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ISO 11783-2

Third edition
2019-04

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

Part 2:
Physical layer

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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

iTeh STANDARD PREVIEW
(standards.iteh.ai)
ISO 11783-2:2019
https://standards.iteh.ai/catalog/standards/sist/232984b5-af03-4f11-8211-8b23175191a4/iso-11783-2-2019

iTeh STANDARD PREVIEW
(standards.iteh.ai)
ISO 11783-2:2019
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Foreword

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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).

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

ISO 11783-2:2019
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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.

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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.

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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.

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

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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

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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

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ISO 11783-2:2019
https://standards.iteh.ai/catalog/standards/sist/232984b5-af03-4f11-8211-8b23175191a4/iso-11783-2-2019

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.

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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):

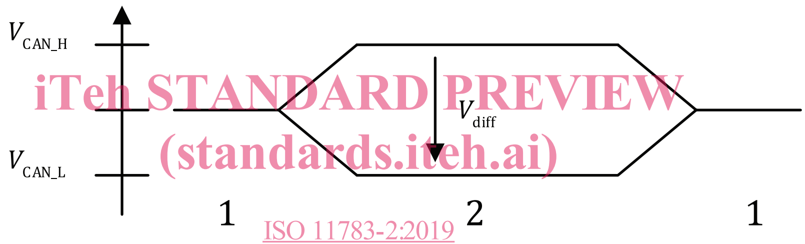
$$V_{diff} = V_{CAN\_H} - V_{CAN\_L} \quad (1)$$

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_{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).



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ISO 11783-2:2019
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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).

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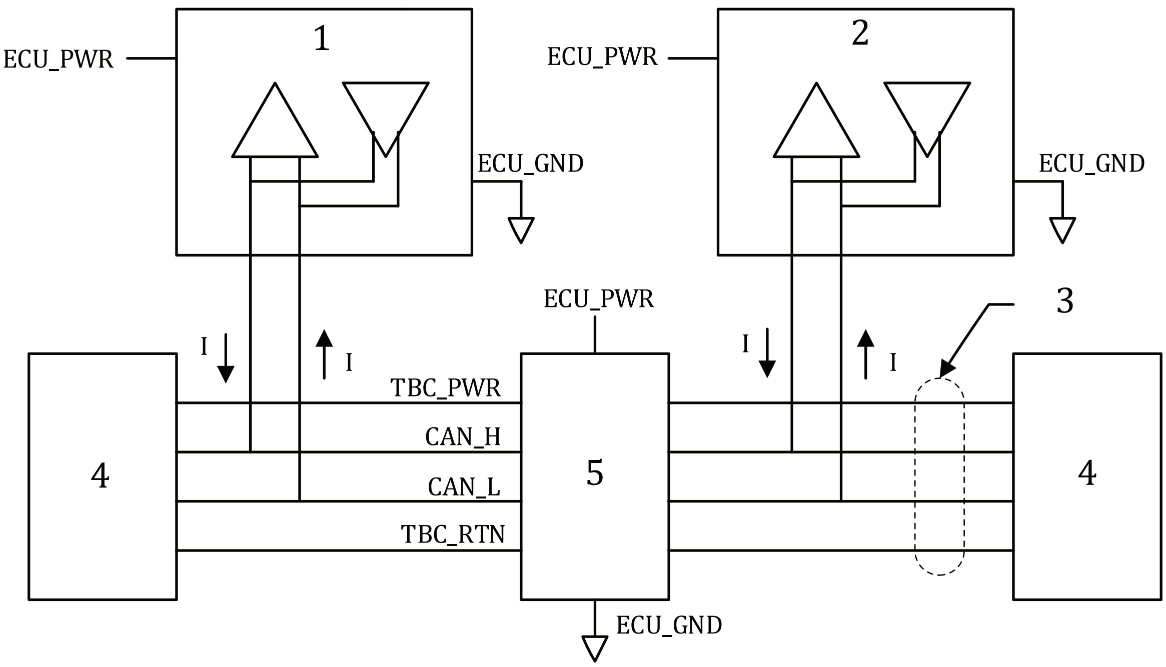

Key

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

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ISO 11783-2:2019
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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.

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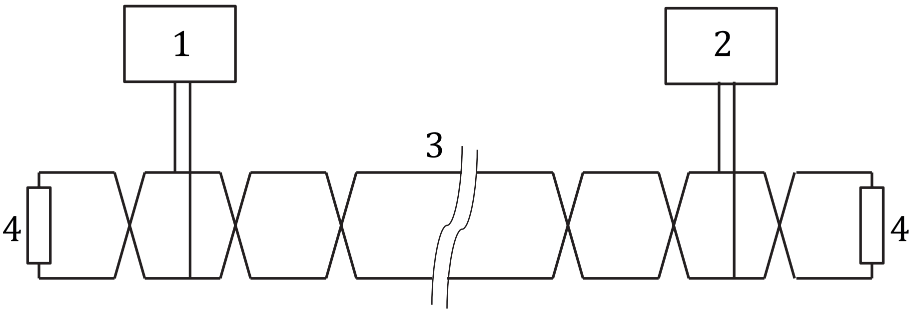


Key

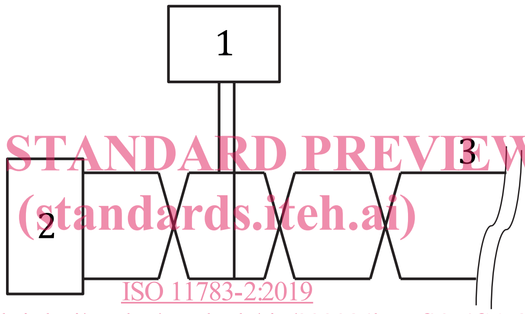
1 ECU Type I No. 1

2 ECU Type I No. *n*

3 unshielded twisted pair

4 terminating resistors R_L

Figure 3 — TPPL functional diagram



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ISO 11783-2:2019
https://standards.iteh.ai/catalog/standards/sist/232984b5-af03-4f11-8211-8b23175191a4/iso-11783-2-2019

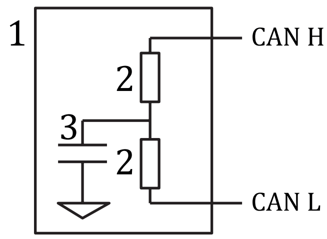
Key

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

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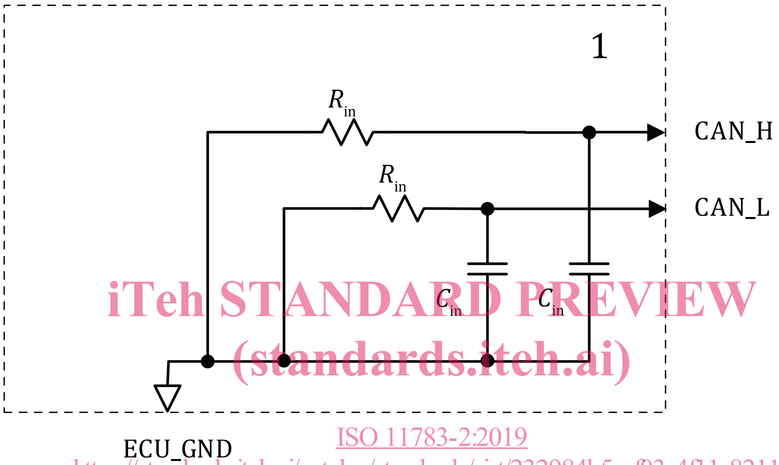
5.5 Resistance and capacitance

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.



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ISO 11783-2:2019
https://standards.iteh.ai/catalog/standards/sist/232984b5-af03-4f11-8211-8b23175191a4/iso-11783-2-2019

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.

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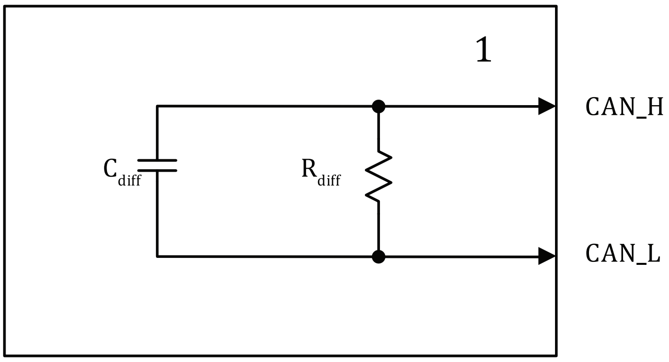

Key

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.

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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.

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ISO 11783-2:2019
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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.

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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 $t_T(rise_1) + t_T(rise_R) + t_T(repeater) + t_T(rise_R) + t_T(repeater) + 2t_T(line) + t_T(node_2)$. 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.

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ISO 11783-2:2019
https://standards.iteh.ai/catalog/standards/sist/232984b5-af03-4f11-8211-8b2317519 1a4/iso-11783-2-2019

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.

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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).

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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).

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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