	μH	—
Operating supply range	12 V system	TBC_PWR	8	—	16	V	25 mV peak to peak ripple in 20 kHz to 2 MHz range
Fault tolerance on bus signal lines		Shorts to supply	—	—	—	—	Continuous
Fault tolerance on bus signal lines		Shorts to ground	—	—	—	—	Continuous

[a] Resistance tracking is specified as $R_{tH}/((1/2)(R_{tH} + R_{tL}))$ and $R_{tL}/((1/2)(R_{tH} + R_{tL}))$.

Table 18 — TPPL Passive termination parameters

Parameter	Symbol	Min.	Nom.	Max.	Unit	Conditions
Single resistor						
Terminating resistance	R_L	114	120	126	Ω	Power rating min 250 mW
Split resistor[a]						
CAN_H terminating resistance	R_{Lh}	58,8	60	61,2	Ω	Power rating min 125 mW
CAN_L terminating resistance	R_{Ll}	58,8	60	61,2	Ω	Power rating min 125 mW
Coupling capacitance	C_{split}	10	47	200	nF	
Series inductance	L_{split}	—		0,02	μH	

[a] Allowed in Type II ECUs only $R\_tL/((1/2)(R\_tH + R\_tL))$.

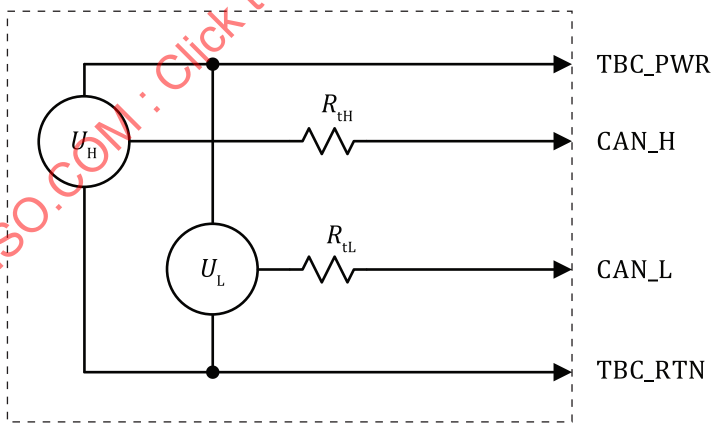


Figure 17 — Equivalent terminating bias circuit (TBC)

7.6 Connectors

7.6.1 General

Three types of connectors are required for the network's implement bus segment (see Figure 18):

— the implement bus breakaway connector (see 7.6.3);

— the in-cab connector (see 7.6.4);

— the diagnostic connector (see 7.6.5).

In addition, a bus extension connector may be provided (see 7.6.2).

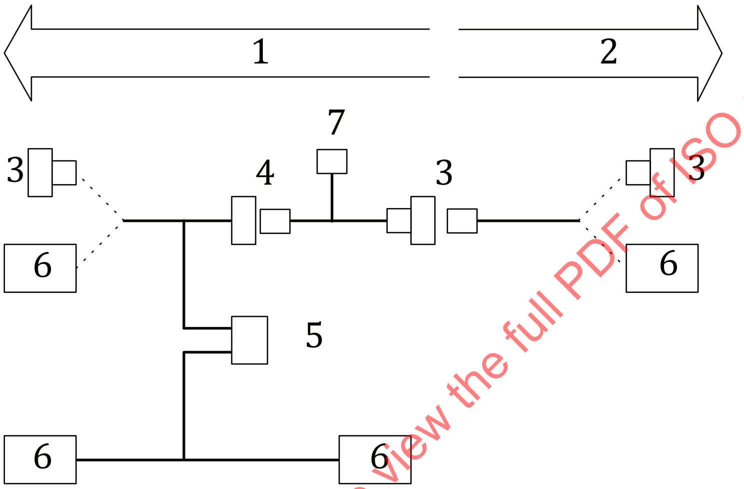
NOTE For further information on the different bus segments and their interconnections, see Figure B.1.

7.6.1.1 Electrical performance

The connectors and associated terminals used to connect bus lines on a bus segment shall conform to the electrical parameters specified in Table 19.

7.6.1.2 Mechanical characteristics

The connectors should have locking, polarizing and retention devices that meet the requirements of a specific application. They should also incorporate environmental protection appropriate to the application.



Key

1 tractor

2 implement

3 breakaway connector

4 bus extension connector

5 diagnostic connector

6 terminating bias circuit

7 in-cab connector

Figure 18 — Example of physical layer architecture, showing the four connector types

Table 19 — Bus connectors electrical parameters

Parameter	Symbol	Min.	Nom.	Max.	Unit	Conditions
Dielectric leakage at withstanding voltage	—	—	—	2	mA	At 1 500 V; any pin to any other pin or to connector shell
Contact resistance	R_c	—	—	20	mΩ	Measured at 100 mA
Current	I	0	32	70	mA	—
Peak current	I_p	2,5	—	—	A	Time restriction: 2 s
Operating voltage	V	—	2,5	40	V	—

Table 19 *(continued)*

Parameter	Symbol	Min.	Nom.	Max.	Unit	Conditions
Characteristic impedance	Z_c	60	120	175	Ω	Maximum connector length should not be greater than twice the interfacial connector length. Measured between CAN_H and CAN_L connector circuits.
Parallel capacitance	C_p	—	—	35	pF	Between CAN_H or CAN_L and all other pins and shell
Corner frequency	f	10	—	—	MHz	3 dB point with 1 V p-p signal

7.6.2 Bus extension connector

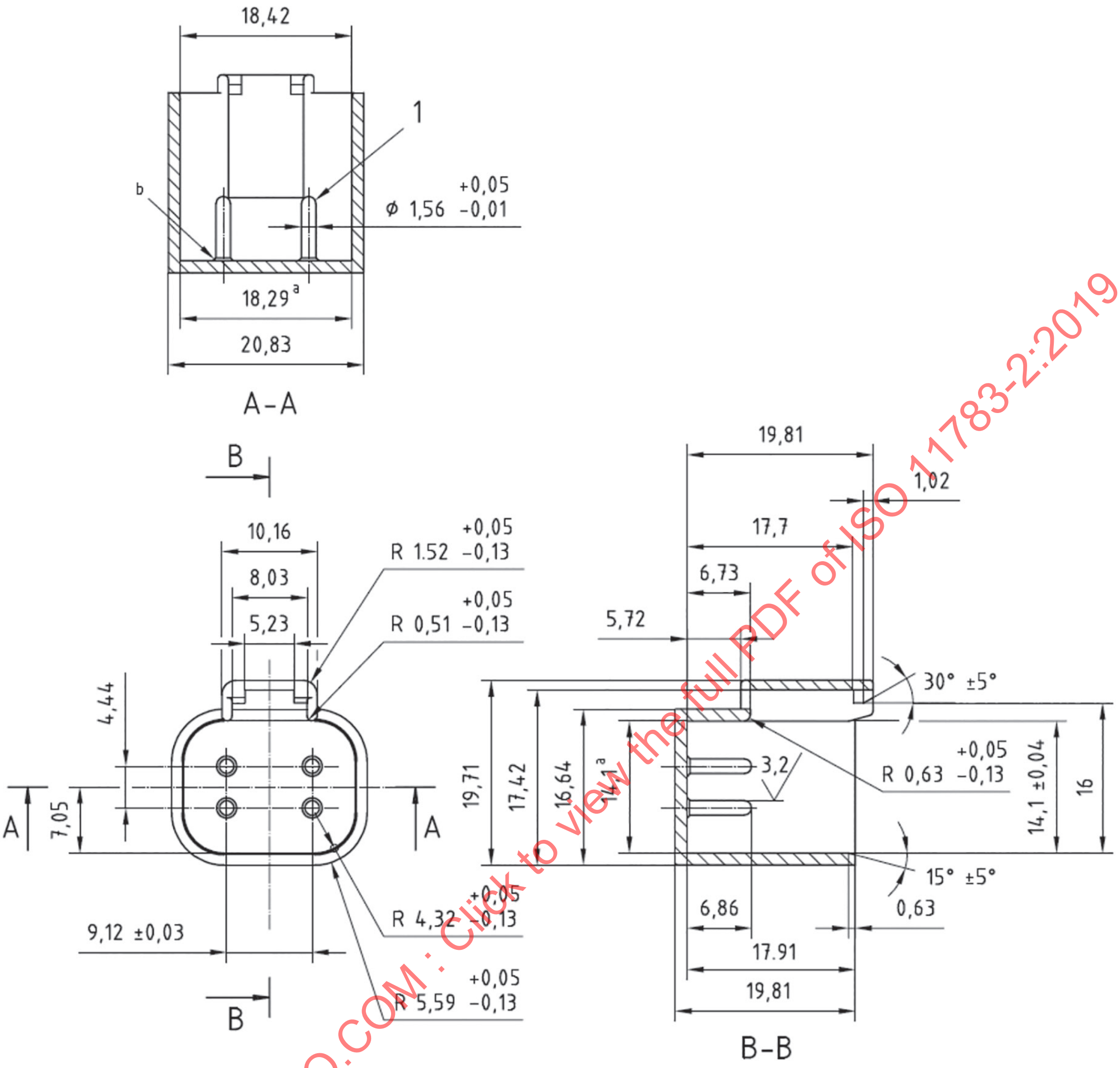
7.6.2.1 General

A mating connector pair may be provided to extend the bus signal lines of the implement bus within the tractor, as needed in the field for additional devices such as virtual terminals.

7.6.2.2 Dimensions

The bus extension connector receptacle shall have the dimensions shown in Figure 19, and the bus extension connector plug shall mate with the receptacle shown.

Dimensions in millimetres



Key

1 full radius pin typ

a Hold tolerance within length of seal area = 5,97 min.

b 0,31 max. × 45° chamfer typ.

Figure 19 — Bus extension connector dimensional requirements

7.6.2.3 Pin allocations

The four bus extension connector pins shall have the following allocations:

— Pin 1: TBC_PWR (reserved for TPPL)

— Pin 2: CAN_H

— Pin 3: TBC_RTN (reserved for TPPL)

— Pin 4: CAN_L

7.6.3 Implement bus breakaway connector

7.6.3.1 General

A receptacle shall be placed on the rear of the tractor adjacent to, and oriented in, the same direction as the existing towed-equipment lighting connector, in accordance with ISO 1724. The receptacle shall have a dust and weather cap that covers the connector when the towed equipment is not connected.

An optional receptacle can be installed on the front of the tractor adjacent to the front-mounted hydraulic outlets when front-mounted implements are accommodated. This connector shall meet the specifications in Annex B.

A plug that mates with the above receptacle shall be placed on the hitch of the implements. This plug shall have sufficient cable length to reach the receptacle. If additional implements can be connected to the implement, a receptacle as specified in 7.6.3.4 shall be placed at the attachment point. This connector shall have a dust and weather cap that covers it when the towed equipment is not connected.

Power on pin 5 of the receptacle disconnects the termination from the implement bus. Pin 5 of the plug is shorted to pin 4, the ECU_PWR connection.

7.6.3.2 Terminating bias circuit for TQPL IBBC

A TBC shall be located at each implement bus breakaway connector receptacle. This active circuit shall be on the receptacle connection side of the bus. Whenever the implement bus breakaway connector plug is connected to the receptacle, the TBC on the receptacle connection side of the bus segment shall be disconnected from CAN_H and CAN_L.

The loading of this disabled TBC on TBC_PWR and TBC_RTN shall be less than 20 mA.

7.6.3.3 Terminating circuit for twisted pair physical layer IBBC

Terminating R_L = 120 Ω resistors shall be located at each implement bus TPPL breakaway receptacle. Whenever a TPPL breakaway connector plug is connected to the receptacle, the terminating resistor on the receptacle connection side of the bus segment shall be disconnected from either CAN_H or CAN_L.

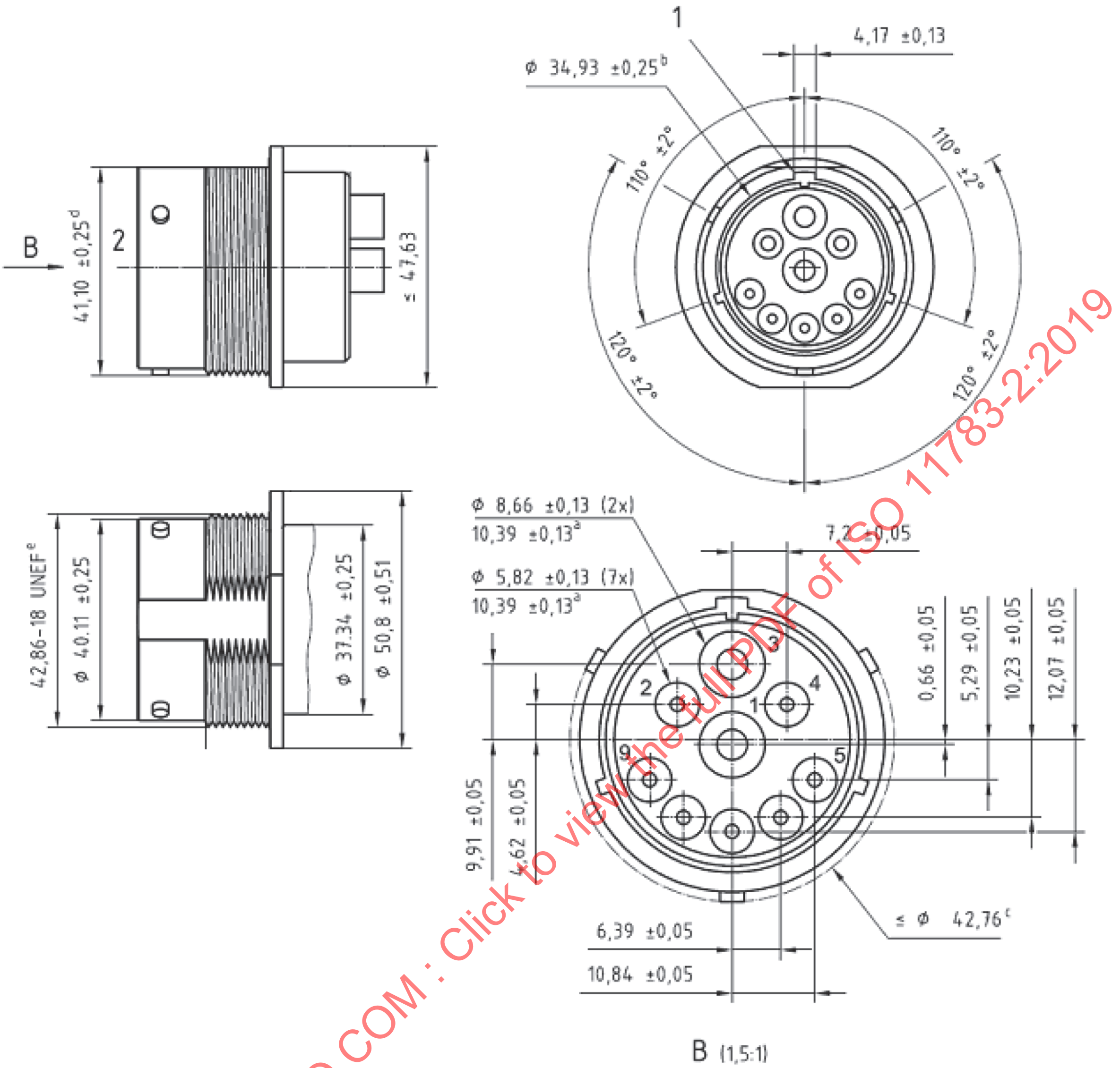
7.6.3.4 Dimensions

The implement bus breakaway receptacle shall conform to the dimensions shown in Figure 20. This tractor or implement-mounted receptacle shall contain pin contacts.

The mating plug shall have the dimensions given in Figure 21. This implement-mounted plug shall contain socket contacts.

The implement bus breakaway connector containing the receptacle and automatic switching TBC shall conform to the mounting dimensions given in Figure 22.

Dimensions in millimetres



Key

1 main polarizing keyway

2 front face

a Deep.

b Shell internal diameter.

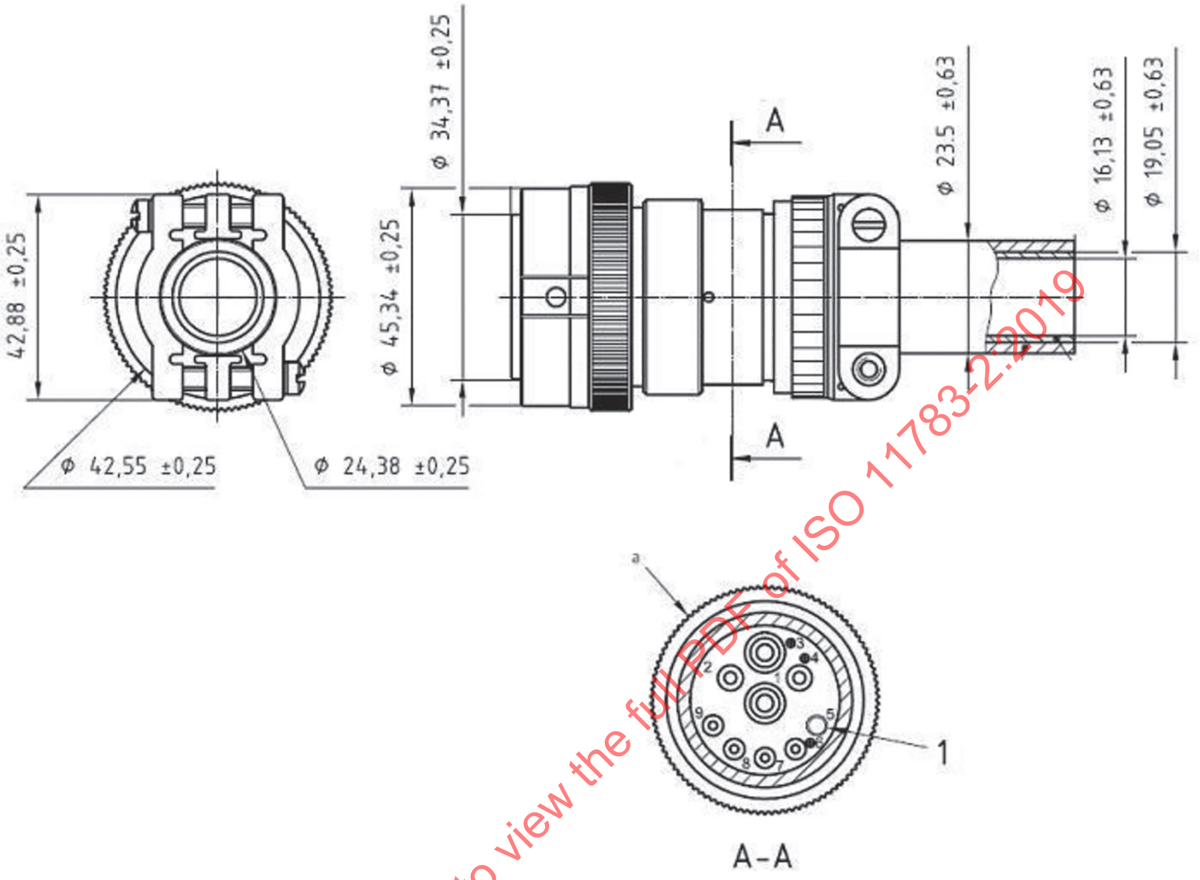
c Over bayonette.

d From threads to flat surface.

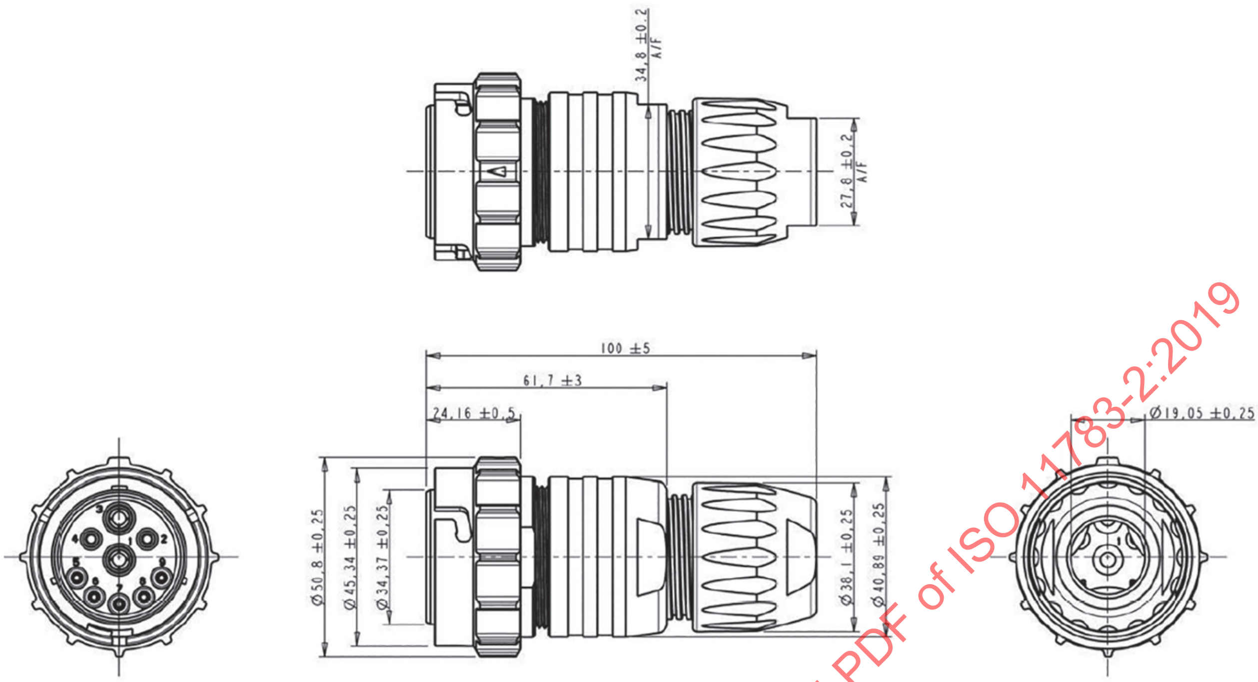
e 11/16 in.

Figure 20 — Implement bus breakaway receptacle dimensional requirements

Dimensions in millimetres



Contact size	Min. OD	Max. OD	Wire mm^2 range	Wire gauge range
A	4,83	6,10	8 to 5	8 to 10
B	3,40	4,32	3 to 2	12 to 14
C	2,00 2	3,40	1 to 0,5	16 to 20



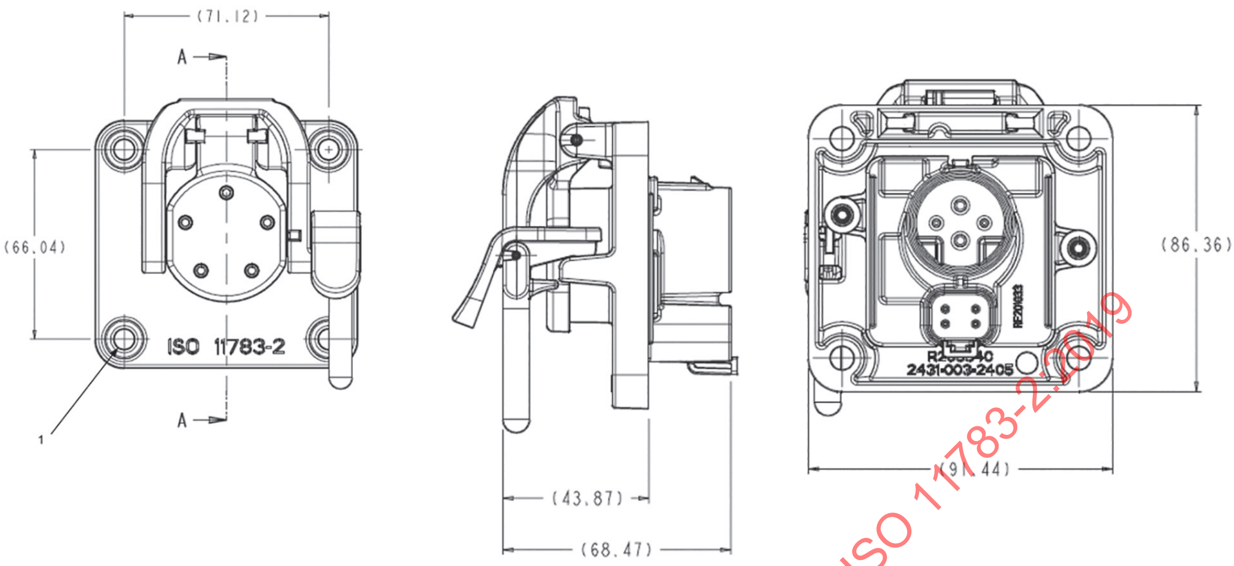
Key

1 sealing plug

2 use wire seal option E for min. OD

a 47,63 Ø max. over knurl.

Figure 21 — Implement bus breakaway plug dimensions



Key

1 ∅ 5,68-∅ 5,40 blind hole, 15,24 deep, suitable for M6 × 1,0 self-threaded screw

Figure 22 — Maximum dimensions of an implement bus breakaway connector

7.6.3.5 Pin allocations

The implement bus breakaway connector shall have the pin allocations shown in Table 20 (examples of wire colours are also given). However, an implement bus breakaway receptacle that includes a TBC may also have a connector with the pin allocations given in Table B.2. A connector with the pin allocations shown in Table B.1 may be used to connect ECU power to the TBC in the receptacle.

NOTE The power to the implement bus breakaway connector or TPPL implement bus breakaway connector is controlled by the Tractor ECU.

7.6.3.6 Ground isolation

The ground circuits for GND and ECU_GND shall be connected only at one location, which is recommended to be at the tractor's power source's (12 V supply) negative terminal. To avoid ground loops, no other connections between GND and ECU_GND shall be made on the tractor or any connected implement. Resistance measurement taken between pin 1 (GND) and pin 2 (ECU_GND) of a single implement's bus breakaway connector plug shall be greater than or equal to 1 k Ω with all ECUs connected on the implement. It is recommended that the ECU functions, including CAN communication, are powered by the ECU_PWR/ECU_GND circuit. However, an ECU on an implement may use only the PWR/GND circuit with no connection with the ECU_PWR/ECU_GND circuit.

For TQPL IBBCs, ECU_PWR and ECU_GND shall only be connected to the TBC included with the implement bus breakaway receptacle. No connections between ECU_PWR and TBC_PWR or between ECU_GND and TBC_RTN shall be made at other TBCs connected to the ISO 11783 bus on the tractor or any connected implement. No connections between PWR and TBC_PWR or between GND and TBC_RTN shall be made at any TBCs connected to the network. Resistance measurement taken between pin 4 and pin 6 or between pin 2 and pin 7 of an implement's bus breakaway connector plug with TBC connected and without any ECUs connected shall be greater than 5 M Ω.

For TQPL the resistance measurement taken between a connected TBCs TBC_RTN pin and ECU_GND harness connection shall be greater than 1 M Ω.

Table 20 — Implement bus breakaway connector pin allocations

Pin no.	Name	Contact size[a]	Wire colour	Comments
1	GND	A	Black	Connected separately from ECU_GND to the tractor's power source (12 V supply) negative terminal. All major power loads (motors, etc.) shall use this return path.
2	ECU_GND	B	Black	Circuit to be limited to providing electrical return for electronic control units mounted on tractors or implements. This pin shall further be electrically isolated from GND and shall be connected to the tractor's power source (12 V supply) negative terminal.
3	PWR	A	Red	Power for all, motors, etc. that normally require significant power and tend to generate transients on the supply line.
4	ECU_PWR	B	Red	Good source of clean positive 12 V supply power that shall be used for powering the ECUs mounted on implements.
5	TBC_DIS	C	N/R	Exists only within the connectors (i.e. not for external connections) to control relay for automatic terminating bias connection/removal. Connected to pin 4 on implement connector plug.
6	TBC_PWR	C	See Table 12	Power for the TBCs and which shall not be used for any other purpose. Connected to ECU_PWR for TPPL IBBC
7	TBC_RTN	C	See Table 12	Provides return path for TBCs and shall not be used for any other purpose. Connected to ECU_GND for TPPL IBBC
8	CAN_H	C	See Table 12	Data transmission line pulled toward higher voltage in dominant state.
9	CAN_L	C	See Table 12	Data transmission line pulled toward lower voltage in dominant state.

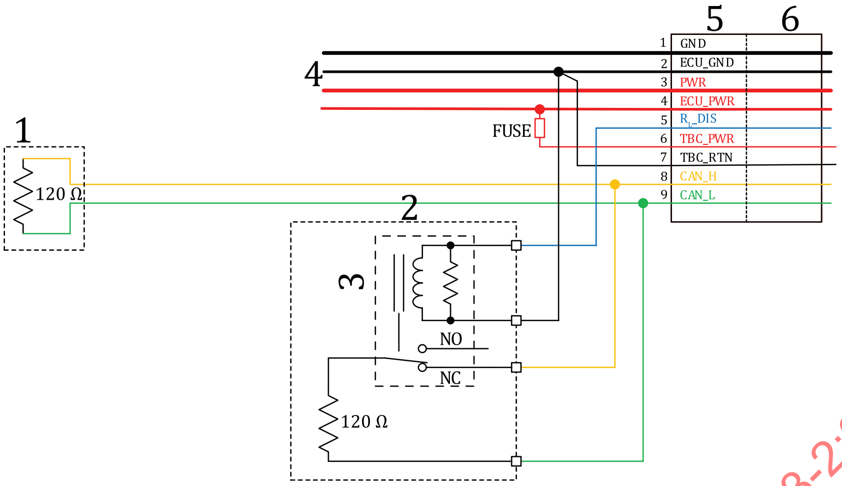
[a] Defined by Figure 10.

7.6.3.7 Backward compatibility

To guarantee backward compatibility, TPPL tractors shall provide power to twisted quad based implement TBC circuit. This shall be achieved by connecting the TBC_PWR pin to the ECU_PWR line and the TBC_RTN pin to the ECU_GND line.

In accordance with the electrical values of the bus connector, the fuse(s) to connect TBC_PWR to ECU_PWR shall be 1 A.

The following images are showing the possible connections.



Key

1 front terminating resistor R_L

2 TPPL IBBC circuit for automatic R_L termination connection/removal

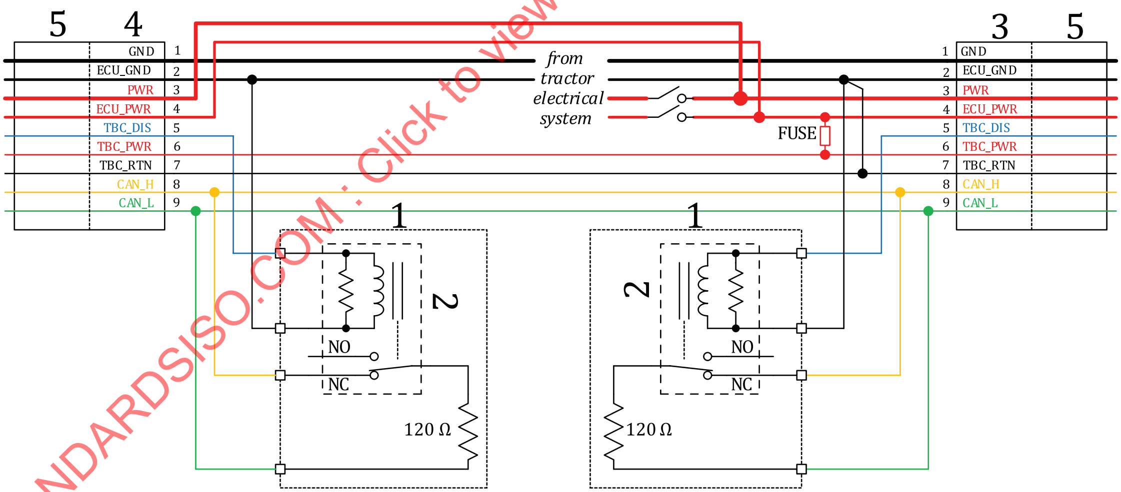
3 normally closed relay

4 power lines

5 TPPL IBBC

6 TPPL IBBP or IBBP

Figure 23 — TPPL tractor with rear TPPL Breakaway Connector



Key

1 TPPL IBBC circuit for automatic R_L termination connection/removal

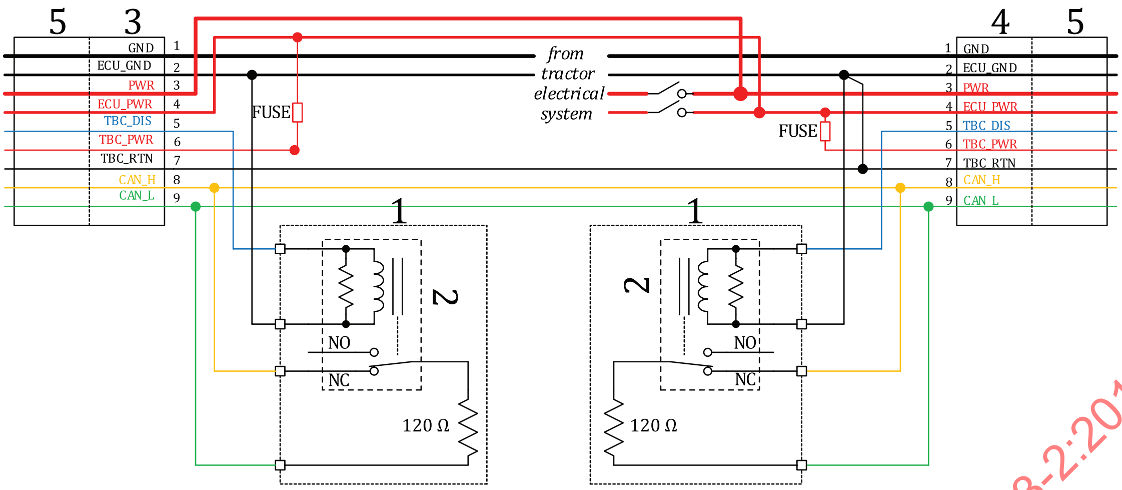
2 normally closed relay

3 primary TPPL IBBC

4 secondary TPPL IBBC

5 TPPL IBBP or IBBP

Figure 24 — TPPL tractor with front and rear TPPL Breakaway Connector (single fuse)



Key

1 TPPL IBBC circuit for automatic R_L termination connection/removal

2 normally closed relay

3 primary TPPL IBBC

4 secondary TPPL IBBC

5 TPPL IBBP or IBBP

Figure 25 — TPPL tractor with front and rear TPPL Breakaway Connector (double fuse)

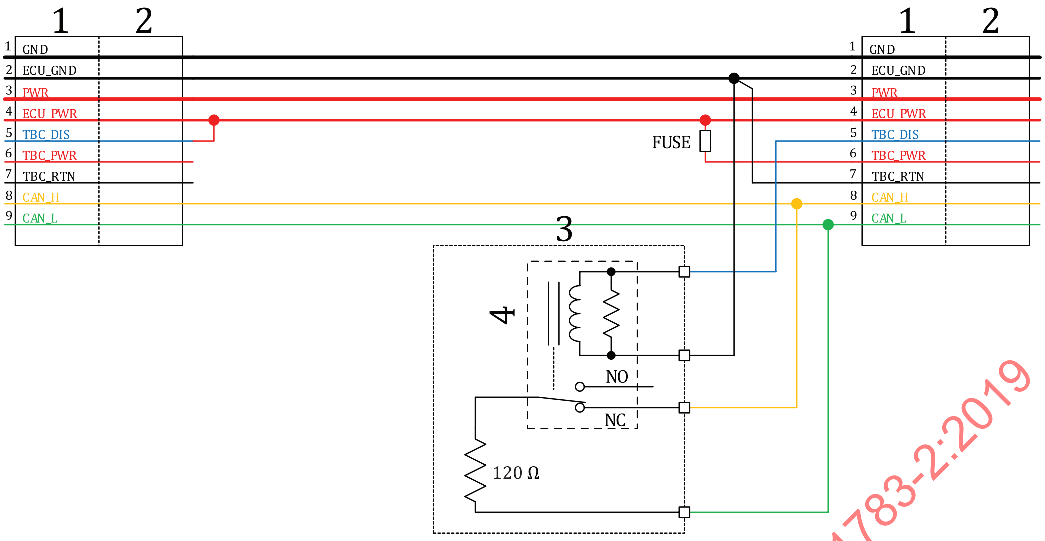
Key

1 TPPL IBBC

2 TPPL IBBP

3 terminating resistor R_L

Figure 26 — TPPL implement



Key

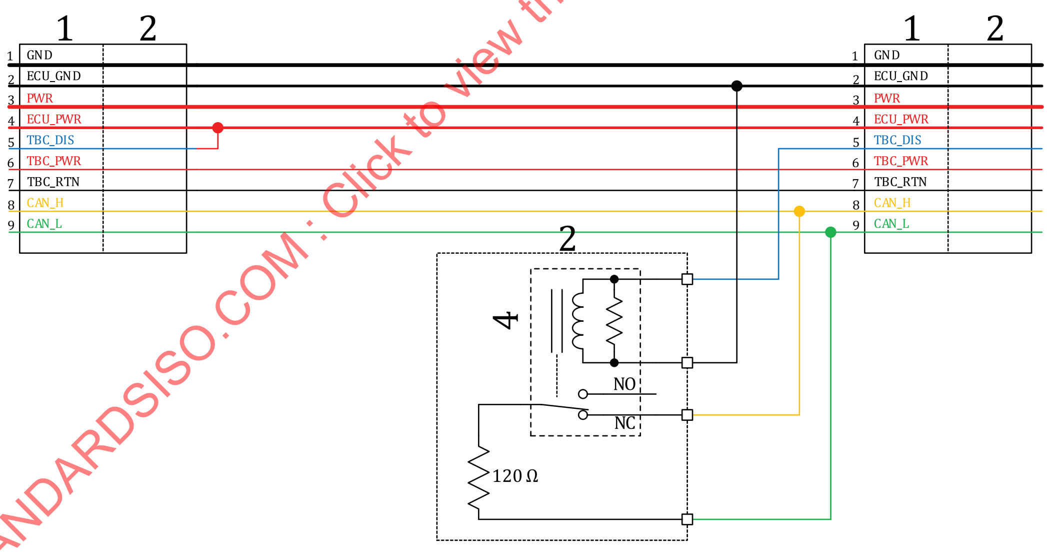
1 TPPL IBBC

2 TPPL IBBP

3 TPPL IBBC circuit for automatic R_L termination connection/removal

4 normally closed relay

Figure 27 — TPPL implement, daisy chain (single fuse)



Key

1 TPPL IBBC

2 TPPL IBBP

3 TPPL IBBC circuit for automatic R_L termination connection/removal

4 normally closed relay

Figure 28 — TPPL implement, daisy chain (no fuse)

7.6.4 In-cab connector

7.6.4.1 General

An in-cab connector shall be available to be used to connect existing components, for example VT's, auxiliary inputs or other ECUs mounted in a tractor cab to the ISO 11783 bus.

7.6.4.2 In-cab connector receptacle dimensions

The in-cab connector receptacle shall have dimensions according to Figure 29.

7.6.4.3 In-cab connector pin allocations

The nine connector pins shall have the following allocations.

— Pin 1: Connected to ECU_PWR

— Pin 2: CAN_L input

— Pin 3: CAN_L output

— Pin 4: CAN_H input

— Pin 5: CAN_H output

— Pin 6: TBC_PWR (Connect to ECU_PWR for TPPL IBBC for backwards compatibility)

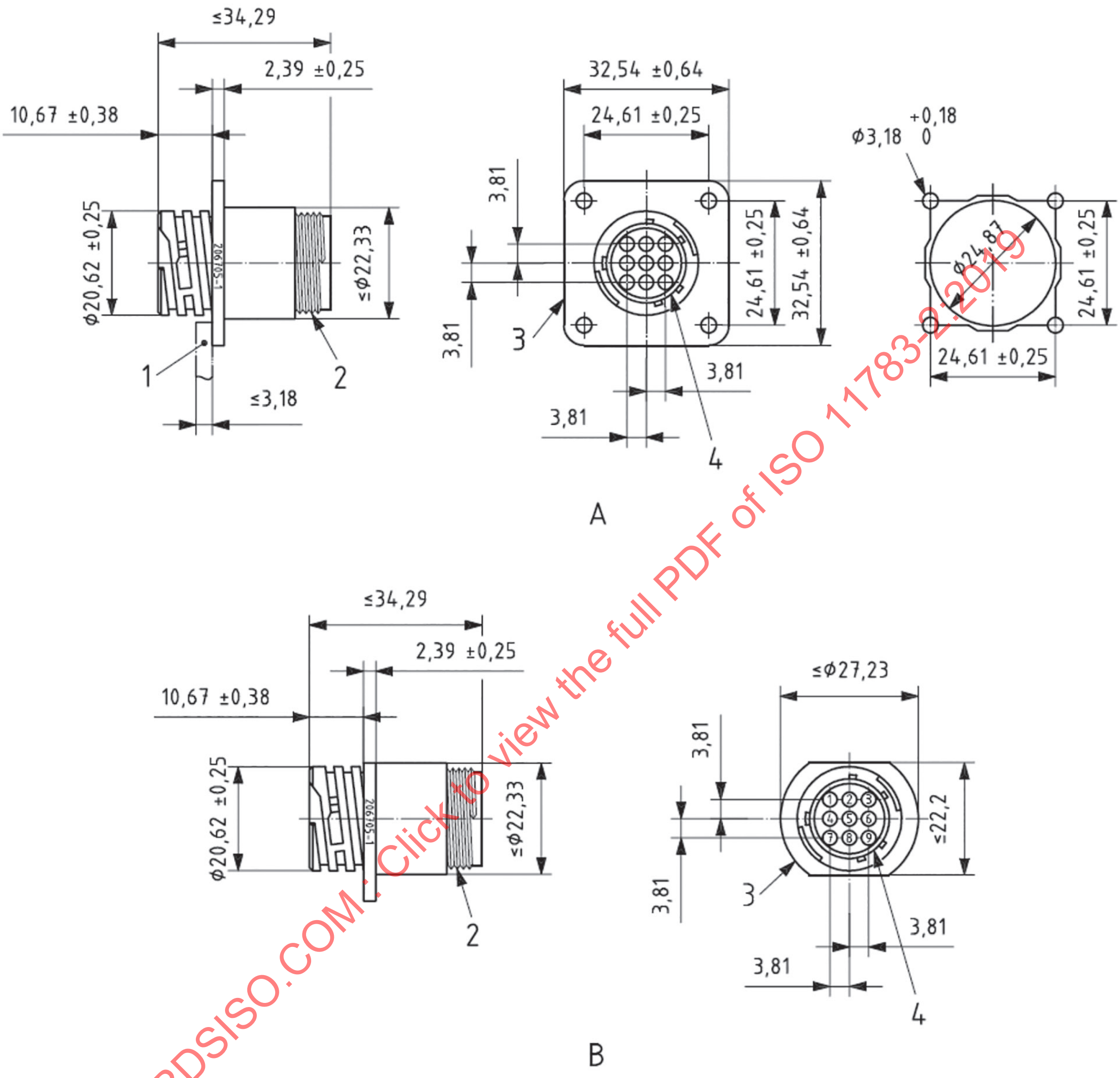
— Pin 7: ECU_PWR

— Pin 8: TBC_RTN (Connect to ECU_GND for TPPL IBBC for backwards compatibility)

— Pin 9: ECU_GND

The loading limit on TBC_PWR and TBC_RTN shall be in accordance with 7.3.2.

Dimensions in millimetres



Key

1 panel

2 3/4-20 UNEF-2A

3 connector housing

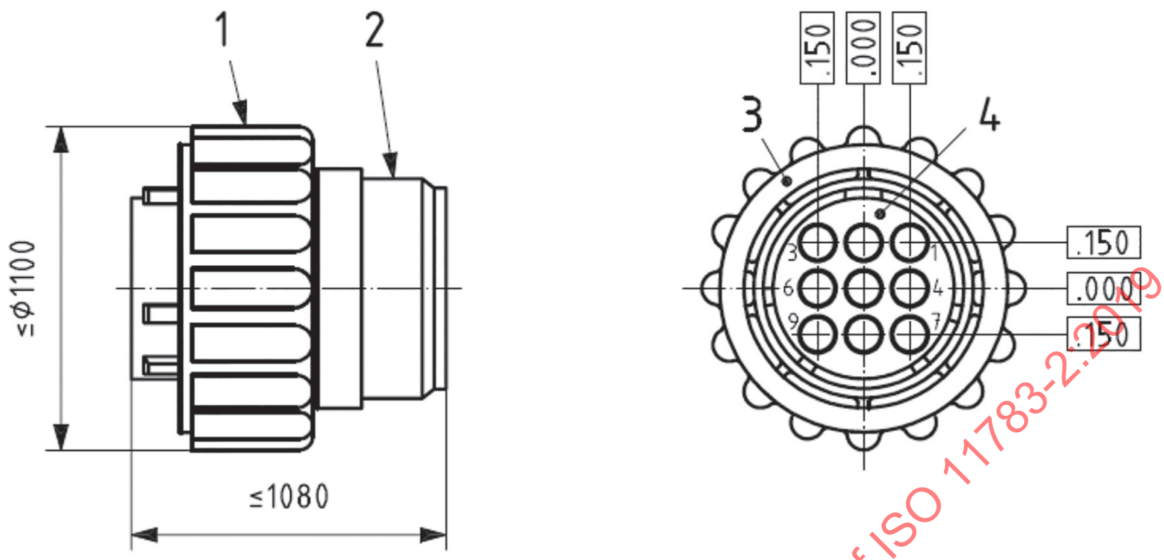
4 peripheral seal

Figure 29 — In-cab receptacle dimensional requirements

7.6.4.4 In-cab connector plug dimensions

The connector plug for the in-cab connector shall have dimensions according to Figure 30, to mate with the in-cab connector receptacle.

Dimensions in millimetres



Key

1 polyester, black

2 glass filled nylon, 6/6 black

3 AMP part no

4 mating face

NOTE The optional in-cab connector plug specifications are met by AMP 206708 1.

Figure 30 — In-cab plug dimensional requirements

7.6.4.5 In-cab connector cable connections for TQPL

The connection of the in-cab connector to ISO controllers or display terminals is as shown in Figure 31. A shorting plug is not required to connect CAN_L input to CAN_L output and CAN_H input to CAN_H output when no controller or terminal is connected to the in-cab connector. When not powered, a normally closed relay circuit is used to maintain the CAN_H and CAN_L connections.

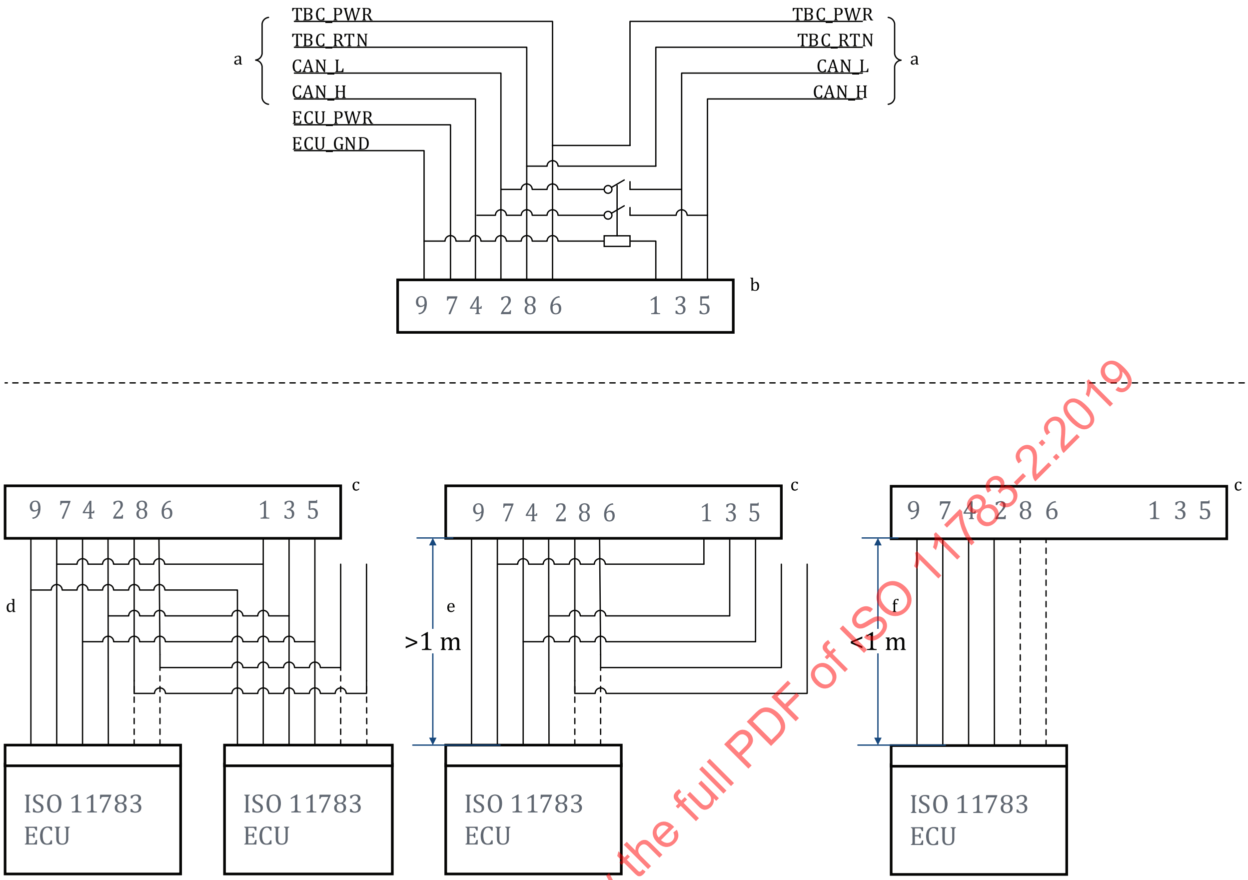
The following three connection configurations are possible, as shown in Figure 31.

a) A loop through the in-cab connector to extend the bus. The relay is powered by a connection to the ECU_PWR terminal to interrupt the bus on the “tractor side”. Stub bus connections are provided for connection of multiple ECUs.

b) When the ECU connection from the in-cab connector is more than 1 m, the ECU is connected by a stub connection to the bus that is looped through the in-cab connector. The TBC_PWR and TBC_RTN connections are not returned through the in-cab connector but are left open circuit at the connector. The relay is powered by a connection to the ECU_PWR terminal to open the bus on the “tractor side” of the connector.

c) When the ECU connection to the bus is less than 1 m, the ECU is connected directly to the bus as a stub and do not daisy-chain the CAN_H and CAN_L.

If the controller or display provides a loop through of the bus, it shall have an internal circuit equivalent to the external connections shown for the configuration described in b) above.



a ISO 11783 bus.

b In-cab connector (plug).

c In-cab connector (socket).

d Bus extension through in-cab connector for connecting multiple ECUs.

e Long bus extension through in-cab connector for connecting an ECU.

f Short bus extension (stub) through in-cab connector for connecting an ECU.

NOTE The TBC_PWR and TBC_RTN are routed together with the CAN_L and CAN_H as twisted quad cable for EMC purposes but only once connected to connector "c".

Figure 31 — In-cab connector cable connections for twisted quad

7.6.4.6 In-cab connector cable connections for TPPL

The connection of the in-cab connector to ISO controllers or display terminals is as shown in Figure 32. A shorting plug is not required to connect CAN_L input to CAN_L output and CAN_H input to CAN_H output when no controller or terminal is connected to the in-cab connector. When not powered, a normally closed relay circuit is used to maintain the CAN_H and CAN_L connections.

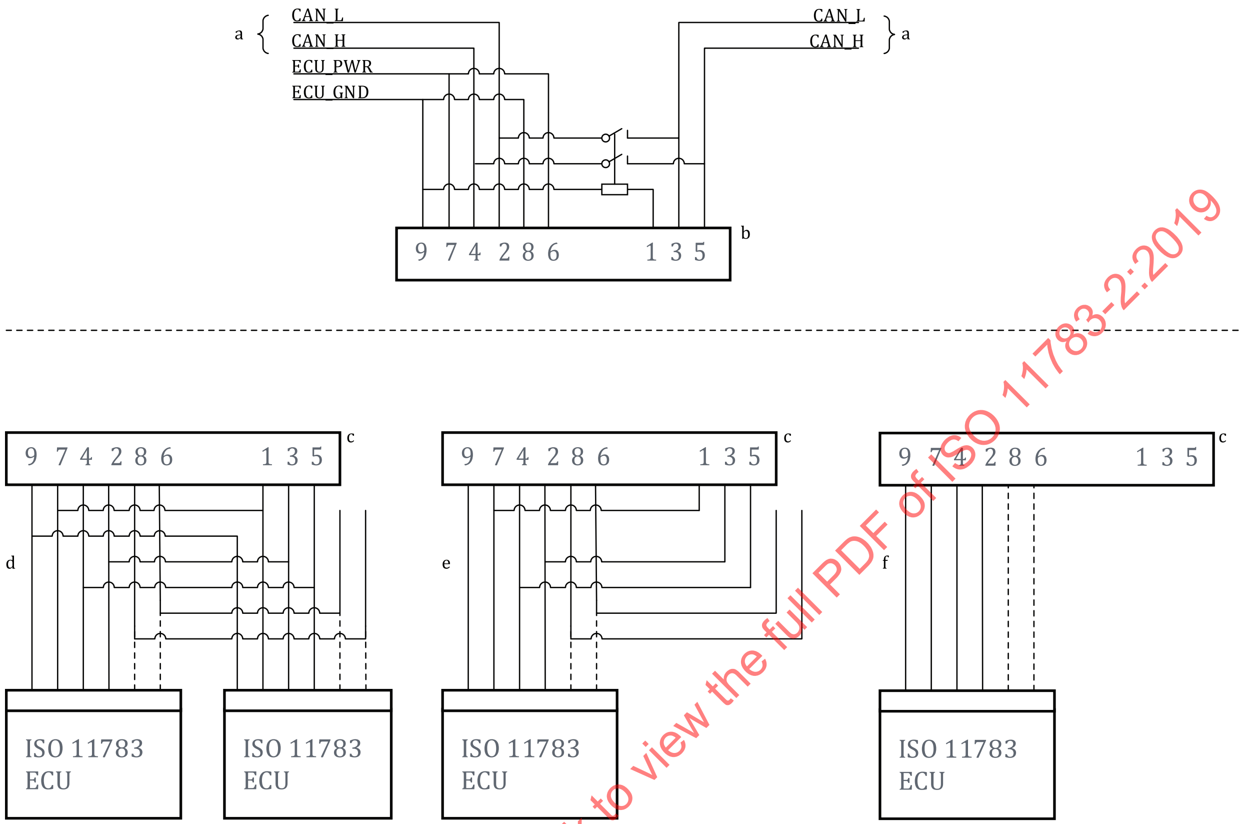
The following three connection configurations are possible, as shown in Figure 32.

a) A loop through the in-cab connector to extend the bus. The relay is powered by a connection to the ECU_PWR terminal to interrupt the bus on the "tractor side". Stub bus connections are provided for connection of multiple ECUs.

b) When the ECU connection from the in-cab connector is more than 1 m, the ECU is connected by a stub connection to the bus that is looped through the in-cab connector. The relay is powered by a connection to the ECU_PWR terminal to open the bus on the "tractor side" of the connector.

c) When the ECU connection to the bus is less than 1 m, the ECU is connected directly to the bus as a stub and do not daisy-chain the CAN_H and CAN_L.

If the controller or display provides a loop through of the bus, it shall have an internal circuit equivalent to the external connections shown for the configuration described in b) above.



a ISO 11783 bus.

b In-cab connector (plug).

c In-cab connector (socket).

d Bus extension through in-cab connector for connecting multiple ECUs.

e Long bus extension through in-cab connector for connecting an ECU.

f Short bus extension (stub) through in-cab connector for connecting an ECU.

Figure 32 — In-cab connector cable connections for TPPL

7.6.5 Diagnostic connector

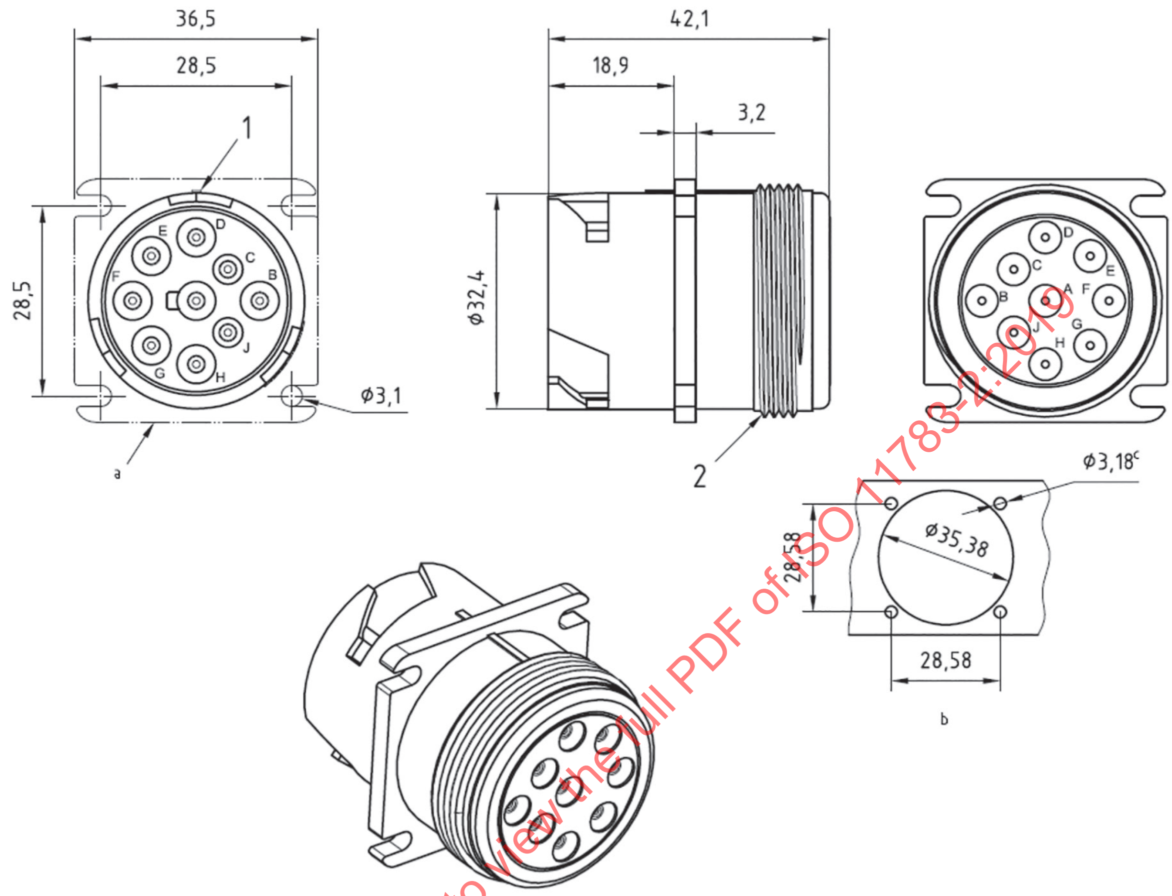
7.6.5.1 General

The diagnostic connector facilitates ISO 11783 network troubleshooting and maintenance and shall be in the tractor cab in an easily accessed location. The stub length between the network backbone and the diagnostic connector should be minimized to accommodate the cable length from the diagnostic connector to the service tool CAN transceiver. The connector and its associated terminals shall meet the electrical specifications of Table 19.

7.6.5.2 Receptacle dimensions

The diagnostic receptacle connector shall have the dimensions given in Figure 33.

Dimensions in millimetres



Key

1 main polarizing rib

2 thread 1,375-18 UNEF-2A

a Phantom line for clarification only.

b Recommended panel.

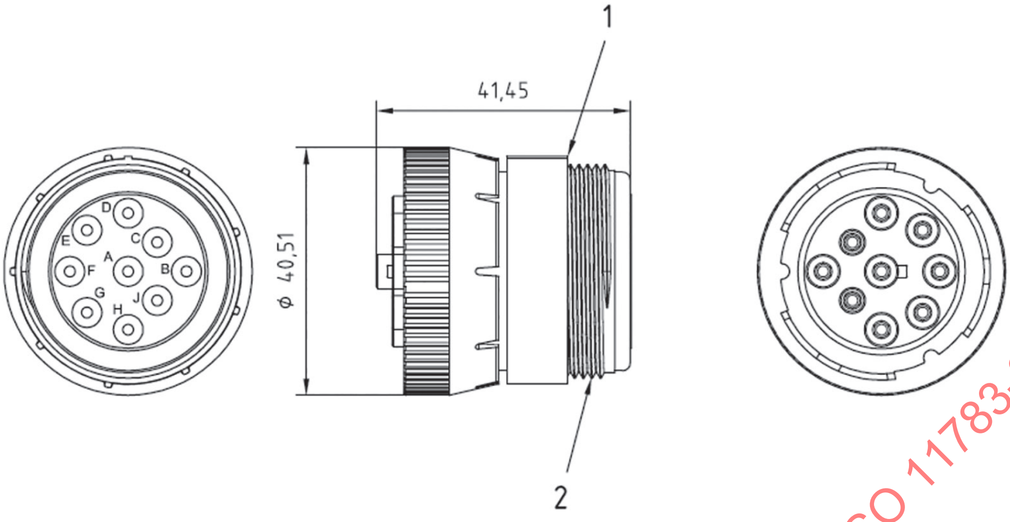
c 4PL.

Figure 33 — Diagnostic connector receptacle dimensions

7.6.5.3 Locking plug dimensions

The diagnostic connector locking plug shall have the dimensions given in Figure 34.

Dimensions in millimetres



Key

1 main polarizing rib

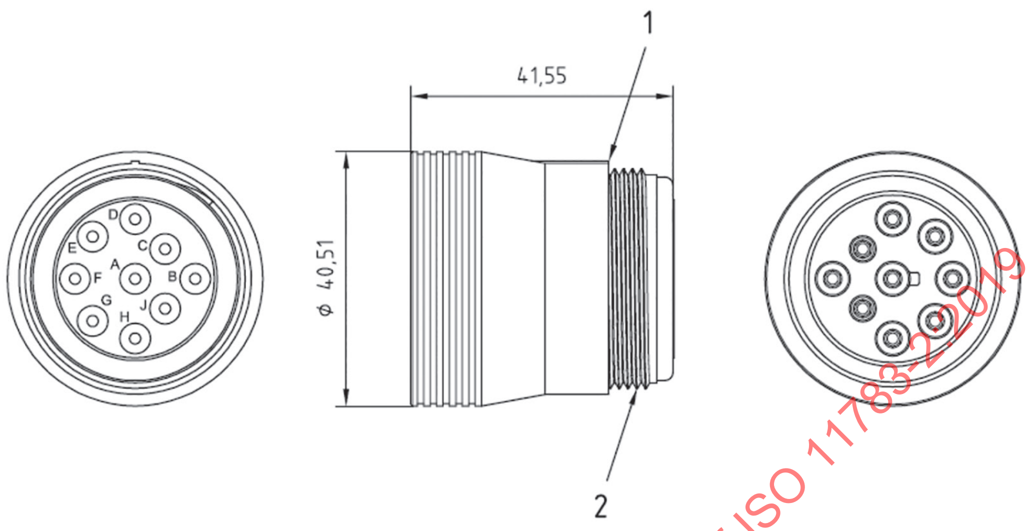
2 thread 1,375-18 UNEF-2A

Figure 34 — Diagnostic connector locking plug dimensions

7.6.5.4 Non-locking plug dimensions

The diagnostic connector non-locking plug shall have the dimensions given in Figure 35.

Dimensions in millimetres



Key

1 main polarizing rib

2 thread 1,375-18 UNEF-2A

Figure 35 — Diagnostic connector non-locking plug dimensions

7.6.5.5 Pin allocations

The diagnostic connector pins shall have the allocations given in Table 21.

NOTE The diagnostic connector is also used by industry in 24 V battery systems.

Table 21 — Diagnostic connector pin allocations

Pin no.	Allocation
A	ECU_GND
B	Unswitched power[a]
C	Tractor bus CAN_H
D	Tractor bus CAN_L
E	Not specified[b]
F	Not specified[c]
G	Not specified[c]
H	Implement bus CAN_H
J	Implement bus CAN_L

a A direct connection to positive 12 V or 24 V battery power through a 10A fuse.

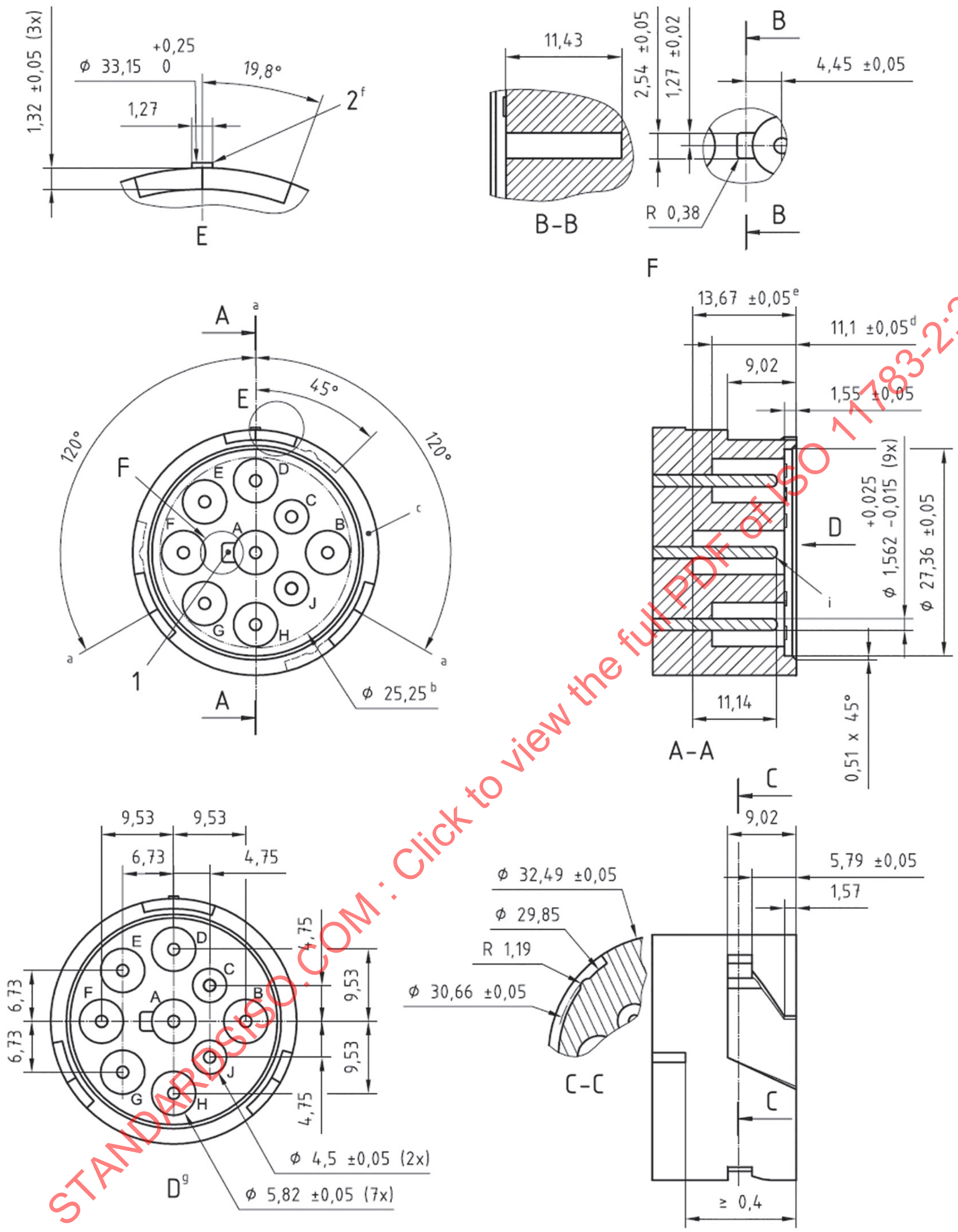
b Used for the shield of an SAE J1939 network in an SAE diagnostic connector.

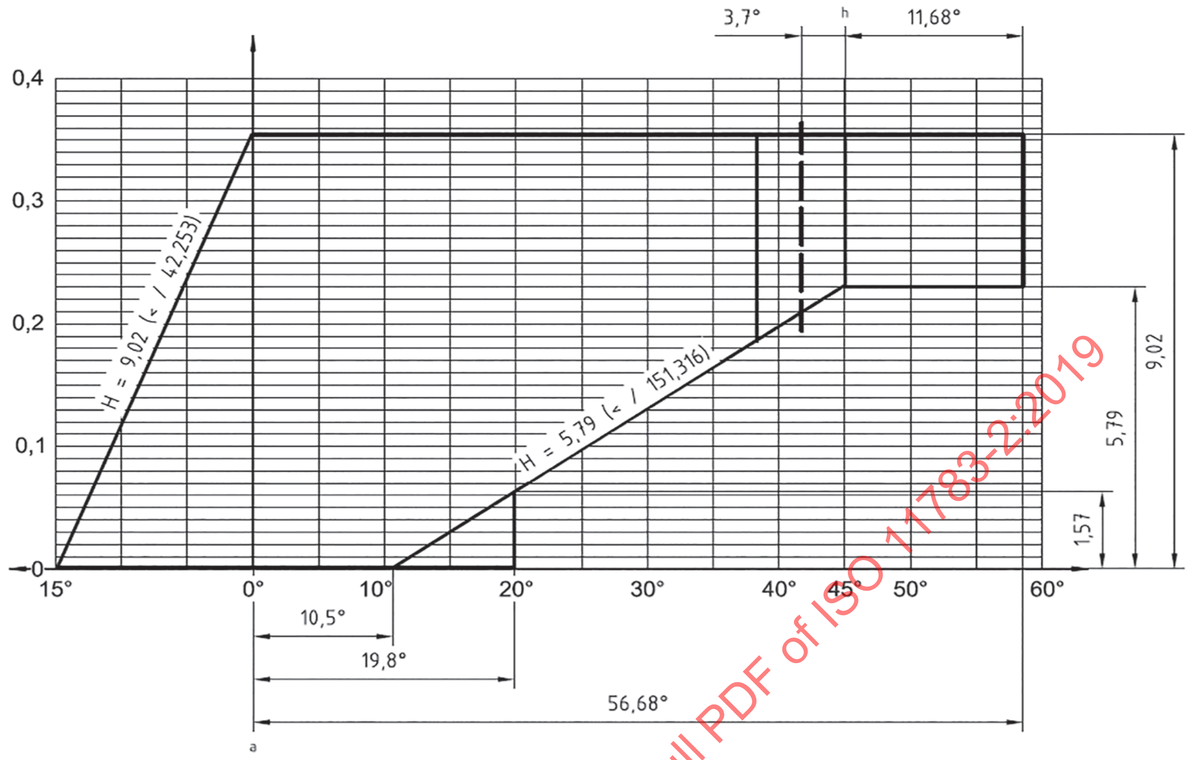
c Used for SAE J1708[5] network in an SAE diagnostic connector.

7.6.5.6 Diagnostic connector dimensions

The diagnostic connector shall have the interface dimensions given in Figure 36.

Dimensions in millimetres





Key

1 key way

2 alignment rib

a Datum A.

b Contact cavity letters are shown for identification only and are not necessarily in their true positions. Letters are not to extend outside Ø 25,25 (no gates or parting lines on sealing surfaces).

c No gates or parting lines on sealing surfaces.

d Dimension applies to cavities B, C, D, E, F, G, H and J.

e Dimension applies to cavity A, only.

f Polarizing rib is optional.

g Cavity locations.

h Datum B.

i Full radius.

NOTE All cavity locations are to be ± 0,05 from centrelines.

Figure 36 — Diagnostic connector interface dimensional requirements

8 Conformance tests

8.1 General requirements

All the following test shall be done and passed by component under test. TBC tests shall not be performed on devices designed for TPPL.

8.1.1 Figures 37 to 42 and Formulae (2) to (4) show how in principle the parameters specified in Clause 7 can be verified by ECU manufacturers, while 8.1.2 to 8.1.6 are general requirements for these conformance tests.

8.1.2 Measurements shall be referenced to ECU_GND, or to GND for ECUs with no separate ECU_GND terminal. TBC_RTN shall not be used as the reference.

8.1.3 The tests shall be conducted over the entire voltage operating range of the ECU, which shall be at least 10 V to 16 V; whereas, the manufacturer shall be responsible for the verification of any applications requiring a broader voltage range.

8.1.4 In order to guarantee bus operation with certain faults, many of the parameters shall be verified without ground or power connected to the ECU, or with neither connected.

8.1.5 All sources for the test shall present an internal impedance, the magnitude of which shall be less than 0,1 Ω for all frequencies below 5 MHz. All measurement devices should have input impedances of above 10 MΩ, shunted by less than 10 pF from DC to 5 MHz.

8.1.6 An independent means shall be available to cause the ECU under test to attempt to initiate message transmission over the CAN bus.

8.2 Internal resistance

8.2.1 Measure internal resistance, R_{in}, (see Figure 6) of CAN_H and CAN_L as shown in Figure 37.

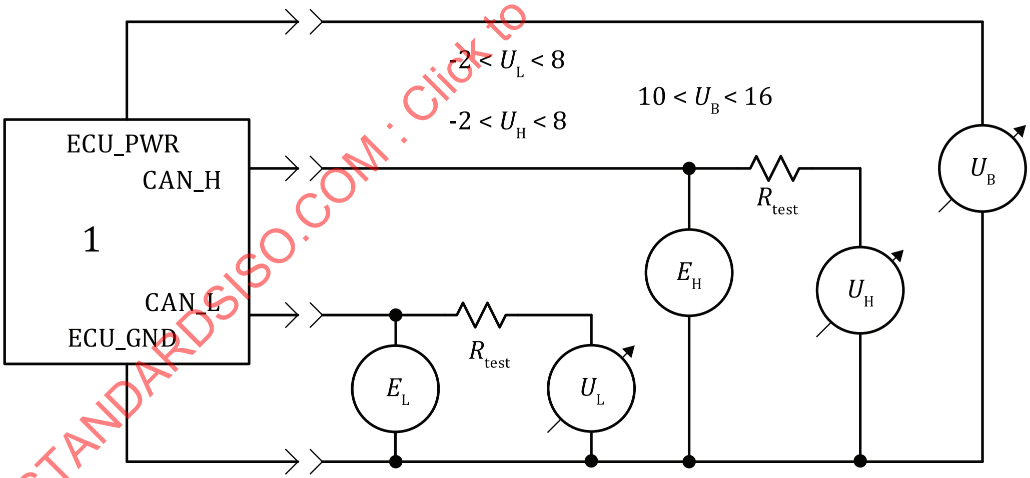
8.2.2 Carry out this test over a range for U (voltage range: −2 V to 8 V), which represents the ground offsets between nodes on a given bus segment, for the following power connection scenarios:

a) ECU connected to ground lead only;

b) ECU connected to both 12 V supply and ground leads;

c) ECU connected to neither 12 V supply lead nor ground lead;

d) ECU connected to 12 V supply lead only.



Key

1 ECU

Figure 37 — Measurement of R_{in} with ECU protocol IC set to bus idle

8.2.3 Apply bias to both CAN_H and CAN_L, concurrently, in the most general case.

8.2.4 Determine R_{in} of CAN_H and CAN_L over the range −2 V ≤ U ≤ 8 V, then use the minimum value to verify that the ECU's R_{in} is above the required minimum.

8.2.5 Carry out the measurements using R_{test} = 5 kΩ, and calculate R_{in} of CAN_H or CAN_L using Formula (2):

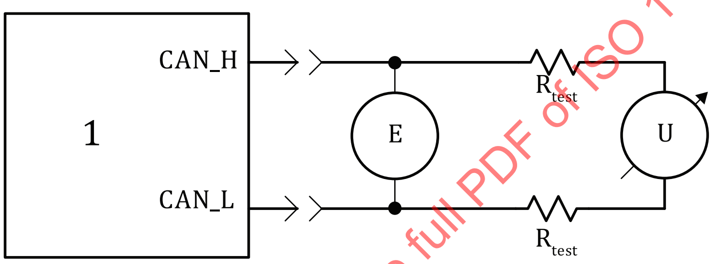
$$R_{in} = R_{test} \frac{E_n - E_{nB}}{U_n - E_n} \tag{2}$$

where R_{in} is defined, for the recessive state and DC parameters, by Table 7. E_{nB} is the bias voltage internal to the ECU for the power connection scenario being tested and is measured with R_{test} disconnected.

8.3 Internal differential resistance

8.3.1 Measure internal differential resistance, R_{diff}, (see Figure 7) of CAN_H and CAN_L as shown in Figure 38.

8.3.2 Carry out this test over the same range for U and for the same power connection scenarios as specified in 5.5.2.



Key

1 ECU

Figure 38 — Measurement of R_{diff} with ECU protocol IC set to bus idle

8.3.3 Determine R_{diff} for U = 5 V and R_{test} = 5 kΩ during bus idle using Formula (3):

$$R_{diff} = 2R_{test} \frac{E - E_B}{U - E} \tag{3}$$

where the power supply shall offer enough isolation to the other ECU supplies so that the measurements represent the ECU impedance and not supply-leakage currents. E_B is the bias voltage internal to the ECU for the power connection scenario being tested and is measured with R_{test} disconnected.

8.4 ECU recessive input threshold

8.4.1 Verify that the recessive input differential voltage threshold meets the requirements in Table 7 and Table 9 over the common mode CAN input voltage range and ECU supply voltage range.

8.4.2 With the supply voltage U_B at 10 V, 12 V and 16 V, measure the state of the RXD signal for all values of U_H and U_L with the following conditions (see Figure 39):

a) U_H = 0,6 V and U_L = 0,1 V;

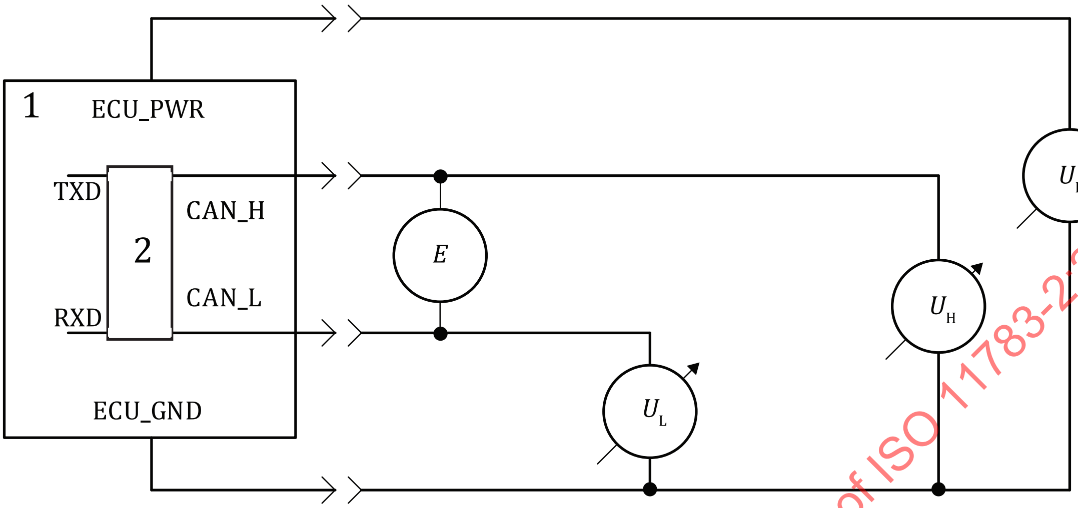
b) U_H = 2,75 V and U_L = 2,25 V;

c) U_H = 4,5 V and U_L = 4,0 V.

8.4.3 For the condition indicated in 8.4.2, the RXD signal shall indicate a recessive (logic HIGH).

This test requires internal access to the CAN transceiver RXD and TXD signals.

The CAN transmitter shall remain in the recessive state during this test.



Key

1 ECU

2 CAN Transceiver: * TXD is tied to logic HIGH to keep transmitter in recessive stat

Figure 39 — Test of input threshold for dominant or recessive bit detection

8.5 ECU dominant input threshold

8.5.1 Verify that the dominant input differential voltage threshold meets the requirements in Table 8 and Table 10 over the common mode CAN input voltage range and ECU supply voltage range.

8.5.2 With the supply voltage U_B at 10 V, 12 V and 16 V, measure the state of the RXD signal for all values of U_H and U_L with the following conditions (see Figure 39):

a) U_H = −1 V and U_L = −2 V;

b) U_H = 3,0 V and U_L = 2,0 V;

c) U_H = 7,0 V and U_L = 6,0 V.

8.5.3 For the condition indicated in 8.5.2 the RXD signal shall indicate a dominant (logic LOW).

This test requires internal access to the CAN transceiver RXD and TXD signals.

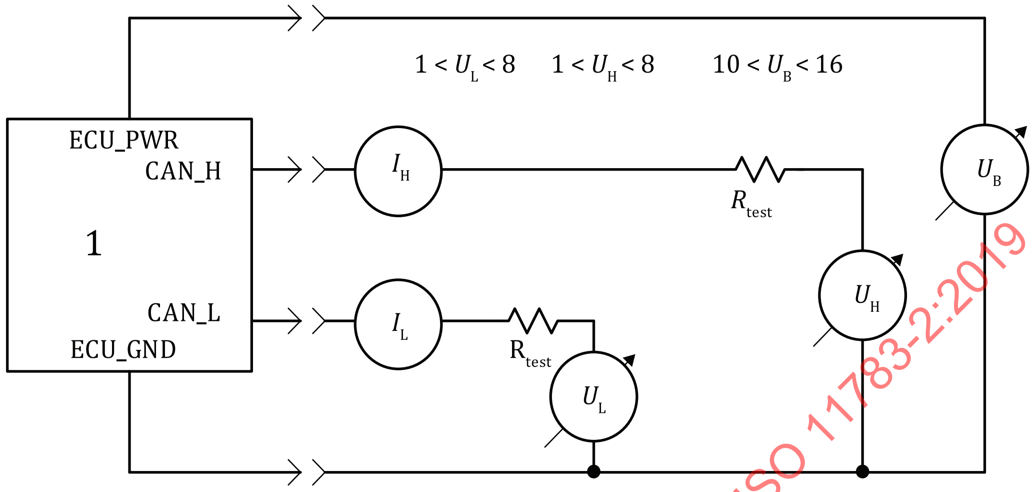
The CAN transmitter must remain in the recessive state during this test.

8.6 ECU dominant output

8.6.1 Measure the dominant output of an ECU as shown in Figure 40. Since the differential voltage is as given by Formula (1), it can be measured differentially, as itself, between the CAN_H and CAN_L bus signal lines. Alternatively, it can be found as the difference between the voltage between CAN_H and ground, and that between CAN_L and ground. The magnitudes of the output currents can be found directly from this test; the current ratio shall be calculated.

NOTE Since this ratio, as well as the variation in the current, is a manufacturer-specific parameter, no acceptable values are presented in Table 16.

These voltages shall be measured using an oscilloscope. The ECU must be actively transmitting.



Key

1 ECU

Figure 40 — Measurement of V_{CAN_H} and V_{CAN_L} while the ECU sends a dominant bit

8.6.2 Measure V_{CAN_H}, V_{CAN_L}, I_H, and I_L during a dominant bit transmission. Set R_{test} at 30 Ω. The value of V_{diff} may be measured or calculated as desired.

8.6.3 Set the load as shown in Figure 41. The ratio of I_H to I_L shall be between 0,95 and 1,05 when measured with $U_H = U_L = 2{,}5$ V.

8.7 ECU internal delay time

8.7.1 Measure the internal delay time of an ECU as shown in Figure 41. The test unit shown synchronizes itself to the start of the frame bit transmitted by the ECU's CAN controller. Upon detection of the first recessive identifier bit, the test unit partly overwrites this bit for the time, t_{overw}, with a dominant level (shaded area in the figure). This overwriting is increased until the protocol IC loses arbitration and stops transmitting, when the available part of the bit time, t_{avail}, for delay time compensation is exhausted (see also Annex A).

8.7.2 Calculate t_{ECU} using Formula (4):

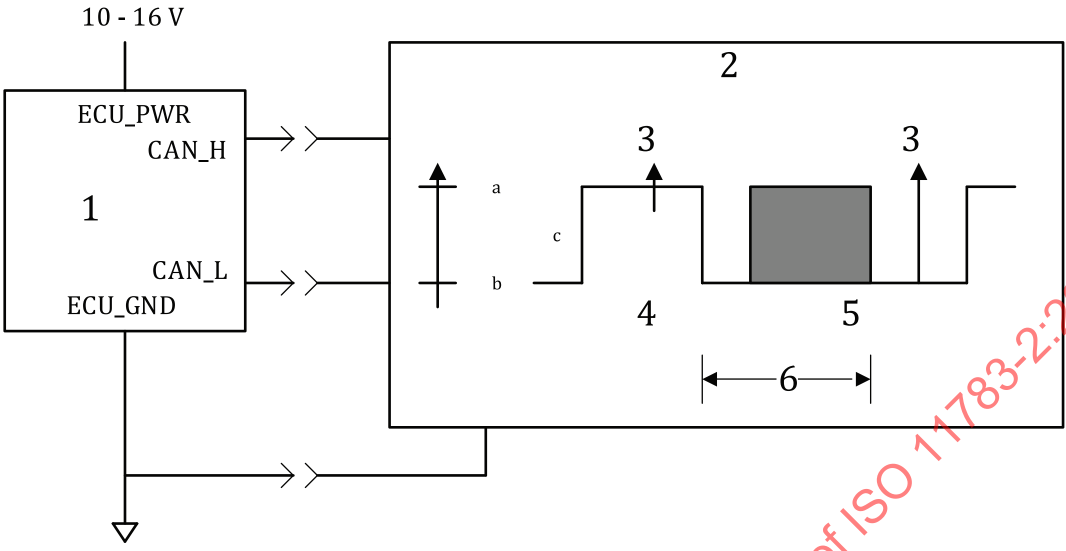
$$t_{ECU} = t_{avail} - t_{overw} \tag{4}$$

where

t_{avail} is known from the bit timing unit of the ECU's CAN controller [2,5 µs, time to the sample point from a bit edge (see 5.6)];

t_{overw} is the time found with the test unit.

8.7.3 The recessive and dominant voltage levels are set by the test unit to the corresponding threshold voltages for reception. This means that the recessive overwriting level is 0,5 V and the dominant 1,0 V and ensures a uniquely defined relationship between voltage levels and internal delay time.



Key

1 ECU

2 test unit

3 sample point

4 start of frame

5 first recessive identifier bit

6 t_{overw}

a Dominant.

b Recessive.

c Idle.

Figure 41 — Measurement of ECU internal delay time t_{ECU}

9 Bus failure and fault confinement

9.1 General

Many different bus failures can occur during normal operation that can influence operation. To ensure safety under all conditions, these failures and the resulting network behaviour are specified in the next sections.

9.2 Loss of network connection

If a node becomes disconnected from a bus segment, the remaining nodes shall continue communication. The exceptions to this requirement are bridges, gateways and routers, as communication between the bus segments on the different ports of such a device would be impossible under the circumstances.

9.3 Node power or ground loss

a) If a node loses power, or is in a low-voltage condition, the bus segment to which it is attached shall not be electrically loaded, and the remaining nodes shall continue communication.

b) If a node loses ground, the voltages on the bus segment to which it is attached shall not be biased up, and the remaining nodes shall continue communication.

9.4 Reaction to power-supply voltage disturbances

ECUs on the network shall be able to manage 12 Vdc supply voltage transients and interruptions, reacting in accordance to the following requirements:

1. If ECU_PWR is restored within 2 ms and if interruptions are spaced at least 98 ms apart (this results in a 100 ms period), there shall be
   - no loss of normal network communications or in-process messages;
   - no processor reset;
   - no loss of data in the volatile memory, such as network-configuration information or messages in progress over the network;
2. If ECU_PWR is disrupted for a period of time greater than 2 ms but less than 1 s, the ECU may either continue normal operation or it may reset;
3. If ECU_PWR is disrupted for a period of time equal to or greater than 1 s, the ECU shall perform a power-up reset when power is restored.

For test purposes the power supply used to perform the test shall be able to source three times the current that the ECU draws at 12 Vdc supply voltage.

9.5 Network disruption during connection, disconnection or power-up

Connection, disconnection, or power-up of the ECU shall not disrupt network communications.

9.6 Open and short failures

In principle, bus failures are detectable if there is a significant message destruction rate, as can be interpreted by the ECUs or the CAN controllers. Cases of external events that can cause failures, with the required network response, are listed and described as follows (see Figure 42). An ECU shall fall back to a fail-safe state of operation if the fault condition does not ensure communication integrity with other ECU's in the network which are required for its normal operation. ECUs should store Diagnostic Trouble Codes in cases when detectable open or short failures are intermittent.

Case 1: CAN_H interrupted between "first" or "last" ECU and a TBC

Data communications shall be able to continue between all nodes. There can be a reduction in the signal-to-noise ratio or an increase in electromagnetic emissions, or both. (The swing on CAN_H is essentially twice that on CAN_L, thereby allowing continued operation.)

Case 2: CAN_H shorted to ECU_PWR

Data communications is not possible. The ECU shall be able to detect this fault condition and fall back to a fail-safe state of operation.

Case 3: CAN_L shorted to GND

Data communications is not possible. The ECU shall be able to detect this fault condition and fall back to a fail-safe state of operation.

Case 4: CAN_H shorted to GND

Data communications is not possible. The ECU shall be able to detect this fault condition and fall back to a fail-safe state of operation.

Case 5: CAN_H interrupted

Data communications shall be able to continue between nodes on each side of the interruption, even though it might not be possible to maintain communications between nodes across the interruption. The ECU shall fall back to a fail-safe state of operation if it relies on communication with an ECU on the other side of the interruption. There can be a reduction in the signal-to-noise ratio between nodes on opposite sides of the interruption.

Case 6: CAN_L interrupted

Data communications shall be able to continue between nodes on each side of the interruption, even though it might not be possible to maintain communications between nodes across the interruption. The ECU shall fall back to a fail-safe state of operation if it relies on communication with an ECU on the other side of the interruption. There can be a reduction in the signal-to-noise ratio between nodes on opposite sides of the interruption.

Case 7: CAN_L shorted to ECU_PWR

Data communications is not possible. The ECU shall be able to detect this fault condition and fall back to a fail-safe state of operation.

Case 8: TBC_PWR shorted to GND

Data communications shall be able to continue between all nodes if TBC_PWR is isolated from ECU_PWR by current limiting circuit or a fuse. There can be a reduction in the signal-to-noise ratio as the system is operating with only one TBC and incorrect signal levels.

Case 9: CAN_H shorted to CAN-L

Data communications is not be possible. The ECU shall be able to detect this fault condition and fall back to a fail-safe state of operation.

Case 10: TBC_PWR interrupted between "supply-end" and "far-end" terminators

Data communications shall be able to continue between all nodes. There can be a reduction in the signal-to-noise ratio, since the signal lines are loaded to ground by the TBC, which are unpowered.

Case 11: Both bus signal lines interrupted at same location

Data communications between nodes on opposite sides of an interruption is not possible. Data communications between nodes on the same side of an interruption shall be able to continue but may do so with reduced signal-to-noise ratio. The ECU shall fall back to a fail-safe state of operation if it relies on communication with an ECU on the other side of the interruption.

Case 12: TBC_RTN interrupted between "supply-end" and "far-end" TBCs

Data communications between nodes is not possible. The ECU shall be able to detect this fault condition and fall back to a fail-safe state of operation.

Case 13: CAN_L interrupted between "first" or "last" ECU and TBCs

Data communications shall be able to continue between nodes. There can be a reduction in the signal-to-noise ratio or an increase in electromagnetic emissions, or both. (The swing on CAN_H is essentially twice that on CAN_L, thereby allowing continued operation.)

Case 14: Supply interrupted before reaching TBCs

Data communications between nodes is not possible. The ECU shall be able to detect this fault condition and fall back to a fail-safe state of operation.

Case 15: Ground interrupted before reaching TBCs

Data communications between nodes is not possible. The ECU shall be able to detect this fault condition and fall back to a fail-safe state of operation.

Case 16: Both CAN_H and CAN_L open to an ECU [i.e. loss of connection to bus segment (see 8.2)]

If a node becomes disconnected from its bus segment, the remaining nodes shall be able to continue communications, except the single ECU. The single ECU shall be able to detect this fault condition and fall back to a fail-safe state of operation.

Case 17: Node power loss

If a node loses power, or is in a low-voltage condition, the remaining nodes shall be able to continue communications.

Case 18: Node ground loss

If a node loses ground, the remaining nodes shall be able to continue communications.

Case 19: Loss of one TBC

Data communications shall be able to continue between all nodes. Fault detection by any ECU is probably not possible. There can be a reduction in the signal-to-noise ratio and an increase in electromagnetic emissions because the media is no longer terminated properly. If both TBCs are disconnected, communications can likely fail.

Case 20: CAN_H shorted to TBC_PWR

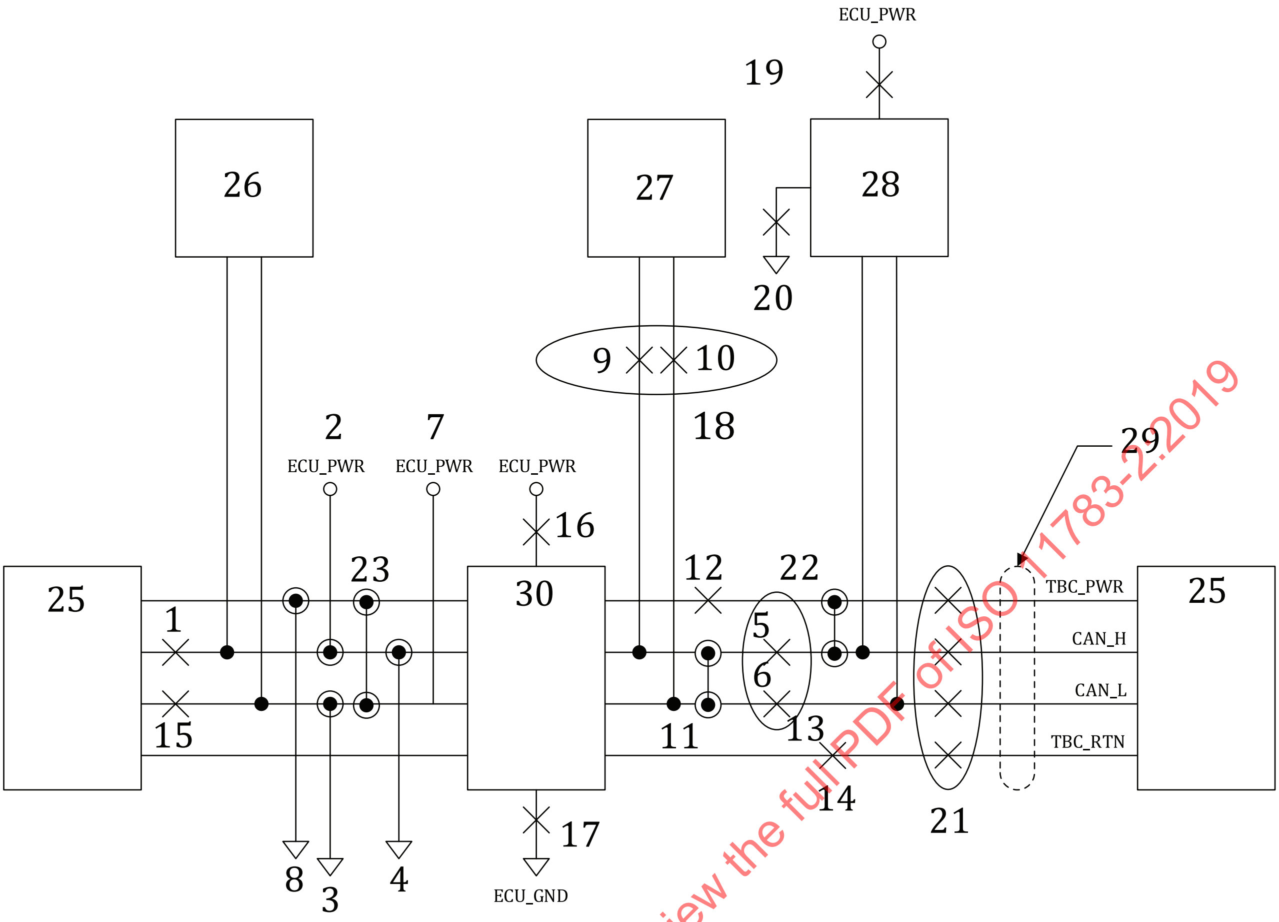
Data communications is not possible. The ECU shall be able to detect this fault condition and fall back to a fail-safe state of operation.

Case 21: CAN_L shorted to TBC_PWR

Data communications is not possible. The ECU shall be able to detect this fault condition and fall back to a fail-safe state of operation.

Case 22: Topology parameter violations (i.e. bus or stub length, node spacing, bias impedance)

Data communications via the bus might be possible, but with a reduction in the signal-to-noise ratio and possible loss of arbitration.



Key

1	case 1	11	case 11	21	case 21	×	open circuits
2	case 2	12	case 12	22	case 22	⊙	closed circuits
3	case 3	13	case 13	23	case 23		
4	case 4	14	case 14	24	case 24 — not shown		
5	case 5	15	case 15	25	TBC		
6	case 6	16	case 16	26	ECU 1		
7	case 7	17	case 17	27	ECU *n* – *1*		
8	case 8	18	case 18	28	ECU *n*		
9	case 9	19	case 19	29	twisted quad transmission cable		
10	case 10	20	case 20	30	power for TBC		

NOTE See 9.4.

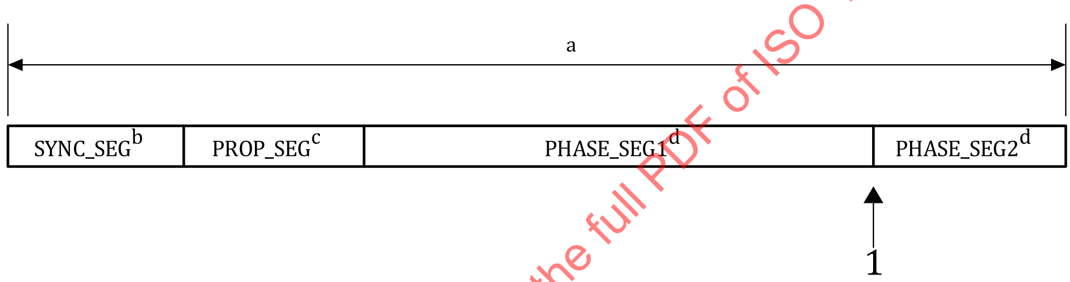
Figure 42 — Possible failures due to external events

Annex A
(informative)

Protocol controller timing and naming

A.1 Bit subdivision

A variety of names are used to refer to the bit segments (see Figure A.1) by different suppliers of CAN protocol controller integrated circuits. However, it is believed this general grouping provides insight into the operation and configuring of these circuits. Since these definitions are not constant, it is possible that two-bit segments in one implementation can be defined as one in another implementation. It is therefore possible that a particular protocol controller ICs cannot be configurable for the bit segmentation described here.



Key

1 sample point (point of time at which the bus level is read and interpreted as the value of the bit)

a Nominal bit time.

b Part of bit time used to synchronize ECUs on the bus; edge expected within this bit segment.

c Part of bit time used to compensate for physical delay times on a bus segment; delay times caused by propagation time of bus signal line and ECUs' internal delay time.

d Phase buffer segments used to compensate for phase-errors; can be lengthened or shortened by resynchronization.

Figure A.1 — Bit segmentation

A.2 Internal delay time

The internal delay time of an ECU, t_{ECU}, is defined as the sum of all asynchronous delays that occur along the transmission and reception path of an ECU, relative to the bit timing logic unit of the protocol IC (see Figure A.2).