INTERNATIONAL STANDARD

ISO 11783-2

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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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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

ISO 11783-2 was prepared by Technical Committee ISO/TC 23, *Tractors and machinery for agriculture and forestry*, Subcommittee SC 19, *Agricultural electronics*.

ISO 11783 consists of the following parts, under the general title *Tractors and machinery for agriculture and forestry — Serial control and communications data network*:

— *Part 1: General standard for mobile data communication*

— *Part 2: Physical layer*

— *Part 3: Data link layer*

— *Part 4: Network layer*

— *Part 5: Network management*

— *Part 6: Virtual terminal*

— *Part 7: Implement messages applications layer*

— *Part 8: Power train messages*

— *Part 9: Tractor ECU*

— *Part 10: Task controller and management information system data interchange*

— *Part 11: Data dictionary*

Annexes A and B of this part of ISO 11783 are for information only.

Introduction

Parts 1 to 11 of ISO 11783 specify a communications system for agricultural equipment based on the CAN 2.0 B [1] protocol. SAE J 1939 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 J 1939 specifications to be used by agricultural and forestry equipment with minimal changes. This part of ISO 11783 is harmonized with SAE J 1939/81 [2]. General information on ISO 11783 is to be found in ISO 11783-1.

The purpose of ISO 11783 is to provide an open, interconnected system for on-board electronic systems. It is intended to enable electronic control units (ECUs) to communicate with each other, providing a standardized system.

The International Organization for Standardization (ISO) draws attention to the fact that it is claimed that compliance with this part of ISO 11783 may involve the use of a patent concerning the controller area network (CAN) protocol referred to throughout the document.

ISO takes no position concerning the evidence, validity and scope of this patent.

The holder of this patent right has assured ISO that he is willing to negotiate licences under reasonable and non-discriminatory terms and conditions with applicants throughout the world. In this respect, the statement of the holder of this patent right is registered with ISO. Information may be obtained from:

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Attention is drawn to the possibility that some of the elements of this part of ISO 11783 may be the subject of patent rights other than those identified above. ISO shall not be held responsible for identifying any or all such patent rights.

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

Part 2: **Physical layer**

1 Scope

This part of 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 sensor, actuators, control elements, and information-storage and -display units, whether mounted on, or part of, the tractor or implement. This part of ISO 11783 defines and describes the network's 250 kbit/s, twisted, non-shielded, quad-cable physical layer.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 11783. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 11783 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 1724, *Road vehicles — Electrical connections between towing and towed vehicles with 12 V systems — 7 pole connector type 12 N (normal)*.

ISO 14982, *Agricultural and forestry machines — Electromagnetic compatibility — Test methods and acceptance criteria*.

3 General Description

3.1 Network physical layer

The physical layer of a network is the realization of the electrical connection of a number of 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 part of ISO 11783, the limit shall be set at 30 ECUs per segment.

3.2 Physical media

This part of ISO 11783 defines a physical media of twisted quad cable. Two of 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. The third and fourth conductors, designated TBC_PWR and TBC_RTN, provide power for the terminating bias circuits (TBCs) on the bus segments.

3.3 Differential voltage

The voltages of CAN_H and CAN_L relative to the particular ground 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 the equation:

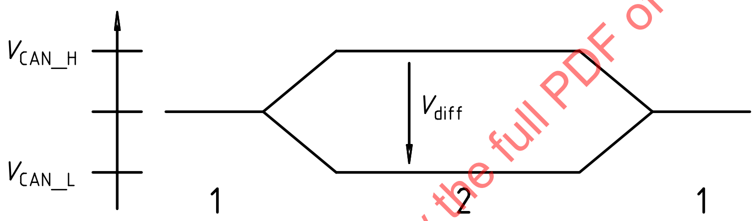
$$V_{diff} = V_{CAN\_H} - V_{CAN\_L} \quad (1)$$

3.4 Bus

3.4.1 Levels

3.4.1.1 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 or a recessive bit. The dominant state is represented by a differential voltage greater than a minimum threshold. The dominant state overwrites the recessive state and is transmitted when there is a dominant bit. (See also clause 4.)



Key

1 Recessive

2 Dominant

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

3.4.1.2 During arbitration

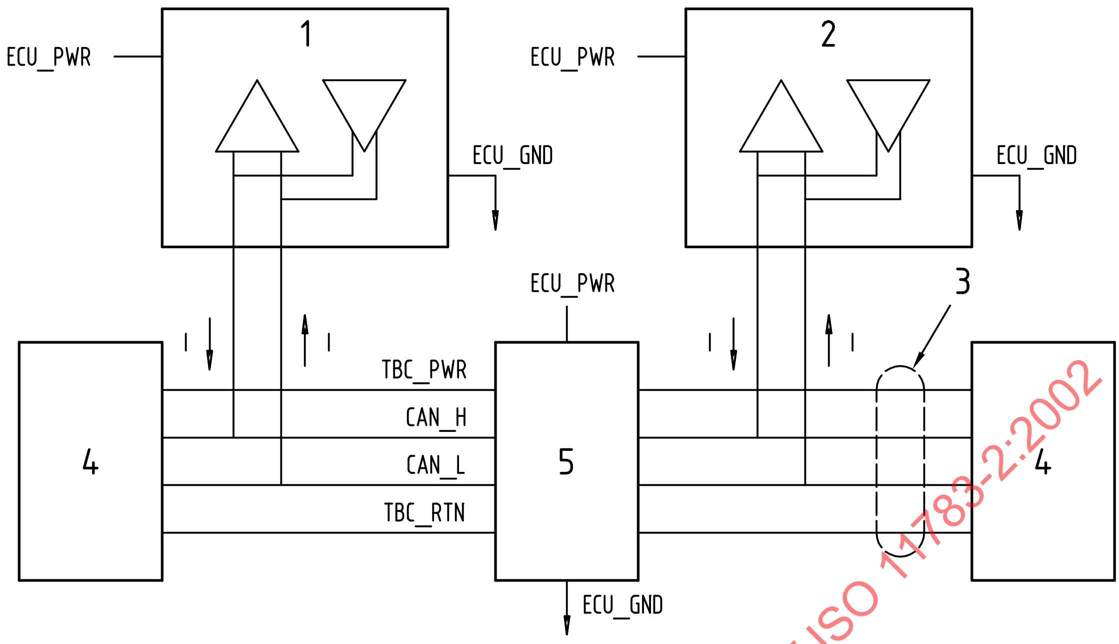
During arbitration, a recessive and a dominant bit imposed on the bus signal lines during a given bit time by two ECUs will result in a dominant bit.

3.4.2 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 particular ground of each ECU, for which proper operation is guaranteed when all ECUs are connected to bus signal lines.

3.4.3 Termination

The bus signal lines of a bus segment are electrically terminated at each end by a terminating bias circuit. This TBC shall be located externally from the ECU, in order to ensure bus bias and termination when the ECU is disconnected (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

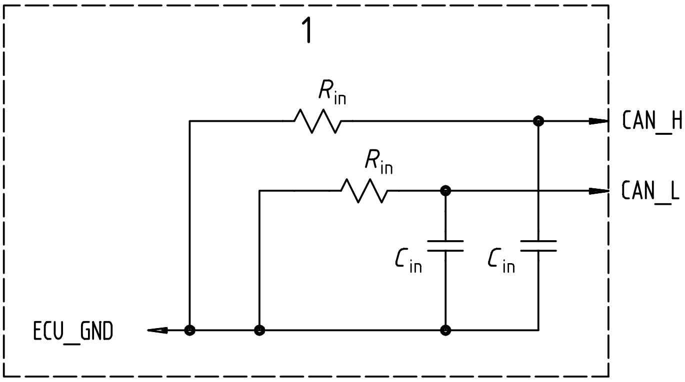
3.5 Resistance and Capacitance

3.5.1 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 minimum value used to confirm compliance.

ECU internal resistance and capacitance are illustrated by Figure 3.



Key

1 ECU

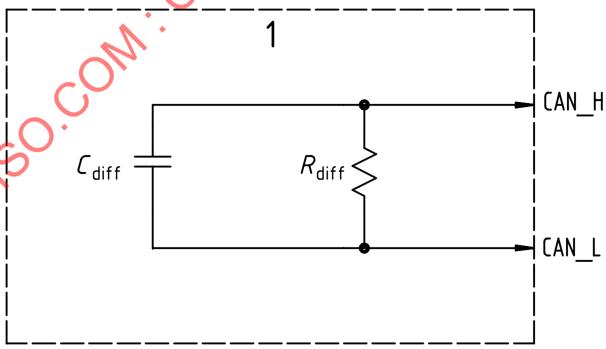
Figure 3 — Internal resistance and capacitance of ECU in recessive state

3.5.2 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 (Figure 4). The measurement shall be made with the ECU both powered and unpowered, and the minimum value used to confirm compliance.

ECU differential internal resistance and capacitance are illustrated by Figure 4.



Key

1 ECU

Figure 4 — Differential internal resistance and capacitance of ECU in recessive state

3.6 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 with this part of ISO 11783 is 4 µs, which corresponds to 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 has to be able to be constructed with ECUs from different suppliers. Without timing restrictions, ECUs from different suppliers might not be able to properly receive and interpret valid messages, making necessary 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.

For an ISO 11783 network with a 250 kbit/s data rate and a bus segment of 40 m in length, the following are typical protocol-controller requirements.

— Synchronize on recessive to dominant edge only.

— Use a single sample point.

— Sample time is to be 80 % ± 3 % of the bit time, referenced to the start of the bit time.

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

3.7 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	600	800	1000	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	50	100	pF	250 kbit/s for CAN_H and CAN_L relative to ground [d]
Differential internal capacitance	C_{diff}	0	25	50	pF	[d]
Common mode rejection	CMR	40	—	—	dB	d.c. to 50 kHz
	CMR_{5MHz}	10	—	—	dB	5 MHz may linearly decrease between 50 kHz and 5 MHz
Available time	t_{avail}	2,75	—	—	µs	with 40 m bus length [e]

[a] Including initial tolerance, temperature and ageing.

[b] 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 waveshape.

[c] The value of t_{ECU} shall be 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 nominal CAN-interface delay of 800 ns is possible (controller not included), with a reserve of about 200 ns. This allows slower transmitter slopes and input filtering. It is recommended that this feature be used to limit EMC. 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 may be zero. The maximum tolerable value shall be 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 ⩾ ¼ bit time, the transition times still consume all possible bit time. Because the ISO 11783 network has a sample point of 80 % of the bit time and allows a transition time equal to ¼ bit time, true repeaters cannot be used.

[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} may be 0, while the maximum tolerable values shall be determined by the bit timing and the topology parameters L and d (see Table 8). 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 3 and Table 4).

[e] The available time results from the bit timing unit of the protocol IC. For example, the time in most controller ICs corresponds to TSEG1. Due to poor synchronization it is possible to lose the length of the synchronization jump width (SJW), so that t_{avail} with one instance of this poor synchronization is TSEG1–SJW. A time quantum (tq) of 250 ns where SJW = 2 tq, TSEG1 = 12 tq, TSEG2 = 3 tq, results in t_{avail} = 2,75 µs.

4 Functional description

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

On the one hand, the bus will be 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). On the other hand, 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.

NOTE ECUs need only be connected to the CAN_H and CAN_L conductors.

5 Electrical Specifications

5.1 Electrical data

5.1.1 General

The parameters specified in Tables 1 to 6 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 given bus segment. The limits given in Tables 1 to 5 apply to the CAN_H and CAN_L pins of each ECU, with the ECU disconnected from the bus signal lines (see clause 6).

5.1.2 Absolute maximum ratings

Table 2 specifies the absolute maximum d.c. 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 will 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 d.c. voltage					
Conditions	12 V nominal battery voltage	V_{CAN_H}	−3,0	16,0	V
	24 V nominal battery voltage	V_{CAN_L}		32,0	

NOTE 1 Operation of the connection cannot be guaranteed under these conditions.

NOTE 2 No damage may occur to the transceiver circuitry.

NOTE 3 No time limit (although operating CAN controllers will go “error passive” after a period of time).

NOTE 4 Relative to ground pin of ECU (transceiver shall handle wider range if there is voltage drop along the lines internal to ECU).

5.1.3 d.c. parameters

5.1.3.1 Bus-disconnected ECU

Tables 3 and 4 define, respectively, the d.c. parameters for the recessive and dominant states of an ECU disconnected from the bus.

Table 3 — d.c. parameters for recessive state of bus-disconnected ECU

Parameter	Symbol	Min.	Max.	Unit	Conditions
Bus voltage	V_{CAN_H} V_{CAN_L}	2,2	2,7	V	a b
Differential internal resistance	R_{diff}	10	—	kΩ	f
Internal resistance	R_{in}	20	—	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 shall be between 80 kΩ and 100 kΩ, and 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 specific network bus segment.

[c] Reception shall be ensured within the common mode voltage range defined in Tables 5 and 6.

[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 waveshape.

[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 3.5.1 and 3.5.2.

Table 4 — d.c. 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
	V_{CAN_L}	0,0	1,5	2,0		
Differential voltage output	V_{diff_OD}	1,5	2,0	3,0		a
Differential voltage detected as dominant	V_{diff_ID}	1,0	—	5,0		a b

[a] The equivalent series resistance of the two TBCs in parallel (37,5 Ω) is connected between CAN_H and CAN_L and TBC_PWR, providing the bias voltage relative to TBC_RTN.

[b] Reception shall be ensured within the common mode voltage range defined in Table 5 or Table 6.

5.1.3.2 Bus-connected ECU

Tables 5 and 6 define, respectively, the d.c. parameters for the recessive and dominant states of an ECU connected to a bus segment and other ECUs.

Table 5 — d.c. 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}	0,5	—	5,0	V	Measured with respect to ground of each ECU [a]
Differential bus voltage	V_{diff_R}	−1,0	0	0,5		Measured at each ECU connected to bus signal lines [b c]

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

[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 6 — d.c. 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} will affect single-ended operation and shall not exceed 3 V.

5.1.4 Bus voltages (operational)

The bus voltage parameters specified in Table 6 apply when all ECUs (from 2 to 30) are connected to a correctly terminated bus segment. The maximum allowable ground offset between ECUs or ECUs and TBCs on the bus is 2 V. The voltage extremes associated with this offset may occur in either the dominant or recessive state.

5.1.5 Electrostatic discharge (ESD)

CAN_H and CAN_L should be tested for ESD while disconnected from the bus signal lines, in accordance with ISO 14982 and using 15 kV.

5.2 Physical media parameters

5.2.1 Twisted quad cable

The parameters for the twisted quad cable shall be as specified in Table 7.

Table 7 — Physical media parameters for twisted quad cable

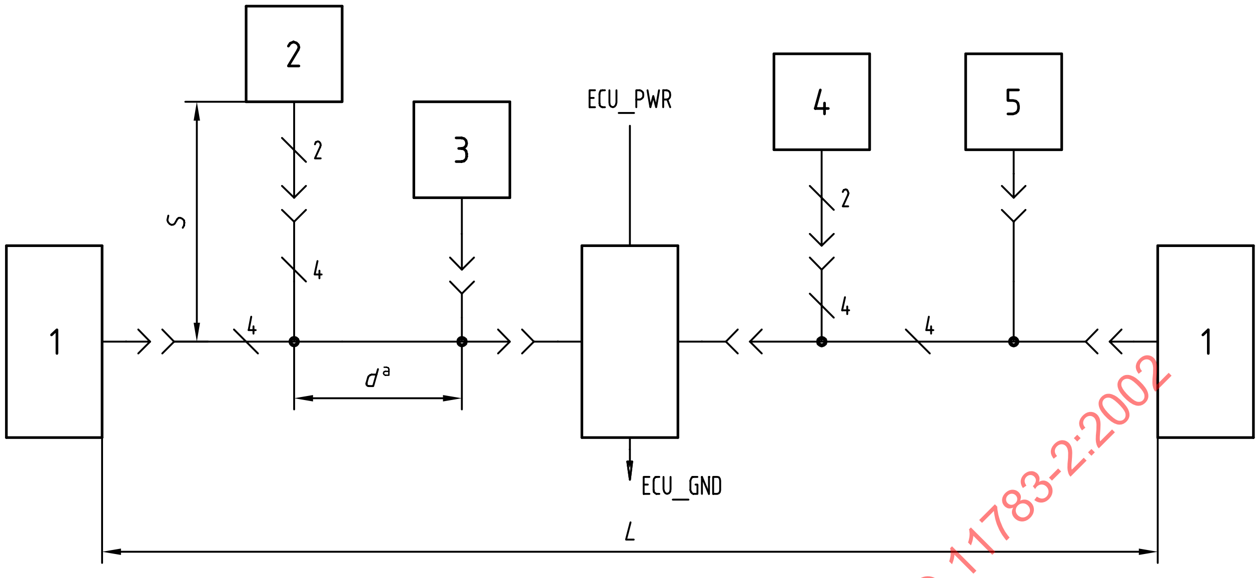
Parameter	Symbol	Min.	Nom.	Max.	Unit	Conditions
Impedance	Z_H Z_L	70	75	80	Ω	Measured at 1 MHz between either signal line and ground with TBC_PWR and TBC_RTN grounded
Specific resistance	R_b	0	25	50	mΩ/m	[a]
Specific line delay	t_p	—	5,0	—	ns/m	[b]
Specific capacitance	C_b	0	40	75	pF/m	Between CAN_H and CAN_L
	C_a	0	70	110	pF/m	Between adjacent conductors
Conductor size	a_c	—	0,5	—	mm²	Cross-section to be formed from a minimum of 19 strands of 32 AWG tinned or bare copper
Conductor insulation diameter	d_{ci}	2,0	2,11	3,05	mm	—
Colour of conductor insulation	—	—	Red	—	—	TBC_PWR
	—	—	Yellow	—	—	CAN_H
	—	—	Black	—	—	TBC_RTN
	—	—	Green	—	—	CAN_L
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	—	+125	°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 may be zero. The maximum value is determined by the bit time and the delay times of the transmitting and receiving circuitry.

5.2.2 Topology

In order to avoid cable reflections, the wiring topology of a bus segment should have, as nearly as possible, a linear structure. In practice, it could be necessary to connect short stubs to a main backbone cable, as shown in Figure 5. 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 shall be as given in Table 8.



Key

1 Terminating bias circuit (TBC)

2 ECU 1

3 ECU 2

4 ECU *n*–1

5 ECU *n*

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

Figure 5 — Topology of bus-segment wiring

Table 8 — 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	—

5.2.3 ECU connection to TBC_PWR and TBC_RTN

In order to sense the status of the network, each node on the bus may provide a pin for TBC_PWR and TBC_RTN. Loading limits shall be those given in Table 9.

Table 9 — Node loading of TBC_PWR and TBC_RTN

Parameter	Symbol	Min.	Max.	Unit	Conditions
Impedance	$\|Z\|_{TBC\_PWR}$	80	—	kΩ	Measured at 1 MHz between TBC_PWR and any other signal in ECU
	$\|Z\|_{TBC\_RTN}$	80	—	kΩ	Measured at 1 MHz between TBC_RTN and any other signal in ECU
Capacitance	C_{TBC_PWR}	—	10	pF	Measured at 1 MHz between TBC_PWR and any other signal in ECU
	C_{TBC_RTN}	—	10	pF	Measured at 1 MHz between TBC_RTN and any other signal in ECU

5.2.4 Power For TBC_PWR and TBC_RTN

TBC_PWR and TBC_RTN for a given bus segment should be supplied at only one point. This single connection point shall be selected to meet the filter requirements in Table 10. Filtering and regulation may be provided within the module providing this interconnection (see annex B).

5.3 TBC parameters

The terminating bias circuit 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 6 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 10.

Table 10 — 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
Resistance matching		R_{tH}/R_{tL}	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
	24 V system	TBC_PWR	16	—	32	V	25 mV peak to peak ripple in 20 kHz to 2 MHz range
Fault tolerance on bus signal lines		Shorts to battery	—	—	—	—	Continuous
Fault tolerance on bus signal lines		Shorts to ground	—	—	—	—	Continuous

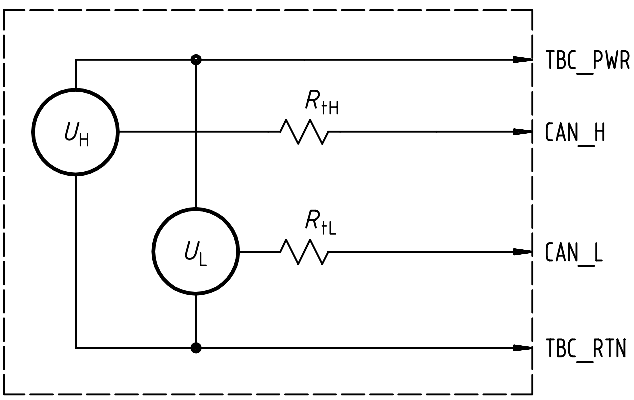


Figure 6 — Thévenin-equivalent terminating bias circuit (TBC)

5.4 Connectors

5.4.1 General

Three types of connectors are required for the network's implement bus segment (see Figure 7):

— the bus extension connector, located in the tractor cab (see 5.4.2);

— the implement bus breakaway connector (see 5.4.3);

— the diagnostic connector, which facilitates ISO 11783 network troubleshooting and maintenance (see 5.4.4).

NOTE For further information on the different network segments and their interconnections, see ISO 11783-4.

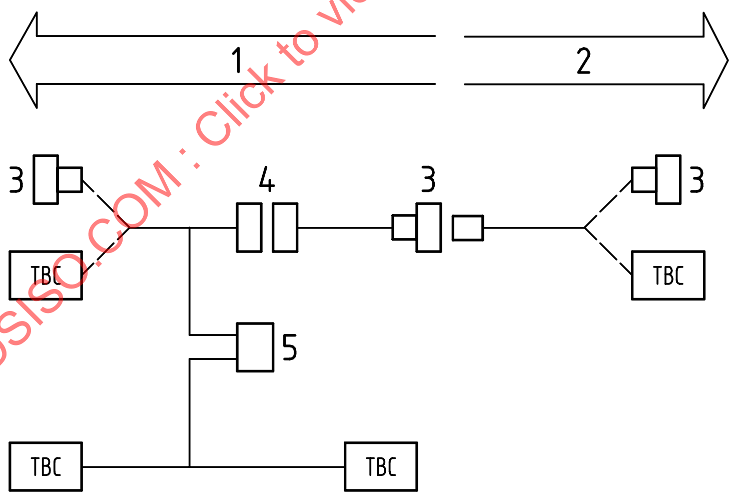
5.4.1.1 Electrical performance

The connectors and associated terminals used to connect bus lines on a bus segment shall conform to the electrical parameters specified in Table 11.

5.4.1.2 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.

NOTE An optional ECU stub connector can be used to connect SAE J1939/11 ECUs to an ISO 11783 network. (See annex B for a description of stub connectors, an optional TBC connector, and an example of a network interconnection using specified and optional connectors.)



Key

1 Tractor
2 Implement
3 Breakaway connector
4 Bus extension connector
5 Diagnostic connector

Figure 7 — Example of physical layer architecture, showing the three connector types

Table 11 — Connector electrical parameters

Parameter	Symbol	Min.	Nom.	Max.	Unit	Conditions
Dielectric Leakage at withstanding voltage	—	—	—	2	mA	At 1500 V; any pin to any other pin or to connector shell
Contact resistance	R_c	—	—	2	mV	Measured at 100 mA (equivalent to 20 mΩ)
Current	I	0	32	70	mA	—
Peak current	I_p	2,5	—	—	A	Time restriction: 2 s
Operating voltage	V	—	2,5	40	V	—
Characteristic impedance	Z_c	30	60	120	Ω	Maximum connector length should not be greater than twice the interfacial connector length.
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

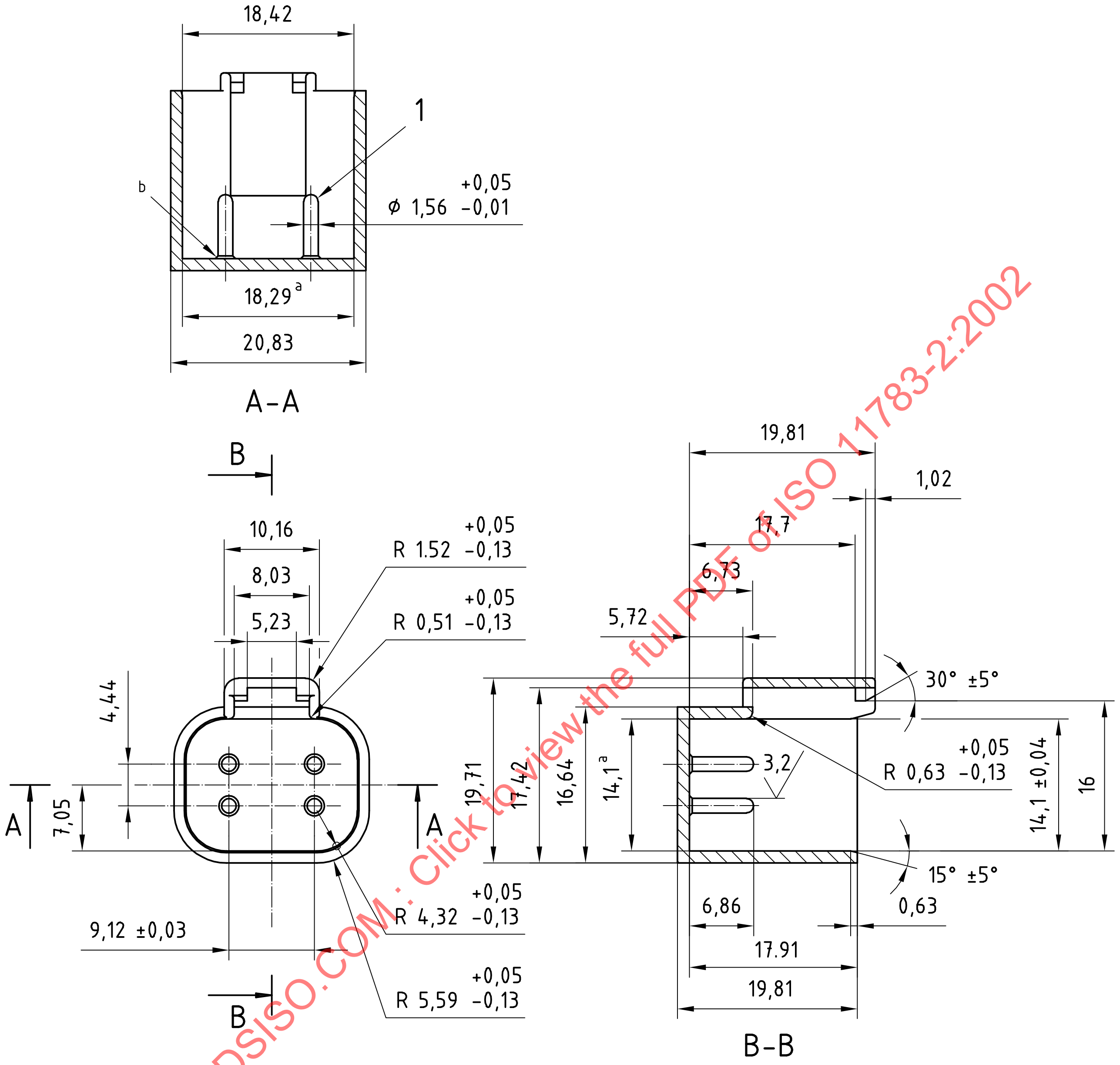
5.4.2 Bus extension connector

A mating connector pair shall 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. This connector pair should be located in the tractor cab on the right side of the operator's seat, forward from the external equipment controls (see annex B).

5.4.2.1 Dimensions

The bus extension connector receptacle shall have the dimensions shown in Figure 8, 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.

NOTE These specifications are met by Deutsch DT04-04PE and DT06-04SE [1)].

Figure 8 — Bus extension connector dimensional requirements

1) Deutsch is a trade name. This information is given for the convenience of users of this part of ISO 11783 and does not constitute an endorsement by ISO of the product named. Equivalent products may be used if they can be shown to lead to the same results.

5.4.2.2 Pin allocations

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

— Pin 1: TBC_PWR

— Pin 2: CAN_H

— Pin 3: TBC_RTN

— Pin 4: CAN_L

5.4.3 Implement bus breakaway connector

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 may be installed on the front of the tractor adjacent to the front-mounted hydraulic outlets when front-mounted implements are accommodated. This connector shall be identical to the rear-mounted connector.

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 5.4.3.2 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.

5.4.3.1 Terminating bias circuit

A TBC shall be located at each implement bus breakaway connector receptacle. This will be an active circuit 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.

Power on pin 5 of the receptacle disconnects the TBC from the implement bus. Pin 5 of the plug is shorted to Pin 4, the ECU_PWR connection. The loading of this disabled TBC on TBC_PWR and TBC_RTN shall be less than 20 mA.

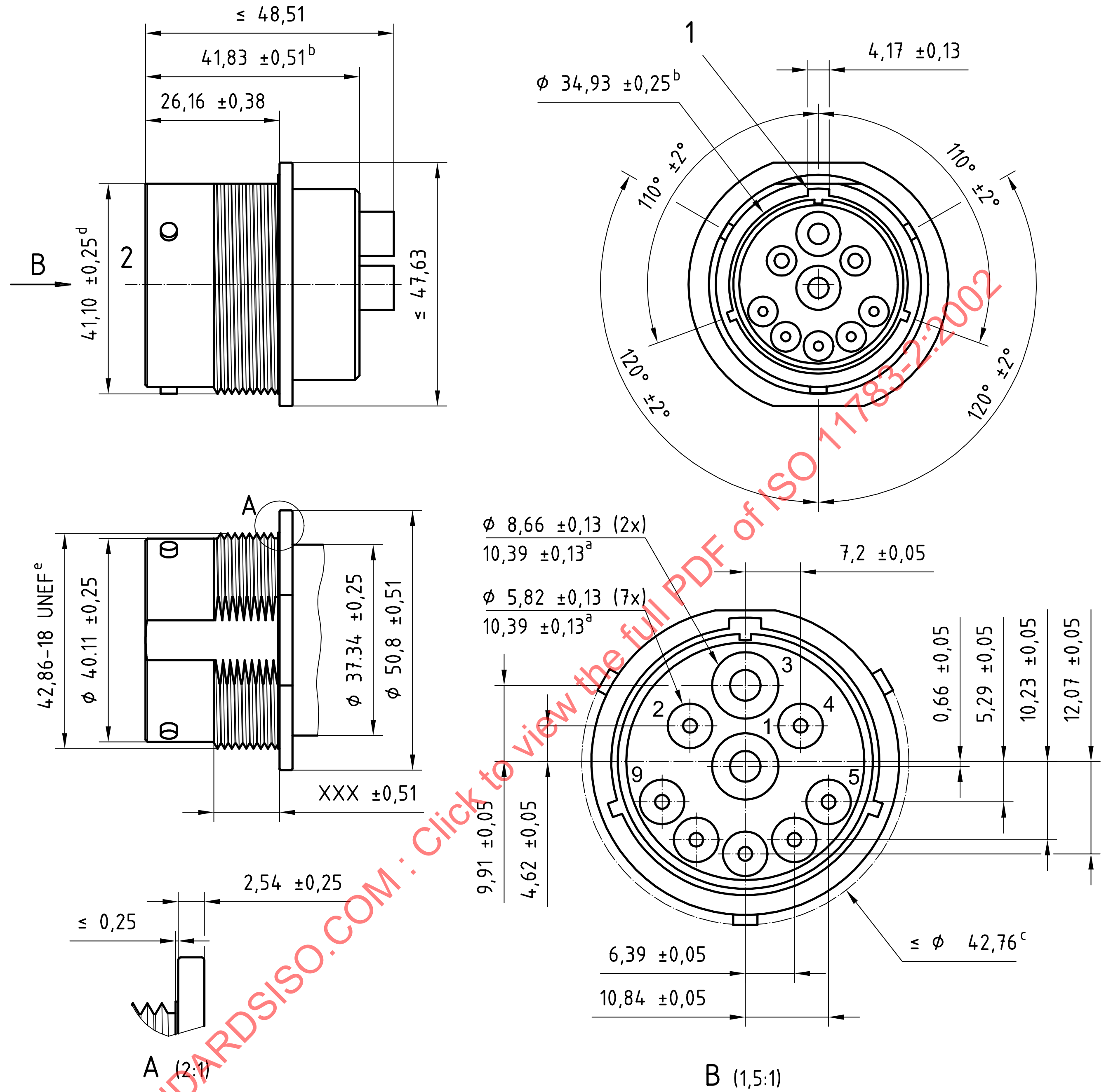
5.4.3.2 Dimensions

The implement bus breakaway receptacle shall conform to the dimensions shown in Figure 9. This tractor or implement-mounted receptacle shall contain pin contacts.

The mating plug shall have the dimensions given in Figure 10. This implement-mounted plug shall contain socket contacts.

A module containing the breakaway receptacle and an automatic switching TBC shall have the mounting dimensions given in Figure 11.

Dimensions in millimetres



Key

1 Main polarizing keyway

2 Front face

a Deep

b Shell ID

c Over bayonet

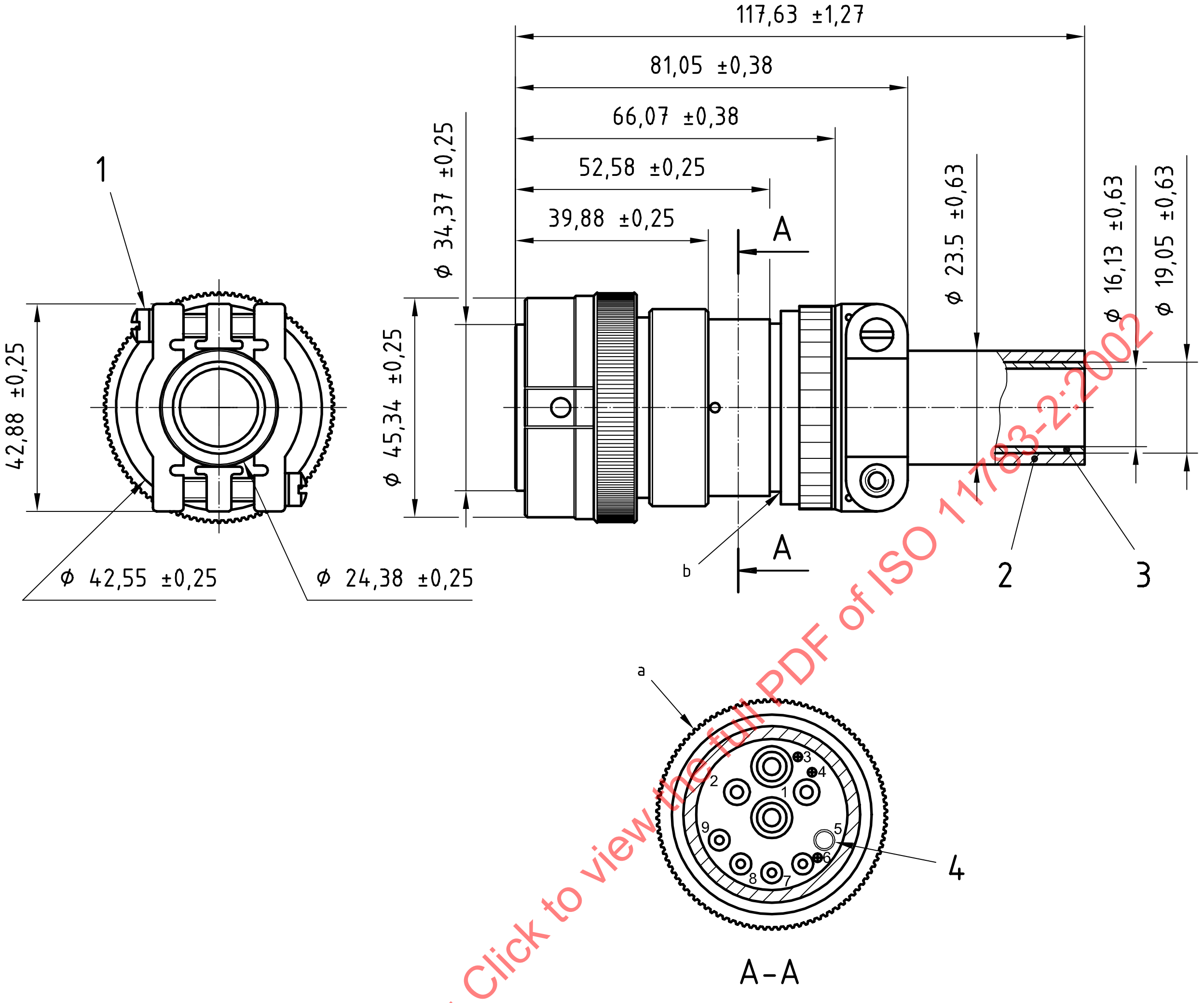
d From threads to flat

e 11/16 inches

NOTE These specifications are met by Deutsch HD34-24-91PE, HDBox-24-91P and HDB36-24-91SE [see footnote 1), Figure 8].

Figure 9 — Implement bus breakaway receptacle dimensional requirements

Dimensions in millimetres



Contact size	Min. OD	Max. OD	Wire mm² 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	2,54	3,40	1 to 0,5	16 to 20

Key

1 8-32, 27,94 LG screw

2 Outer bushing

3 Inner bushing

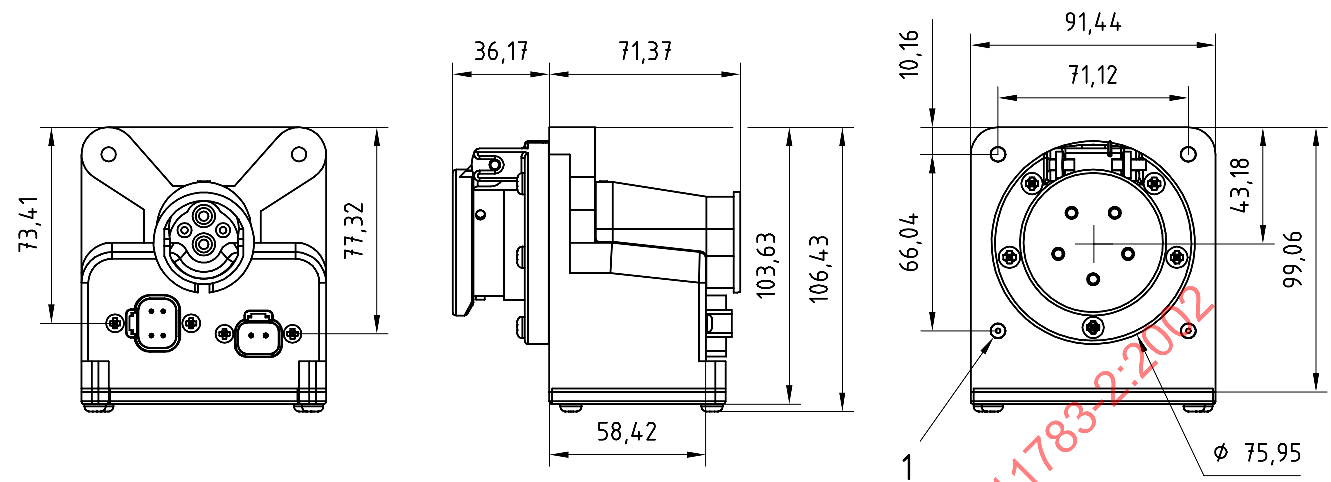
4 Sealing plug

a 47,63 ∅ max. over knurl

b 36,512-18 thread (7/16 inches)

Figure 10 — Implement bus breakaway plug dimensions

Dimensions in millimetres



Key

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

Figure 11 — Dimensions of an implement bus breakaway connector with automatic TBC

5.4.3.3 Pin allocations

The implement bus breakaway connector shall have the pin allocations shown in Table 12 (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 on the pins in the bus breakaway connector will be controlled by the Tractor ECU, specified in ISO 11783-9. Annex B of this part of ISO 11783 includes an example of a power control circuit.

Table 12 — Implement bus breakaway connector pin allocations

Pin no.	Name	Contact size [a]	Wire colour	Comments
1	GND	A	Black	Connected to chassis ground on both tractor and implement. All major power loads (lights, motors, etc.) will use this return path. Connection to chassis ground will assure there is no potential or static charge difference between the implement and tractor.
2	ECU_GND	B	Black	Circuit to be limited to providing electrical return for electronic modules mounted on implements. Connection on the tractor should be to quiet electrical point near battery ground. This pin should be electrically isolated from implement chassis ground.
3	PWR	A	Red	Power for all lights, motors, etc. that normally require significant power and tend to generate transients on the supply line. On implements that are so equipped, lighting normally powered by the ISO 1724 connector may be powered by this pin.
4	ECU_PWR	B	Red	Intended to provide a good source of positive battery power for 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 7	Power for the TBCs and which may not be used for any other purpose.
7	TBC_RTN	C	See Table 7	Provides return path for TBCs, and may not be used for any other purpose.
8	CAN_H	C	See Table 7	Data transmission line pulled toward higher voltage in dominant state.
9	CAN_L	C	See Table 7	Data transmission line pulled toward lower voltage in dominant state.

[a] Defined by Figure 10.

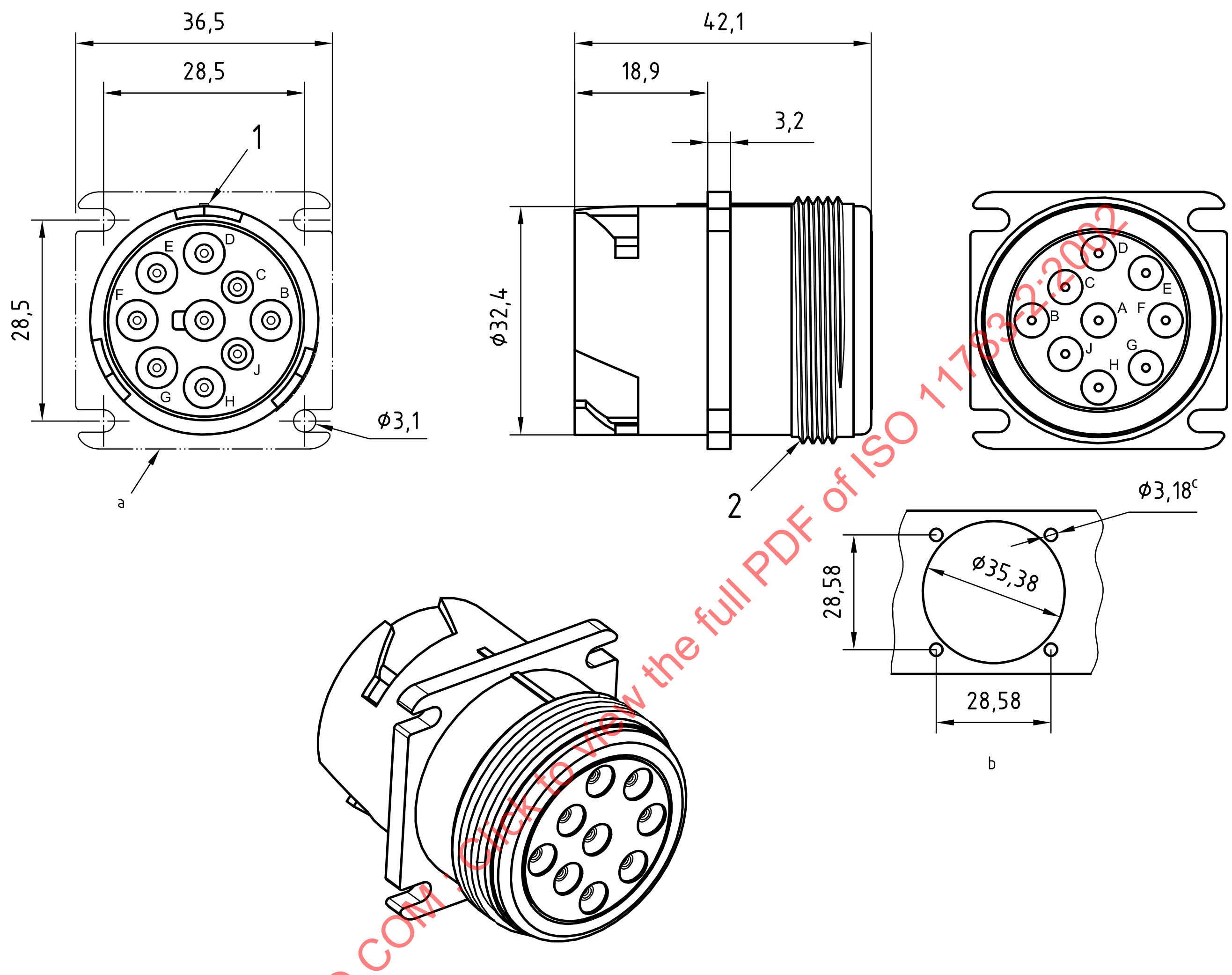
5.4.4 Diagnostic connector

The diagnostic connector should be located in the tractor cab in an easily accessed location. The connector and its associated terminals shall meet the electrical specifications of Table 11.

5.4.4.1 Receptacle dimensions

The diagnostic receptacle connector shall have the dimensions given in Figure 12.

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

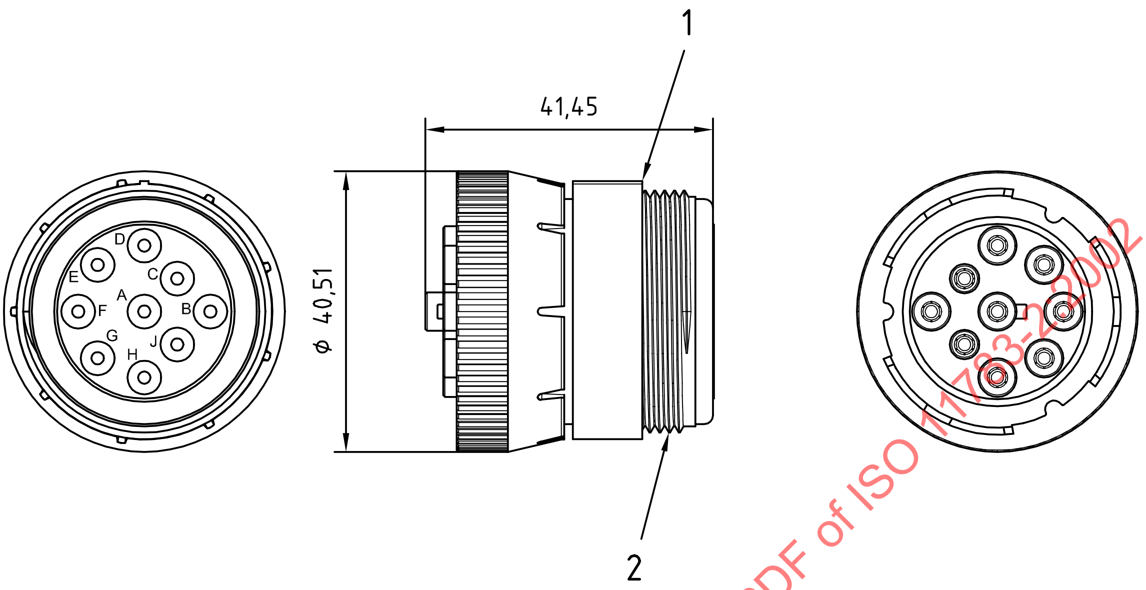
NOTE These specifications are met by Deutsch HD10-9-1939PE [see footnote 1), Figure 8].

Figure 12 — Diagnostic connector receptacle dimensions

5.4.4.2 Locking plug dimensions

The diagnostic connector locking plug shall have the dimensions given in Figure 13.

Dimensions in millimetres



Key

1 Main polarizing rib

2 Thread 1,375-18 UNEF-2A

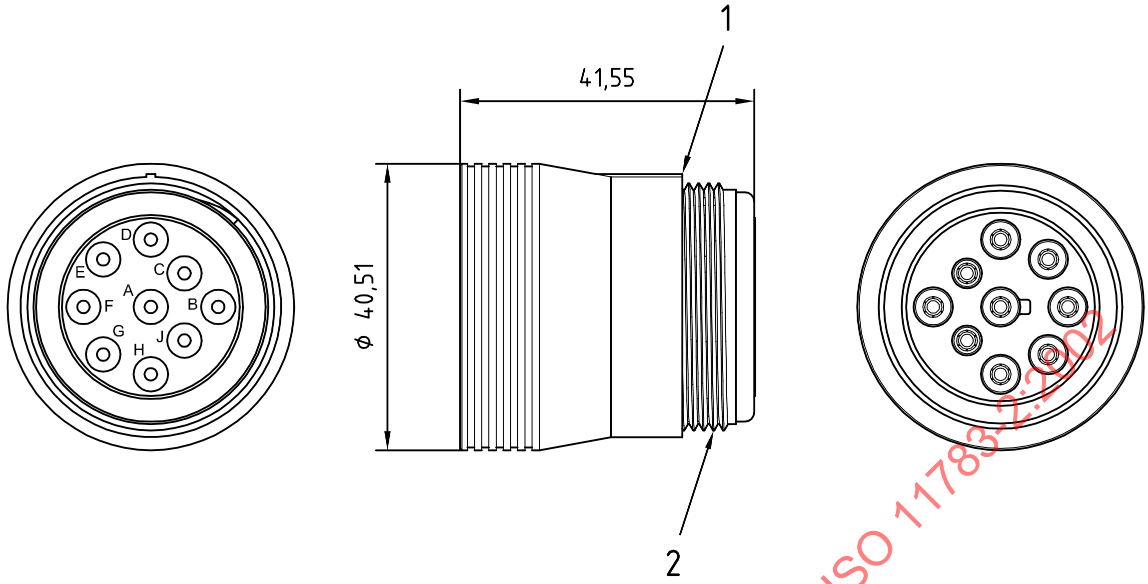
NOTE These specifications are met by Deutsch HD16-9-1939SE [see footnote 1), Figure 8].

Figure 13 — Diagnostic connector locking plug dimensions

5.4.4.3 Non-locking plug dimensions

The diagnostic connector non-locking plug shall have the dimensions given in Figure 14.

Dimensions in millimetres



Key

1 Main polarizing rib

2 Thread 1,375-18 UNEF-2A

NOTE These specifications are met by Deutsch HD17-9-1939S [see footnote 1), Figure 8].

Figure 14 — Diagnostic connector non-locking plug dimensions

5.4.4.4 Pin allocations

The diagnostic connector pins shall have the allocations given in Table 13.

Table 13 — 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 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 [3] network in an SAE diagnostic connector.

5.4.4.5 Diagnostic connector dimensions

The diagnostic connector shall have the interface dimensions given in Figure 15.

Dimensions in millimetres

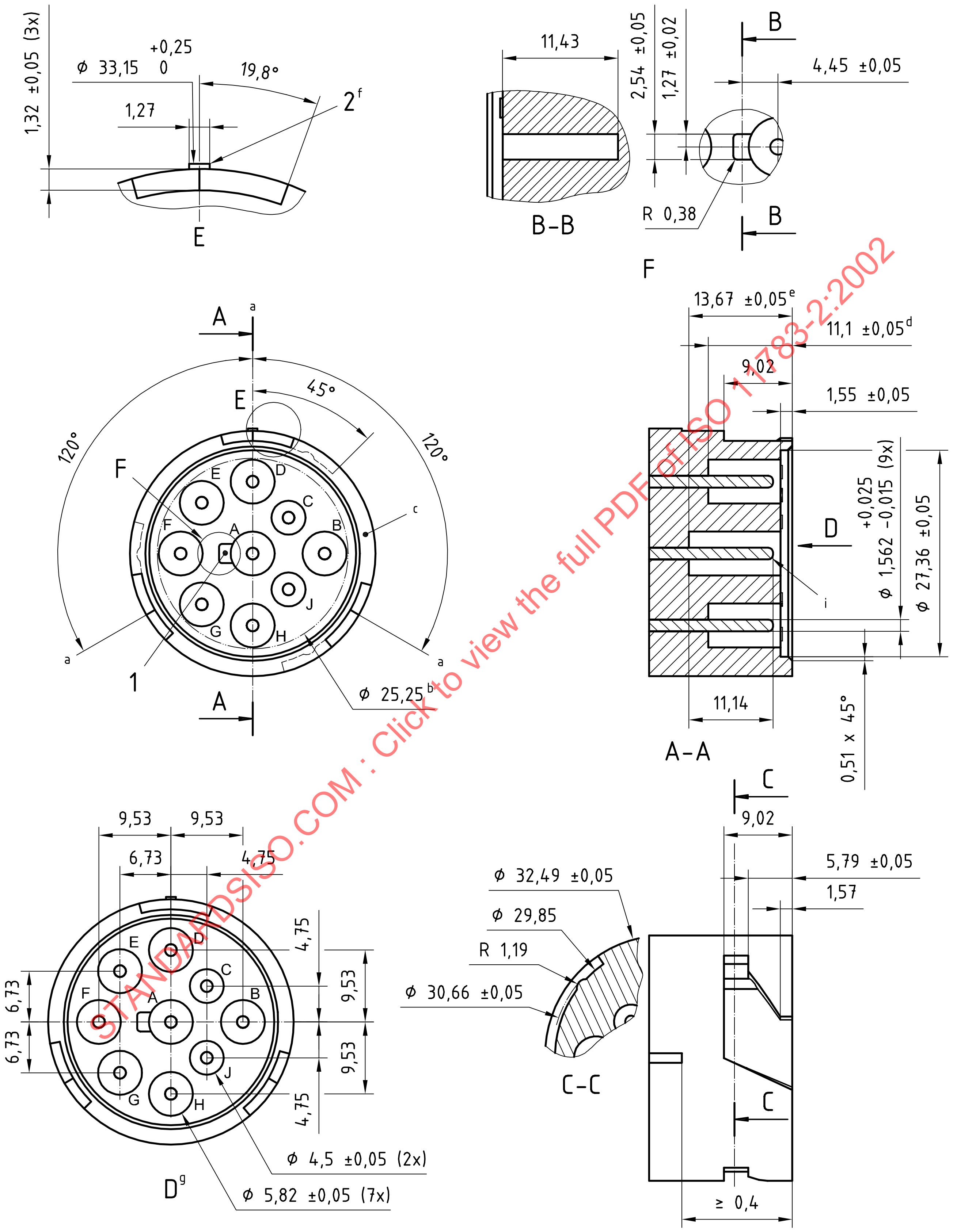
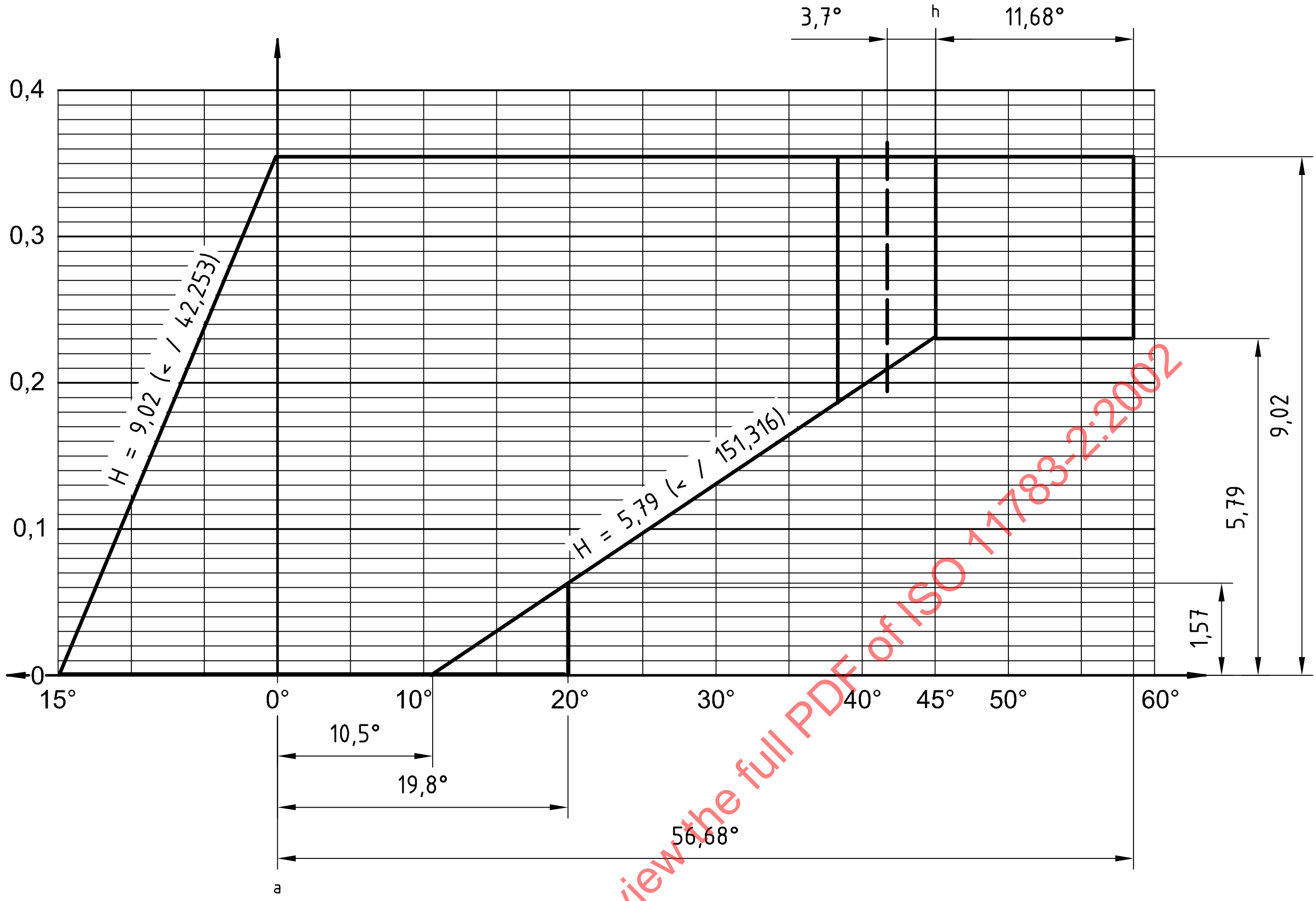


Figure 15 — Diagnostic connector interface dimensional requirements



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 ∅ 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.

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

[f] Polarizing rib is optional.

[g] Cavity locations

[h] Datum B

[i] Full radius

Figure 15 *(continued)*

6 Conformance tests

6.1 General requirements

6.1.1 Figures 16 to 21 and Equations 2 to 4 show how in principle the parameters specified in clause 5 can be verified by component manufacturers, while 6.1.2 to 6.1.6 are general requirements for these conformance tests.

6.1.2 The ground connection shall reference the ECU power ground, not TBC_RTN.

6.1.3 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.

6.1.4 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.

6.1.5 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 d.c. to 5 MHz.

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

6.2 Internal resistance

6.2.1 Measure internal resistance, R_{in}, (see Figure 3) of CAN_H and CAN_L as shown in Figure 16.

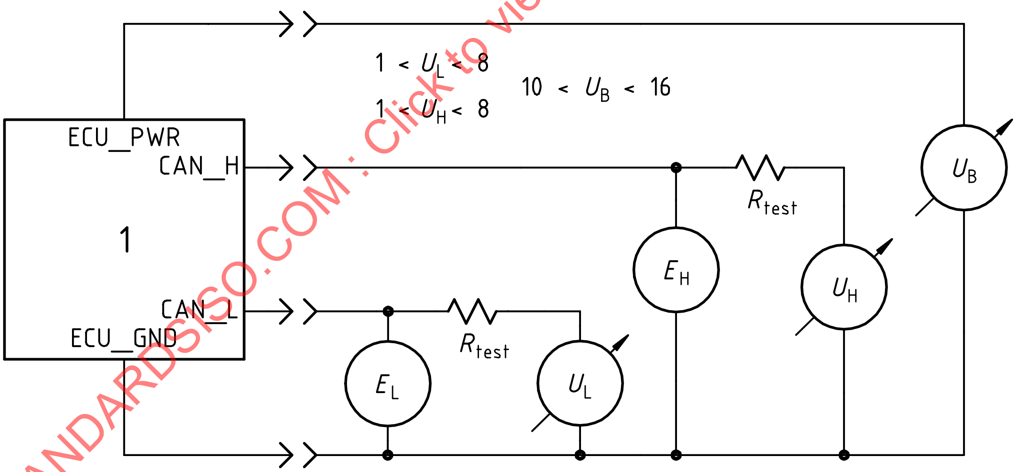
6.2.2 Carry out this test over a range for U (voltage range: –2 V to 8 V), which represents the ground offsets between nodes on a given bus segment, for the following power connection scenarios:

a) ECU connected to ground lead only;

b) ECU connected to both battery and ground leads;

c) ECU connected to neither battery lead nor ground lead;

d) ECU connected to battery lead only.



Key

1 ECU

Figure 16 — Measurement of R_{in} with ECU protocol IC set to bus idle

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

6.2.4 Determine R_{in} of CAN_H and CAN_L over the range $-2\ V \leqslant U \leqslant 8\ V$, then use the minimum value to verify that the ECU's R_{in} is above the required minimum.

6.2.5 Carry out the measurements using R_{test} = 5 kΩ, and calculate R_{in} of CAN_H or CAN_L using the following equation:

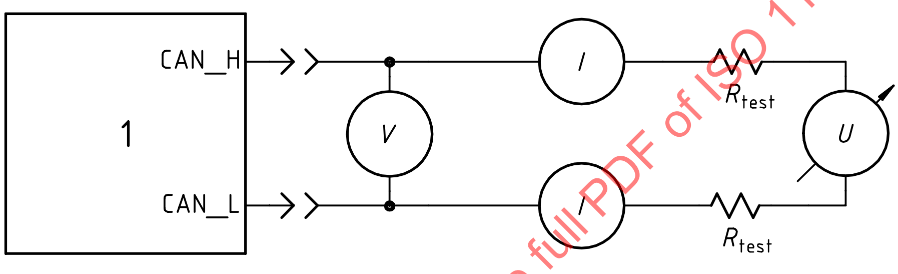
$$R_{in} = R_{test} \frac{E_n}{U_n - E_n} \tag{2}$$

where R_{in} is defined, for the recessive state and d.c. parameters, by Table 3.

6.3 Internal differential resistance

6.3.1 Measure internal differential resistance, R_{diff}, (see Figure 4) of CAN_H and CAN_L as shown in Figure 17.

6.3.2 Carry out this test over the same range for U and for the same power connection scenarios as specified in 6.2.2.



Key

1 ECU

Figure 17 — Measurement of R_{diff} with ECU protocol IC set to bus idle

6.3.3 Determine R_{diff} for U = 5 V and R_{test} = 5 kΩ during bus idle using the following equation:

$$R_{diff} = \frac{V}{I} \tag{3}$$

where the power supply shall offer sufficient isolation to the other ECU supplies so that the measurements represent the ECU impedance and not supply-leakage currents.

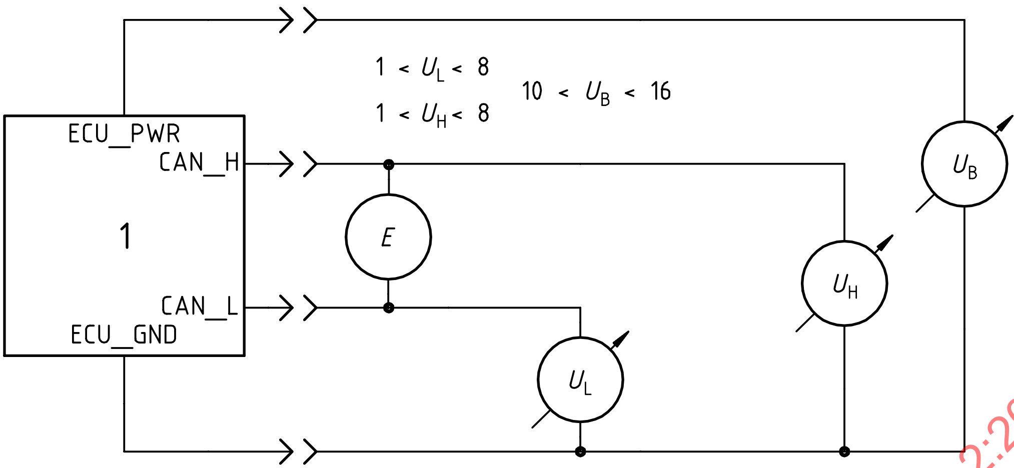
6.4 ECU recessive input threshold

6.4.1 Verify the recessive input threshold over the common mode range as shown in Figure 18.

6.4.2 Verify that the ECU is able to detect recessive bit levels by its capacity to begin, or continue, to transmit for all values of U_H and U_L in the range of 1 V to 8 V, yielding a value for E of 0,5 V (i.e. all cases where CAN_H is 0,5 V more positive than CAN_L). Measure this with power applied to the ECU.

NOTE 1 This test presupposes that the smallest differential voltage represents the more difficult condition. Should this be unknown, the user can verify using the largest differential, E of –1,0 V (i.e. where CAN_L is 1,0 V more positive than CAN_H).

NOTE 2 The 6 V value is used instead of 7 V since the maximum threshold for receiving a dominant bit is 0,5 V, as per Table 3.



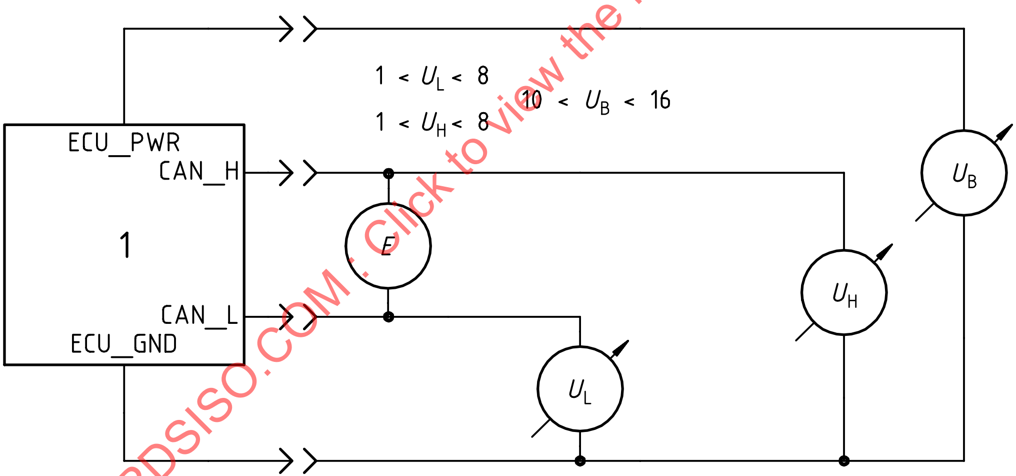
Key

1 ECU

Figure 18 — Test of input threshold for recessive bit detection

6.5 ECU dominant input threshold

6.5.1 Verify the dominant input threshold of an ECU over the common mode range as shown in Figure 19.



Key

1 ECU

Figure 19 — Test of input threshold for dominant bit detection

6.5.2 Verify that the ECU is able to detect dominant bit levels by its capacity to begin, or continue, to transmit for all values of U_H and U_L in the range of 1 V to 8 V, yielding a value for E of 0,075 V (i.e. all cases where CAN_H is 0,075 V more positive than CAN_L). Measure this with power applied to the ECU.

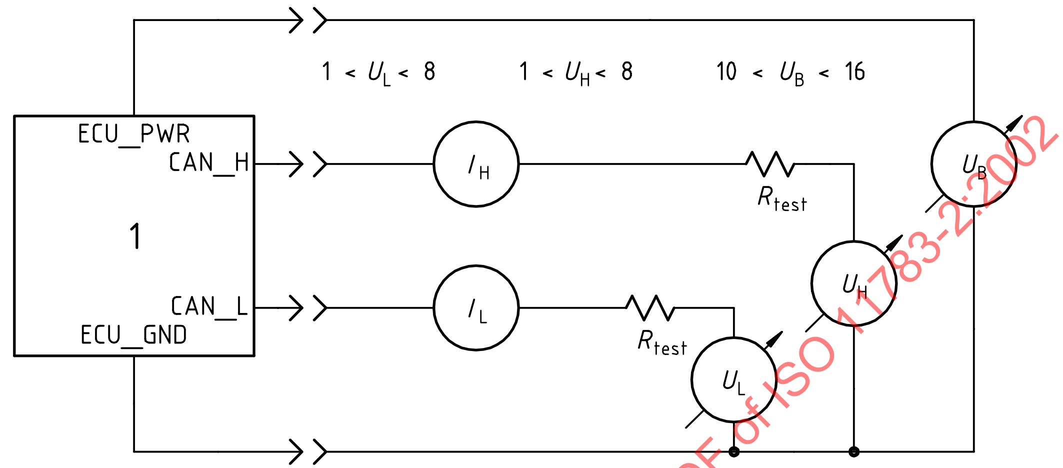
NOTE The 6 V value is used instead of 7 V since the maximum threshold for receiving a dominant bit is 1 V, as per Table 4.

6.6 ECU dominant output

6.6.1 Measure the dominant output of an ECU as shown in Figure 20. Since the differential voltage is as given by Equation 1, it may be measured differentially, as itself, between the CAN_H and CAN_L bus signal lines.

Alternatively, it may 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 this part of ISO 11783.



Key

1 ECU

Figure 20 — Measurement of V_{CAN_H} and V_{CAN_L} while the ECU sends a dominant bit

6.6.2 Measure V_{CAN_H}, V_{CAN_L}, I_H, and I_L during a dominant bit transmission. Set R_{test} at 37,5 Ω. The value of V_{diff} may be measured or calculated as desired.

6.6.3 Set the load as shown in Figure 20. The ratio of I_H to I_L shall be between 0,98 and 1,02 at 2,5 V recessive nominal voltage.

6.7 ECU internal delay time

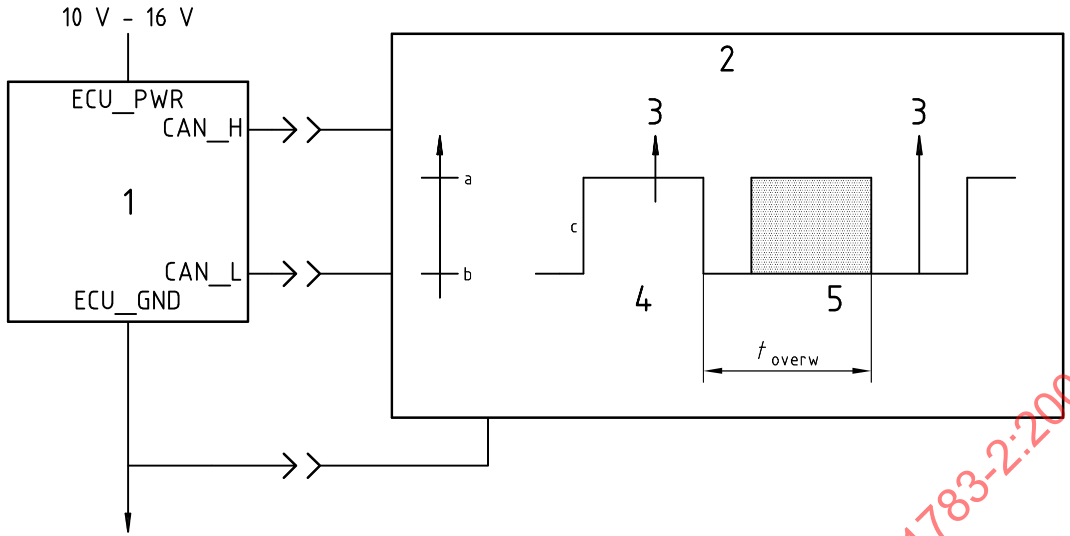
6.7.1 Measure the internal delay time of an ECU as shown in Figure 21. The test unit shown will synchronize itself to the start of the frame bit transmitted by the ECU's protocol IC. Upon detection of the first recessive identifier bit, the test unit partly overwrites this bit for the time, t_{overw}, 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).

6.7.2 Calculate t_{ECU} using the following equation:

$$t_{ECU} = t_{avail} - t_{overw} \quad (4)$$

where t_{avail} is known from the bit timing unit of the protocol IC [2,75 µs, time to the sample point from a bit edge (see 3.6)] and t_{overw} is the time found with the test unit.

6.7.3 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 one 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
a Dominant
b Recessive
c Idle

Figure 21 — Measurement of ECU internal delay time t_{ECU}

7 Bus failure and fault confinement

7.1 General

Many different bus failures can occur during normal operation that can influence operation. Any specific implementation of the physical layer should be capable of single-ended operation, as this enables the communications network to continue operating even under several fault conditions. It is also recommended that any implementation provide data integrity during switching between differential and single-ended operation.

7.2 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.

7.3 Node power or ground loss

7.3.1 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.

7.3.2 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.

7.4 Open and short failures

In principle, failures are detectable if there is a significant message destruction rate, as interpreted by the ECUs. Cases of external events that can cause failures, with the required network response, are listed and described as follows (see Figure 22).

Case 1: CAN_H interrupted between “first” or “last” ECU and a TBC
Data communications shall be able to continue between all nodes. Fault indication shall be provided by the ECU. There could be a reduction in the signal-to-noise ratio or an increase in electromagnetic emissions, or both. (The swing on CAN_H will be essentially twice that on CAN_L, thereby allowing continued operation.)

Case 2: CAN_H shorted to ECU_PWR
Data communications shall be able to continue between all nodes. Fault indication shall be provided by the ECU. There could be a reduction in the signal-to-noise ratio and an increase in electromagnetic emissions. (The system will be operating single-ended, since this will normally be recognized as a fault by the bus transceiver.)

Case 3: CAN_L shorted to GND
Data communications shall be able to continue between all nodes, because the bus voltages will be within the allowed common mode voltage range. Fault indication shall be provided by the ECU. The signal-to-noise ratio will be reduced and electromagnetic emissions could increase. Electromagnetic immunity will decrease. (The system will be operating single-ended, since this will normally be recognized as a fault by the bus transceiver.)

Case 4: CAN_H shorted to GND
Data communications shall be able to continue between nodes. Fault indication shall be provided by the ECU. The signal-to-noise ratio will be reduced and electromagnetic emissions could increase. Electromagnetic immunity will decrease. Fault indication shall be provided by the ECU. (The system will be operating single ended, since this will normally be recognized as a fault by the bus transceiver.)

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. Fault indication shall be provided by the ECU. There could 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. Fault indication shall be provided by the ECU. There could 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 shall be able to continue between all nodes. Fault indication shall be provided by the ECU. There could be a reduction in the signal-to-noise ratio because the system will be operating single-ended.

Case 8: TBC_PWR shorted to GND
Data communications shall be able to continue between all nodes. Fault indication shall be provided by the ECU. There could be a reduction in the signal-to-noise ratio as the system will be operating with only one TBC and incorrect signal levels.

Case 9: CAN_L opened to a single ECU
Data communications shall be able to continue between all nodes. Fault indication shall be provided by the ECU. There could be a reduction in the signal-to-noise ratio, as this node will be transmitting single-ended. Receiver time constants will be important in this fault condition. The receivers will need to be able to switch to single-ended receive without bit loss when this ECU begins transmitting.

Case 10: CAN_H opened to a single ECU
Data communications shall be able to continue between nodes. Fault indication shall be provided by the ECU. There could be a reduction in the signal-to-noise ratio as this node will be transmitting single-ended. Receiver time

constants will be important in this fault condition. The receivers will need to be able to switch to single-ended receive without bit loss when this ECU begins transmitting.

Case 11: CAN_H shorted to CAN-L
Data communications will not be possible.

Case 12: TBC_PWR interrupted between "supply-end" and "far-end" terminators
Data communications shall be able to continue between all nodes. Fault indication shall be provided by the ECU. There could be a reduction in the signal-to-noise ratio, since the signal lines will be loaded to ground by the TBC, which will be unpowered.

Case 13: Both bus signal lines interrupted at same location
Data communications between nodes on opposite sides of an interruption will not be 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. Fault indication shall be provided by the ECU.

Case 14: TBC_RTN interrupted between "supply-end" and "far-end" TBCs
Data communications between nodes will not be possible. Fault indication shall be provided by the ECU.

Case 15: CAN_L interrupted between "first" or "last" ECU and TBCs
Data communications shall be able to continue between nodes. Fault indication shall be provided by the ECU. There could be a reduction in the signal-to-noise ratio or an increase in electromagnetic emissions, or both. (The swing on CAN_H will be essentially twice that on CAN_L, thereby allowing continued operation.)

Case 16: Battery supply interrupted before reaching TBCs
Data communications between nodes will not be possible. Fault indication shall be provided by the ECU.

Case 17: Ground interrupted before reaching TBCs
Data communications between nodes will not be possible. Fault indication shall be provided by the ECU.

Case 18: Both CAN_H and CAN_L open to an ECU [i.e. loss of connection to bus segment (see 7.2)]
If a node becomes disconnected from its bus segment, the remaining nodes shall be able to continue communications.

Case 19: Node power loss
If a node loses power, or is in a low-voltage condition, the remaining nodes shall be able to continue communications.

NOTE See ISO 11783-5 for reaction to power supply voltage disturbances.

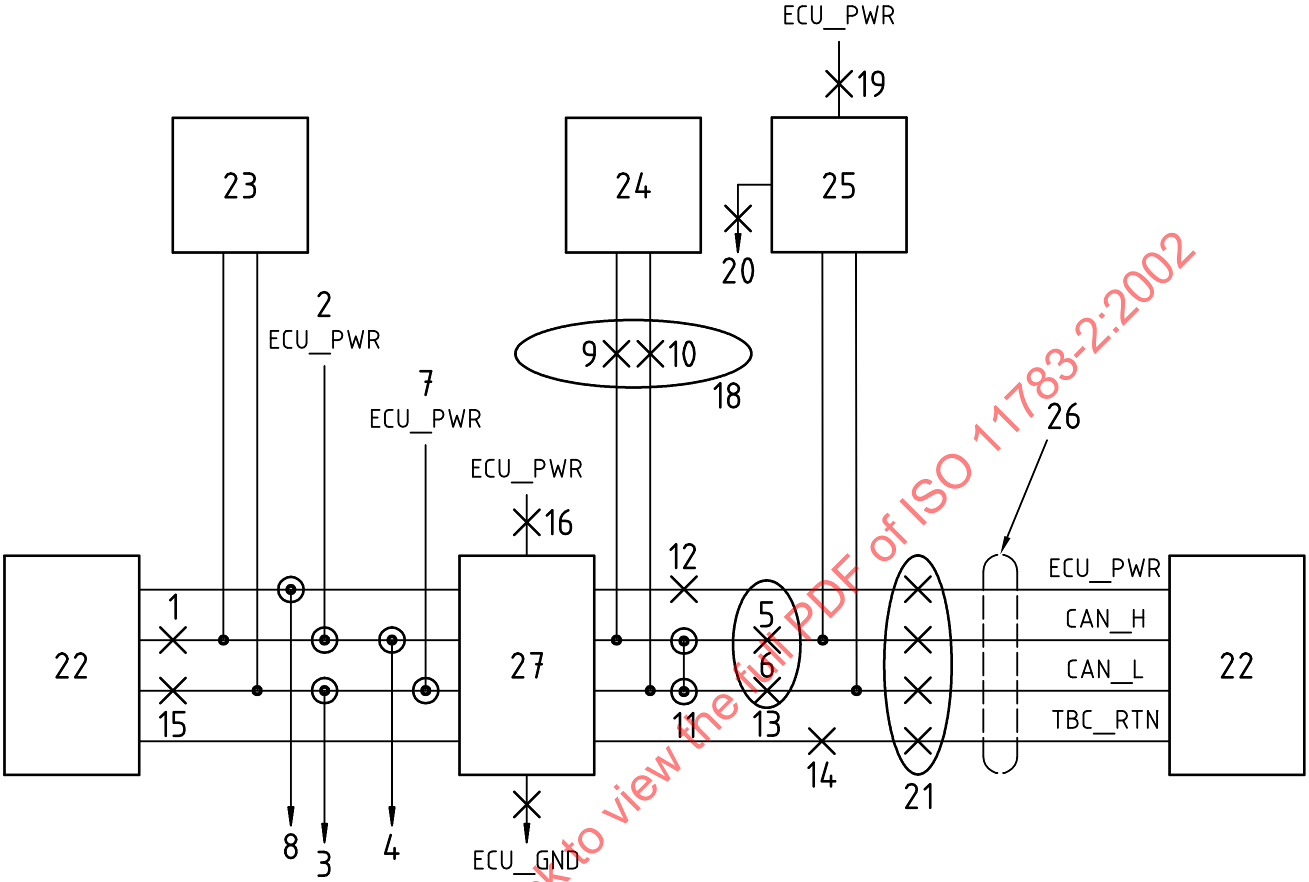
Case 20: Node ground loss
If a node loses ground, the remaining nodes shall be able to continue communications.

Case 21: Loss of one TBC
Data communications shall be able to continue between all nodes. Fault detection by any ECU will probably not be possible. There could be a reduction in the signal-to-noise ratio and an increase in electromagnetic emissions because the media will no longer be terminated properly. If both TBCs are disconnected, communications will most likely fail.

Case 22: CAN_H shorted to TBC_PWR
Data communications shall be able to continue between all nodes. Fault indication shall be provided by the ECU. There could be a reduction in the signal-to-noise ratio and an increase in electromagnetic emissions. (The system will be operating single-ended, since this will normally be recognized as a fault by the bus transceiver.)

Case 23: CAN_L shorted to TBC_PWR
Data communications shall be able to continue between all nodes. Fault indication shall be provided by the ECU. There could be a reduction in the signal-to-noise ratio and an increase in electromagnetic emissions. (The system will be operating single-ended, since this will normally be recognized as a fault by the bus transceiver.)

Case 24: 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
2 Case 2
3 Case 3
4 Case 4
5 Case 5
6 Case 6
7 Case 7
8 Case 8
9 Case 9
10 Case 10
11 Case 11
12 Case 12
13 Case 13
14 Case 14
15 Case 15
16 Case 16
17 Case 17
18 Case 18
19 Case 19
20 Case 20
21 Case 21
22 TBC
23 ECU 1
24 ECU *n* – 1
25 ECU *n*
26 Twisted quad transmission cable
27 Power for TBC_PWR and TBC_RTN

× Open circuits

⊙ Closed circuits

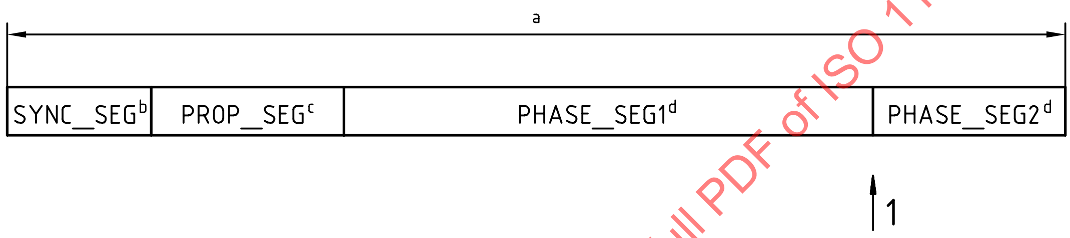
Figure 22 — Possible failures due to external events (see 7.4)

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-integrated circuits. However, it is believed this general grouping will provide insight into the operation and configuring of the circuits. Since these definitions are not constant, it is possible that two bit segments in one implementation may be defined as one in another implementation. It is therefore possible that a particular protocol controller ICs may not 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.

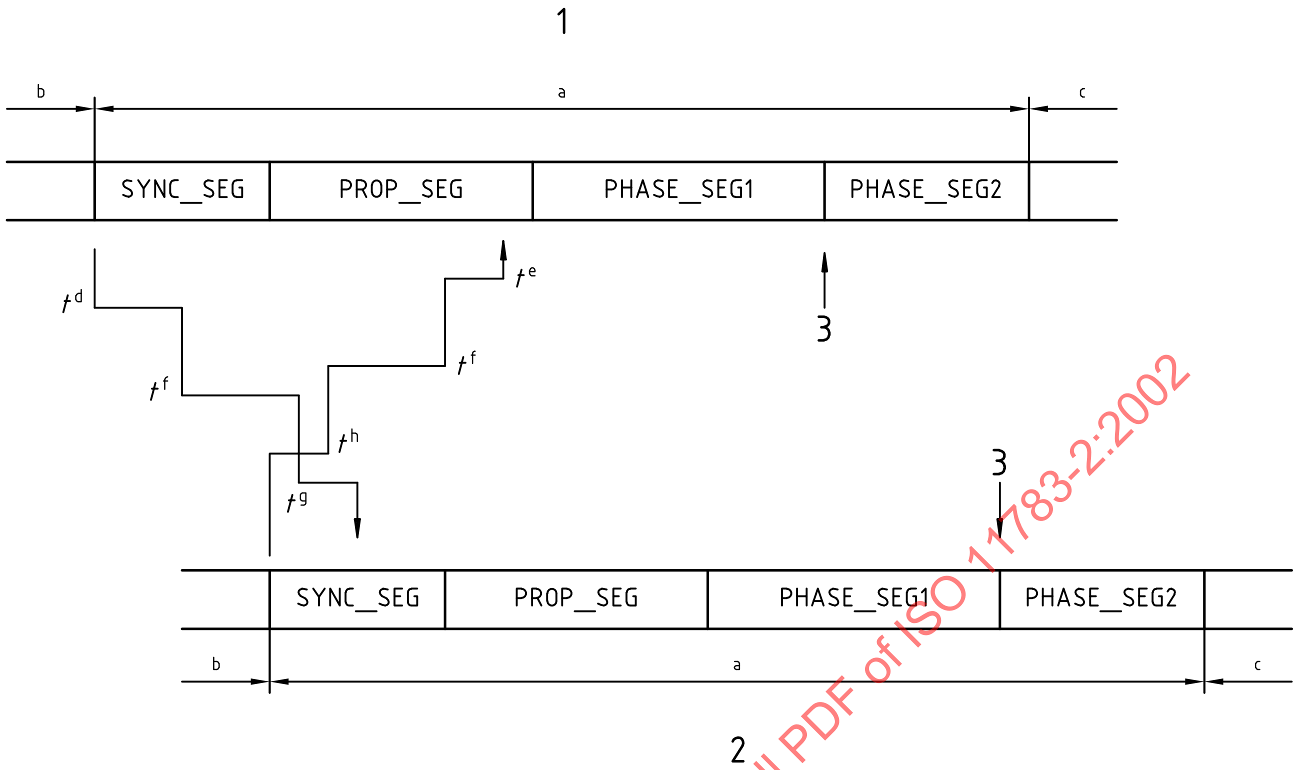
[c] Part of bit time used to compensate for physical delay times on a bus segment; delay times caused by propagation time of bus signal line and ECUs' internal delay time.

[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).



Key

1 Bit timing of ECU A
2 Bit timing of ECU B
3 Sample point
a Bit *n*
b Bit *n* – 1
c Bit *n* + 1
d Delay time, A output
e Delay time, A input
f Delay time, bus line
g Delay time, B input
h Delay time, B output

NOTE 1 The sum of output and input ECU delays, with ECU disconnected from the bus relative to the bit timing logic is critical. The important characteristic parameter of an ECU is *t*_ECU = *t*_Output + *t*_Input [where _ = ECU (A,B...)]

NOTE 2 For proper arbitration, the following condition needs to be met:

$$t_A\text{ECU} + t_B\text{ECU} + 2t_{\text{Bus line}} \leqslant t_{\text{PROP\_SEG}} + (t_{\text{PHASE\_SEG1}} - t_{\text{SJW}})$$

NOTE 3 SYNC_SEG is not taken into account, as it is possible that this segment is lost when there is a phase shift between modules.

NOTE 4 t_{SJW} is part of PHASE_SEG1 to compensate phase-errors. It is subtracted from the available time, as it is possible that a spike may cause a missynchronization with a phase shift of t_{SJW}. This means that the leading transmitting bit timing logic with respect to synchronization of ECU A must be capable of knowing the correct bus level of bit *n* at the sample point. The tolerable values of t_{ECU} strongly depend on the bit rate and line length of the bus, and the possible bit timing, indicated by the arbitration condition.

NOTE 5 The acceptable crystal tolerances of the protocol ICs and the potential for missynchronization are determined by PHASE_SEG1 and 2.

Figure A.2 — Bit-timing relationship between ECU A and B during arbitration

A.3 Synchronization

The two forms of synchronization, hard synchronization and resynchronization, obey the following rules.

a) Only one synchronization within one bit time is allowed.

b) An edge will be used for synchronization only if the value detected at the previous sample point (previously read bus value) differs from the bus value immediately after the edge.

c) Hard synchronization is performed at this edge whenever the edge is recessive to dominant.

d) All other recessive to dominant edges fulfilling a) and b) will be used for resynchronization, except that a transmitter will not perform resynchronization as a result of a recessive to dominant edge with a positive phase error if only recessive to dominant edges are used for resynchronization.

A.4 Synchronization jump width (SJW)

As a result of synchronization, PHASE_SEG1 could be lengthened, or PHASE_SEG2 shortened. The amount of lengthening or shortening of the phase buffer bit segments has an upper bound given by the SJW (⩽ PHASE_SEG1).

A.5 CAN bit timing requirements

Bit timing restrictions are needed so that devices from different suppliers are able to properly receive and interpret valid messages. Without this, under certain conditions a particular device might have unfair access to the network, and network management (system diagnostics) will be made generally much more difficult.

CAN chip suppliers recommend that all devices on a given network be programmed with the same bit timing values.

All CAN ICs divide the bit time into smaller sections defined as tq (time quantum). For certain CAN ICs, 1 tq = 250 ns (determined by oscillator frequency and baud rate prescaler).

Thus specific values are needed for the bit timing registers in each protocol controller. These numbers need to be defined to ensure that a reliable network exists for all nodes, and must be based on the best tradeoffs between propagation delay and clock tolerance (there are even differences in the definitions of the bit segments used by different manufacturers of CAN ICs).

For a 250 kbps, 40 m bus segment, the following are the recommended actual tq values for typical controller ICs (see also 3.6 and Table 1).

SYNC = 0 (sync on recessive to dominant edge only)
SAMPLE = 0 (maximum time for external delays available)

TSEG1 = 12 tq
TSEG2 = 3 tq

SJW = 2 tq (SJW is a part of TSEG1 and TSEG2)
Total bit time = TSEG1 + TSEG2 + Tsyncseg = 12 + 3 + 1 = 16 tq = 4 µs

PROP_SEG + PHASE_SEG1 = TSEG1
PHASE_SEG2 = TSEG2
SYNC_SEG = SYNC_SEG

Annex B
(informative)

Examples of physical layer circuits

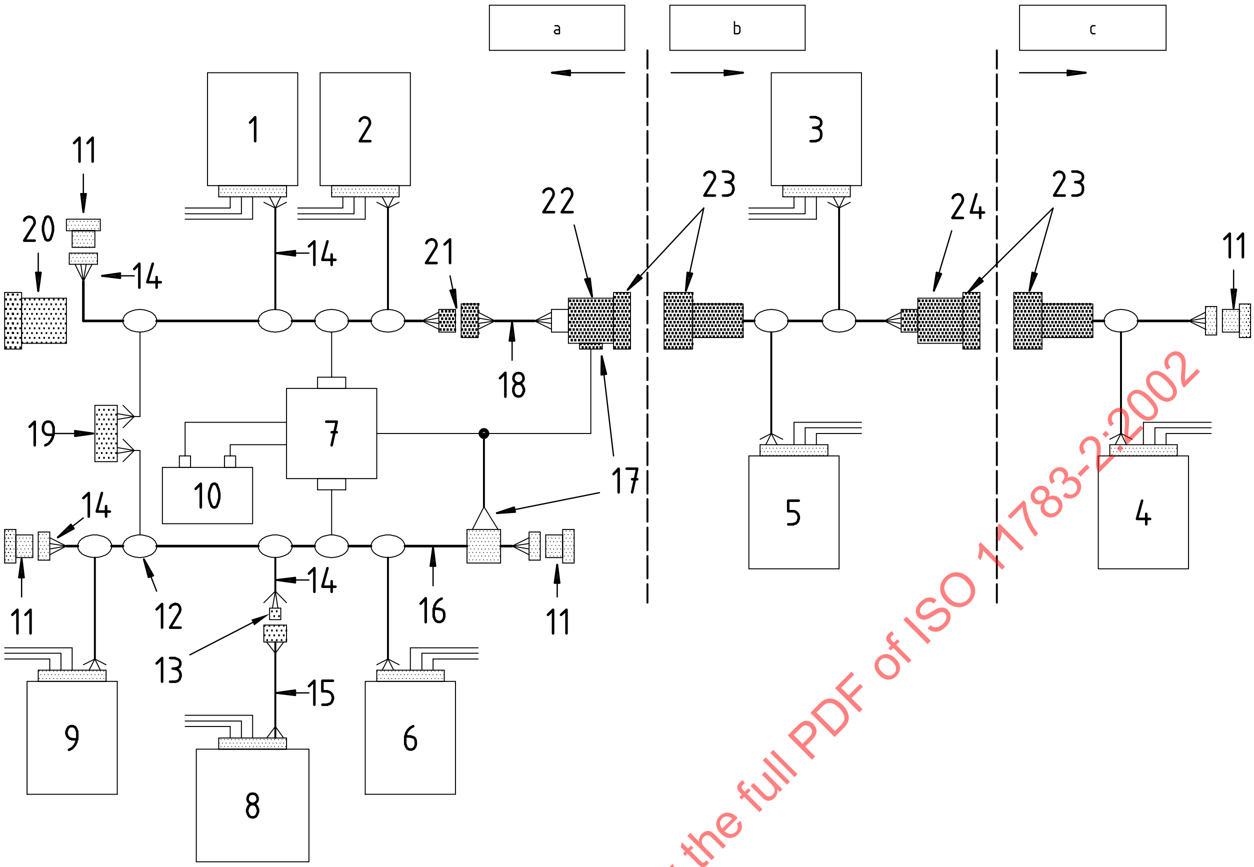
B.1 General

This annex presents a number of examples of physical layer circuits. However, a complete ECU node could need circuitry from more than one of these examples to conform with the specifications of this part of ISO 11783. Moreover, it might be necessary to invert in logic or shift in magnitude the logic levels in and out of the example circuitry in order to achieve an interface with particular protocol-controller or software designs. In the case of certain applications, it might also be acceptable to remove status indication outputs or the single-ended operation capability.

B.2 to B.9 provide, respectively, examples of network interconnections illustrating the use of connectors and the node connections to various ECUs, an integrated transmitter and receiver that uses a commercially available CAN integrated transmitter/receiver circuit, discrete transmitter and receiver circuitry that meets the electrical specifications of the physical layer contained within this part of ISO 11783, a terminating bias circuit, an automatic TBC for use with a bus breakaway connector, a connector for use on a TBC unit, and the optional stub connector used by an ECU to connect itself to the network.

B.2 Network interconnection

Figure B.1 illustrates a network interconnection with standard, optional and proprietary connectors. Also shown are a number of the possible TBC connections.



Key

1 ECU 1 (ISO 11783-2)
2 ECU 2 (ISO 11783-2)
3 ECU *n* (ISO 11783-2)
4 ECU *n* – 2 (ISO 11783-2)
5 ECU *n* – 1 (ISO 11783-2)
6 ECU z (ISO 11783-2)
7 Tractor ECU
8 ECU y (SAE J1939-11)
9 ECU x (ISO 11783-2)
10 Battery
11 TBC
12 Splice
13 Optional ECU stub connector
14 Four leads
15 Three leads
16 Tractor bus
17 Power connection to network
18 Implement bus
19 Diagnostic connector
20 Optional automatic TBC
21 Bus in-cab connector
22 Automatic TBC with network power connection
23 Implement bus breakaway connector
24 Automatic TBC
a Tractor
b Implement 1
c Implement 2

Standard connectors
Optional standard connectors
Proprietary connectors

Figure B.1 — Network interconnection

B.3 Commercial Integrated Transmitter/Receiver

Figure B.2 shows the connections of a commercially available integrated circuit with transmitter and receiver for the physical layer. This device offers adjustable slew-rate control on the output voltages. Protection circuitry is also included to limit dissipation in fault conditions.