



BSI Standards Publication

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

Part 2: Physical layer

National foreword

This British Standard is the UK implementation of [ISO 11783-2:2019](#). It supersedes [BS ISO 11783-2:2012](#), which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee AGE/6, Agricultural tractors and forestry machinery.

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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



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Contents

Page

Foreword	v
Introduction	vi
1 Scope	1
2 Normative references	1
3 Terms and definitions	1
4 Abbreviated terms	2
5 General requirements	2
5.1 Network physical layer	2
5.2 Physical media	2
5.3 Differential voltage	3
5.4 Bus 3	
5.4.1 Levels	3
5.4.2 Voltage range	3
5.4.3 Bus termination	3
5.5 Resistance and capacitance	6
5.5.1 Internal resistance (R_{in}), capacitance (C_{in})	6
5.5.2 Differential internal resistance (R_{diff}), capacitance (C_{diff})	6
5.5.3 Weak termination for stubs	7
5.6 Bit time	7
5.7 AC parameters	7
6 Bus segment specifications	8
6.1 Twisted quad bus segment	8
6.2 TPPL bus segment	9
7 Electrical specifications	9
7.1 Electrical data	9
7.1.1 General	9
7.1.2 Absolute maximum ratings	9
7.1.3 DC parameters	9
7.1.4 Bus voltages (operational)	13
7.1.5 Electrostatic discharge (ESD)	13
7.2 Physical media parameters	14
7.2.1 Unshielded twisted quad cable	14
7.2.2 Unshielded twisted pair	14
7.3 Topology of twisted quad physical layers	16
7.3.1 ECU connection to TBC_PWR and TBC_RTN	17
7.3.2 Power for TBC_PWR and TBC_RTN	17
7.4 Topology of twisted pair physical layer	17
7.4.1 General	17
7.4.2 Simple stub	17
7.4.3 Compound stub	18
7.4.4 Multiple splice	19
7.5 TBC parameters	20
7.6 Connectors	21
7.6.1 General	21
7.6.2 Bus extension connector	22
7.6.3 Implement bus breakaway connector	24
7.6.4 In-cab connector	33
7.6.5 Diagnostic connector	37
8 Conformance tests	42
8.1 General requirements	42
8.2 Internal resistance	43

8.3	Internal differential resistance.....	44
8.4	ECU recessive input threshold.....	44
8.5	ECU dominant input threshold.....	45
8.6	ECU dominant output.....	45
8.7	ECU internal delay time.....	46
9	Bus failure and fault confinement.....	47
9.1	General.....	47
9.2	Loss of network connection.....	47
9.3	Node power or ground loss.....	47
9.4	Reaction to power-supply voltage disturbances.....	48
9.5	Network disruption during connection, disconnection or power-up.....	48
9.6	Open and short failures.....	48
Annex A (informative) Protocol controller timing and naming.....		52
Annex B (informative) Examples of physical layer circuits.....		56
Annex C (informative) Optional ECU stub connector.....		63
Bibliography.....		65

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](http://www.iso.org/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 $V_{\text{CAN_H}}$ and $V_{\text{CAN_L}}$. The differential voltage, V_{diff} , between $V_{\text{CAN_H}}$ and $V_{\text{CAN_L}}$ is defined by [Formula \(1\)](#):

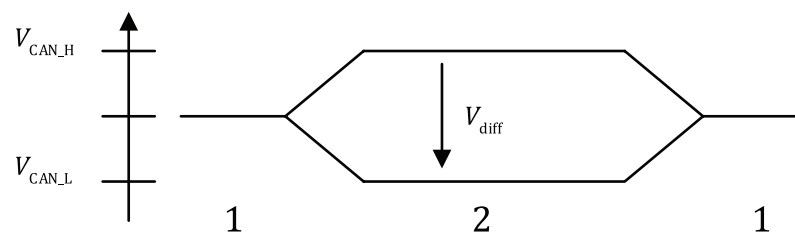
$$V_{\text{diff}} = V_{\text{CAN_H}} - V_{\text{CAN_L}} \quad (1)$$

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, $V_{\text{CAN_H}}$ and $V_{\text{CAN_L}}$ 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 dominant 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.

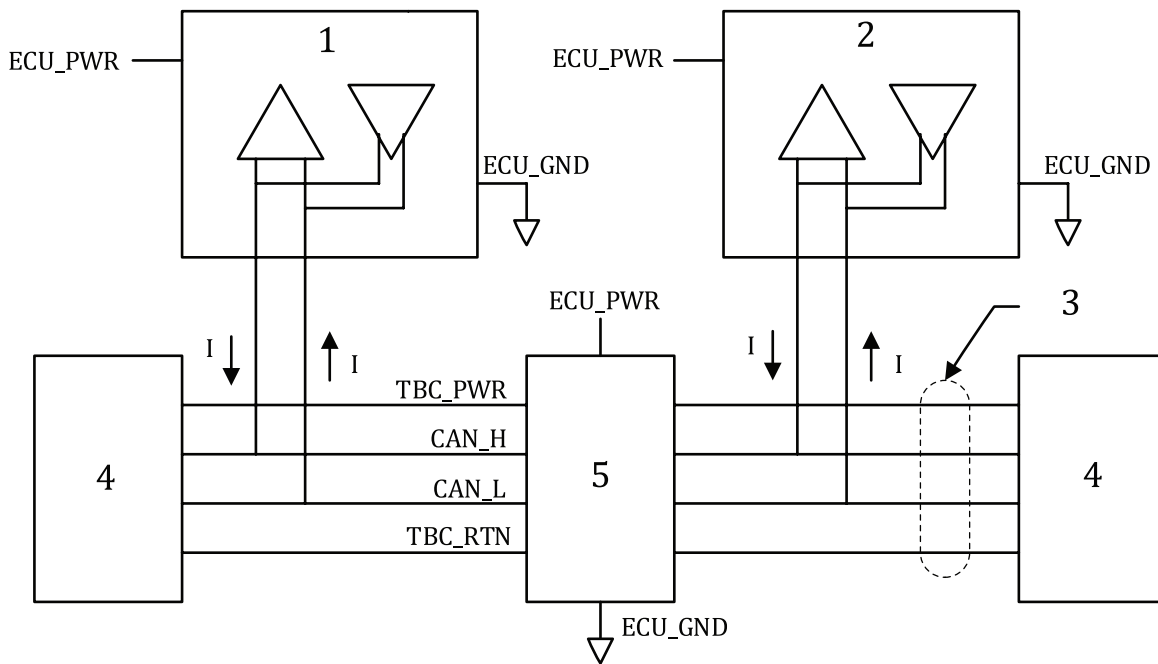
5.4.2 Voltage range

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

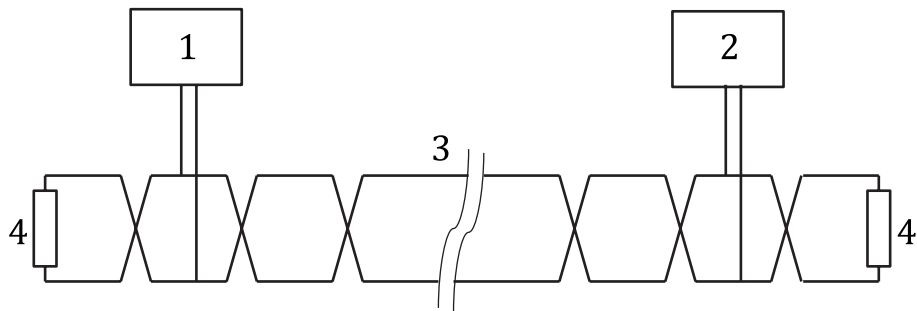
The bus signal lines of a TPPL bus segment are electrically terminated at each end with a passive load resistor denoted by R_L where $R_L = 120 \Omega$.

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.

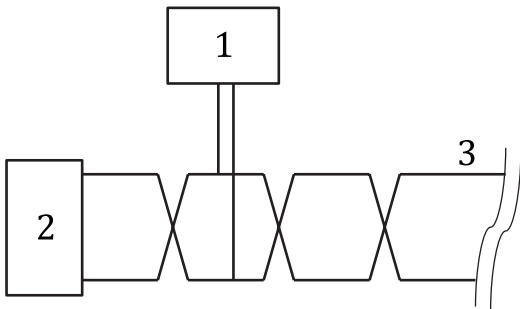
Type II ECUs shall only be powered by ECU_PWR/ECU_GND.

See [Figures 3](#) and [4](#).



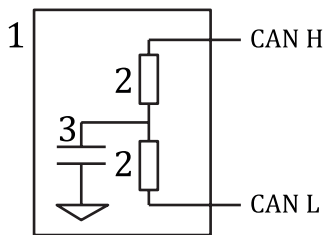
- Key**
- 1 ECU Type I No. 1
 - 2 ECU Type I No. *n*
 - 3 unshielded twisted pair
 - 4 terminating resistors R_L

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

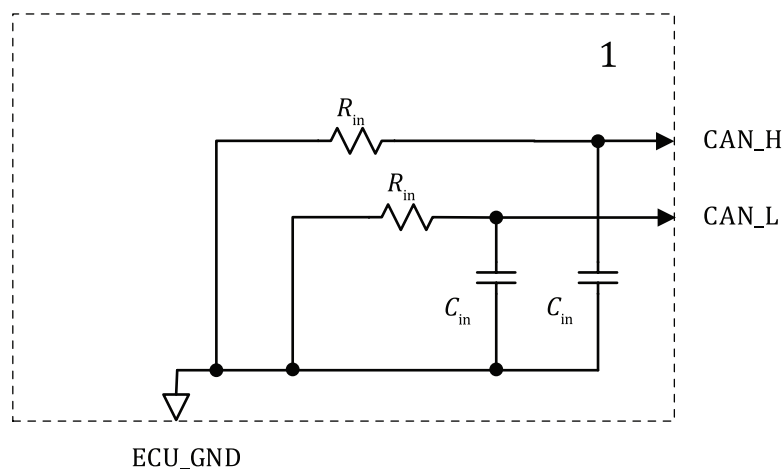
5.5 Resistance and capacitance

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

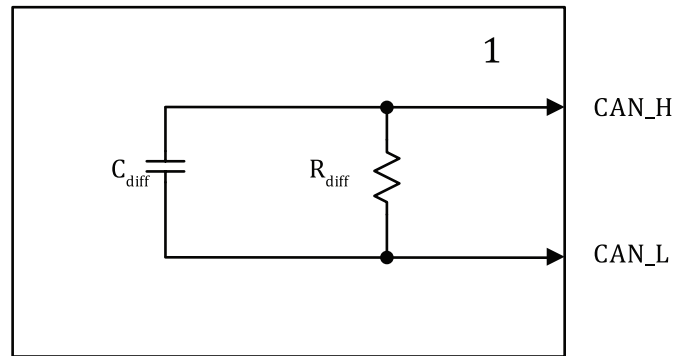
Figure 6 — Internal resistance and capacitance of ECU in recessive state

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 $750\ \Omega + 750\ \Omega$ 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 μ s, 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 % $\pm$ 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 $V_{\text{diff}} = 1,0 \text{ V}$ for a transition from recessive to dominant, $V_{\text{diff}} = 0,5 \text{ V}$ 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 node₂, 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 $V_{\text{diff}} = 1 \text{ V}$, nor increase the recessive differential voltage level above $V_{\text{diff}} = 0,5 \text{ V}$, 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 t_{TSEG1} . 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 $t_{\text{TSEG1}} - \text{SJW}$. A time quantum (t_q) of 250 ns with $\text{SJW} = 2 t_q$, $t_{\text{TSEG1}} = 12 t_q$, $t_{\text{TSEG2}} = 3 t_q$, results in $t_{\text{avail}} = 2,5 \mu\text{s}$.

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	V_{CAN_H}	-16,0	16,0	V
Conditions 12 V nominal supply voltage	V_{CAN_L}			
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	10,0	16,0	V
	ECU_PWR			

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
$V(\text{ECU_PWR}) - V(\text{ECU_GND})$	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
$V(\text{PWR}) - V(\text{GND})$	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

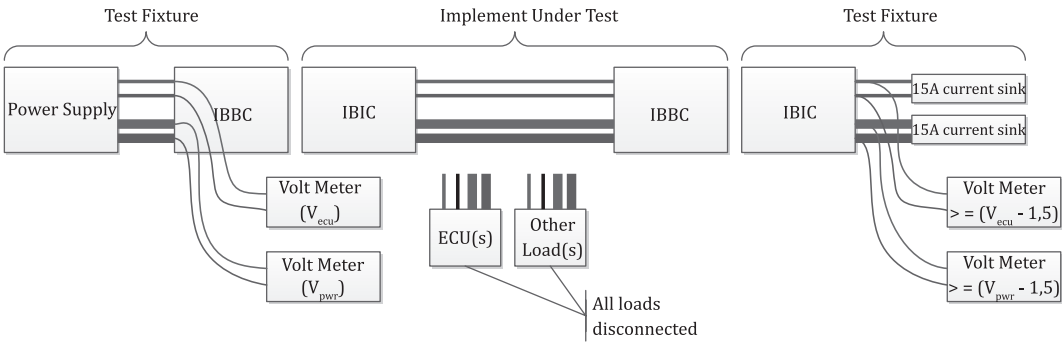


Figure 8 — Voltage drop measurement

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
^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.						

Parameter	Symbol	Min.	Nom.	Max.	Unit	Conditions
Differential bus voltage	$V_{\text{diff_R}}$	-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 $V_{\text{diff}} < -1,0$ 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	$V_{\text{CAN_H}}$	—	3,5	7,0	V	Measured with respect to ground of each ECU ^a
	$V_{\text{CAN_L}}$	-2,0	1,5	—		
Differential bus voltage	$V_{\text{diff_D}}$	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 $V_{\text{CAN_H}}$ is determined by the minimum value of $V_{\text{CAN_L}}$ plus the minimum value of V_{diff} . The maximum value of $V_{\text{CAN_L}}$ is determined by the maximum value of $V_{\text{CAN_H}}$ 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 k Ω 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	m Ω /m	^a Measured at 20 °C
Specific line delay	T_p	—	5,0	—	ns/m	^b
Specific capacitance	C_b	0	40	75	pF/m	Between CAN_H and CAN_L
	C_a	0	70	110	pF/m	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

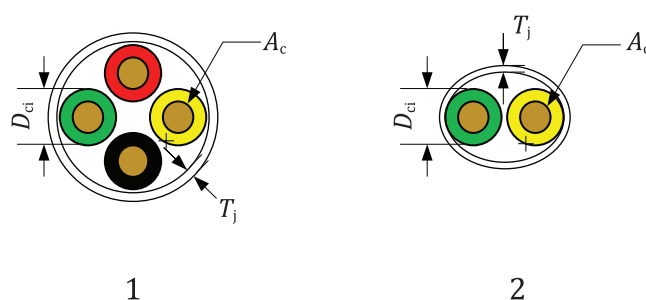
Parameter	Symbol	Min.	Nom.	Max.	Unit	Conditions
Impedance	Z	108	120	132	Ω	Three-meter sample length measured at 1 MHz between the two signal wires, using open/short method.
Specific resistance	R_b	—	25	50	m Ω /m	^a Measured at 20 °C
Specific line delay	T_p	—	5,0	—	ns/m	^b
Specific capacitance	C_b	—	40	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

**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