DRAFT INTERNATIONAL STANDARD ISO/DIS 11898-3.2

ISO/TC **22**/SC **3** Secretariat: **DIN**

Voting begins on: **2005-03-14** Voting terminates on: **2005-05-16**

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION • МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ • ORGANISATION INTERNATIONALE DE NORMALISATION

Road vehicles — Controller area network (CAN) —

Part 3: **Low-speed, fault-tolerant, medium dependent interface**

Véhicules routiers — Gestionnaire de réseau de communication (CAN) —

Partie 3: Interface dépendant du support, tolérant les défaillances, à basse vitesse

ICS 43.040.15

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Foreword

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ISO 11898-3 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 3, *Electrical and electronic equipment*.

This first edition of ISO 11898-3 replaces ISO 11519-2:1994, of which it constitutes a technical revision. It also incorporates the Amendment ISO 11519-2:1994/Amd.1:1995.

ISO 11898 consists of the following parts, under the general title *Road vehicles — Controller area network (CAN)*:

— *Part 1: Data link layer and physical signalling*

— *Part 2: High-speed medium access unit*

— *Part 3: Low-speed, fault-tolerant, medium dependent interface*

— *Part 4: Time-triggered communication*

Introduction

The ISO 11898 was published first in November 1993. The standard covered the CAN data link layer as well as the high-speed physical layer.

In the reviewed and restructured ISO 11898,

- Part 1 describes the data link layer protocol as well as the medium access control;
- Part 2 specifies the high-speed medium access unit (MAU) as well as the medium dependent interface (MDI).

Part 1 and 2 are equal to ISO 11898: 1993 and will replace it.

In addition to the high-speed CAN, the development of the low speed CAN, which was originally covered by ISO 11519-2, gained new means like fault tolerant behaviour. Subject of this standard is the definition and description of requirements necessary to obtain a fault tolerant behaviour as well as the specification of fault tolerance itself. In particular it describes the medium dependent interface and parts of medium access control.

This part of ISO 11898 will replace ISO 11519-2.

Road vehicles — Controller area network (CAN) — — Part 3: Low-speed fault tolerant medium dependent interface

Part 3: **Low-speed, fault-tolerant, medium dependent interface**

1 Scope

This part of ISO 11898 specifies characteristics of setting up an interchange of digital information between electronic control units of road vehicles equipped with the controller area network (CAN) at transmission rates above 40 kBit/s up to 125 kBit/s.

The controller area network (CAN) is a serial communication protocol which supports distributed control and multiplexing.

This specification describes the fault tolerant behaviour of low-speed CAN applications, and parts of the physical layer according to the ISO/OSI layer model. The following parts of the physical layer are covered by this part of ISO 11898:

— medium dependent interface (MDI);

— physical medium attachment (PMA).

In addition parts of the physical signalling (PLS) and parts of the medium access control (MAC) are also affected by the definitions provided by this standard.

All other layers of the OSI model either do not have counterparts within the CAN protocol and are part of the user's level or do not affect the fault tolerant behaviour of the low speed CAN physical layer and therefore are not part of this part of ISO 11898.

2 Normative references

The following referenced documents are indispensable for the application 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 7498:1984, *Information processing systems — Open System Interconnection — Basic Reference Model*

ISO 7637-3, *Road vehicles — Electrical disturbance by conduction and coupling — Part 3: Passenger cars and light commercial vehicles with nominal 12 V supply voltage and commercial vehicles with 24 V supply voltage — Electrical transient transmission by capacitive and inductive coupling via lines other than supply lines*

ISO 8802-2:1989, *Information processing systems — Local area networks — Part 2: Logical link control*

ISO 11898:1993, *Road vehicles — Interchange of digital information — Controller area network (CAN) for high-speed communication*

3 Terms and definitions

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

3.1
bus
topology of a communication network, where all nodes are reached by passive links which allow transmission in both directions

3.2
bus failure
failure caused by a malfunction of the physical bus such as interruption, short circuits

3.3
bus value
one or two complementary logical values: dominant or recessive

NOTE The dominant value represents a logical “0” while the recessive represents a logical “1”. During simultaneous transmission of dominant and recessive bits, the resulting bus value will be dominant.

3.4
bus voltage
voltage of the bus line wires CAN_L and CAN_H relative to ground of each individual CAN node

NOTE V_{CAN_L} and V_{CAN_H} denote the bus voltage.

3.5
differential voltage
V_{diff}
voltage seen between the CAN_H and CAN_L lines

NOTE $V_{diff} = V_{CAN\_H} - V_{CAN\_L}$

3.6
fault-free communication
mode of operation without loss of information

3.7
fault tolerance
ability to operate under specified bus failure conditions, at least with a reduced performance

EXAMPLE Reduced signal-to-noise ratio.

3.8
transceiver loop time delay
delay time from applying a logical signal to the input on the logical side of the transceiver until it is detected on the output on the logical side of the transceiver

3.9
low-power mode
operating mode with reduced power consumption

NOTE A node in low-power mode is not to disturb communication between other nodes.

3.10
node
assembly, connected to the communication line, capable of communicating across the network according to the given communication protocol specification

3.11
normal mode
operating mode of a transceiver which is actively participating (transmitting and/or receiving) in network communication

3.12
operating capacitance
overall capacitance of bus wires and connectors seen by one or more nodes, depending on the topology and properties of the physical media

3.13
physical layer
electrical circuit realisation that connects an ECU to the bus

3.14
physical medium (of the bus)
pair of wires, parallel or twisted, shielded or unshielded

NOTE The individual wires are denoted as CAN_H and CAN_L.

3.15
receiver
device that transforms physical signals used for the transmission back into logical information or data signals

3.15
transmitter
device that transforms logical information or data signals to electrical signals so that these signals can be transmitted via the physical medium

3.16
transceiver
device that adapts logical signals to the physical layer and vice versa

4 Abbreviated terms

ACK Acknowledge

CRC Cyclic Redundancy Check

DLC Data Length Code

ECF End of Frame

IC Integrated Circuit

LLC logical link control

LPDU LLC Protocol Data Unit

LSDU LLC Service Data Unit

MAC medium access control

MPDU MAC Protocol Data Unit

MSDU MAC Service Data Unit

OSI open system interconnection

PLS physical layer signalling

RTR Remote Transmission Request

CAN Controller Area Network

CSMA Carrier Sense Multiple Access

ECU Electronic Control Unit

FCE Fault Confinement Entity

LAN Local Area Network

LME Layer Management Entity

LSB Least Significant Bit

LS-MAU Low-Speed Medium Access Unit

MDI Medium Dependent Interface

MSB Most Significant Bit

NRZ Non Return-to-Zero

PL Physical Layer

PMA Physical Medium Attachment

SOF Start of Frame

5 OSI reference model

According to the OSI reference model, shown in Figure 1, the CAN architecture represents two layers:

— data link layer,

— physical layer.

This part of ISO 11898 describes physical layer of a fault-tolerant, low-speed CAN transceiver. Only a few influences on the data link layer are given.

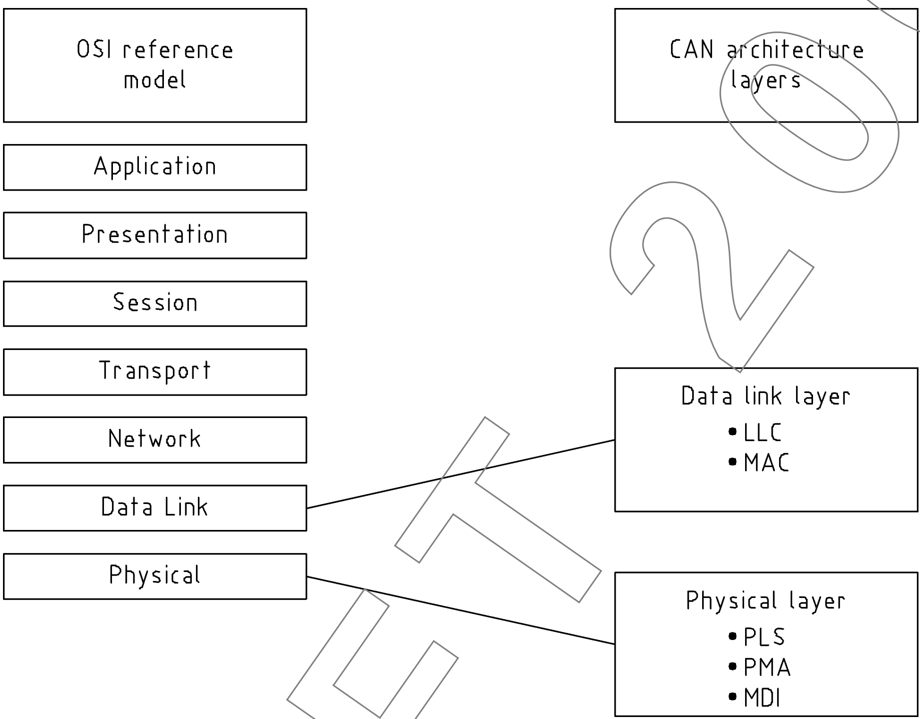


Figure 1 — OSI reference model/CAN layered architecture

6 MDI specification

6.1 Physical medium

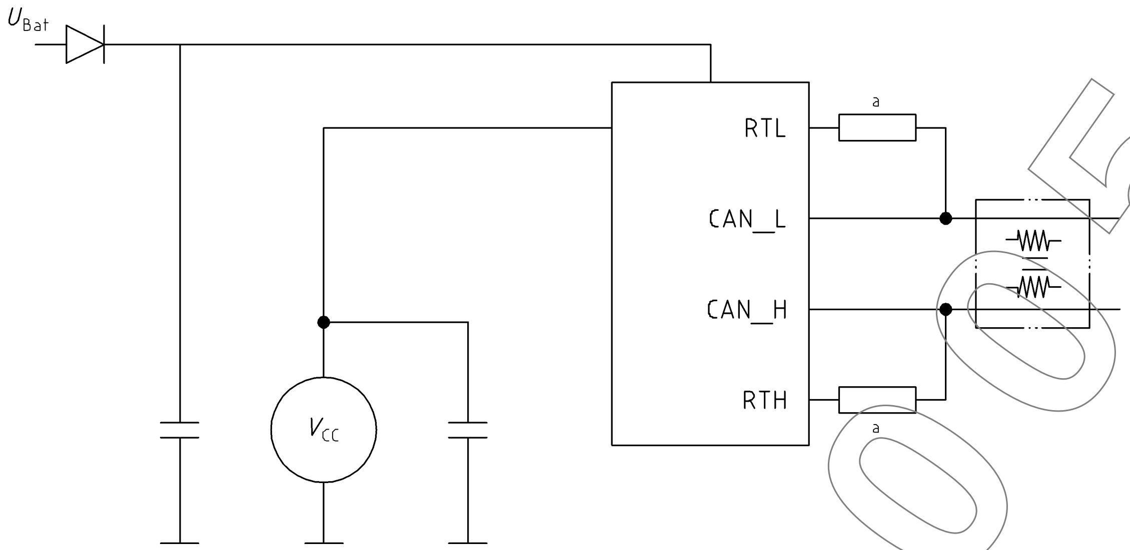
6.1.1 General

The physical medium used for the transmission of CAN broadcasts shall be a pair of parallel (or twisted) wires, shielded or unshielded, depending on EMC requirements. The individual wires are denoted as CAN_H and CAN_L. In the dominant state, CAN_L has a lower voltage level than in the recessive state and CAN_H has a higher voltage level than in the recessive state.

6.1.2 Node bus connection

The two wires CAN_H and CAN_L are terminated by a termination network, which shall be realised by the individual nodes themselves. The overall termination resistance of each line should be W 100 Ω. However, the termination resistor’s value for a designated node should not be below 500 Ω, due to the semiconductor manufacturer's constraints. To represent the recessive state CAN_L is terminated to V_{CC} and CAN_H is terminated to GND.

Figure 2 illustrates the normal termination of a designated bus node.



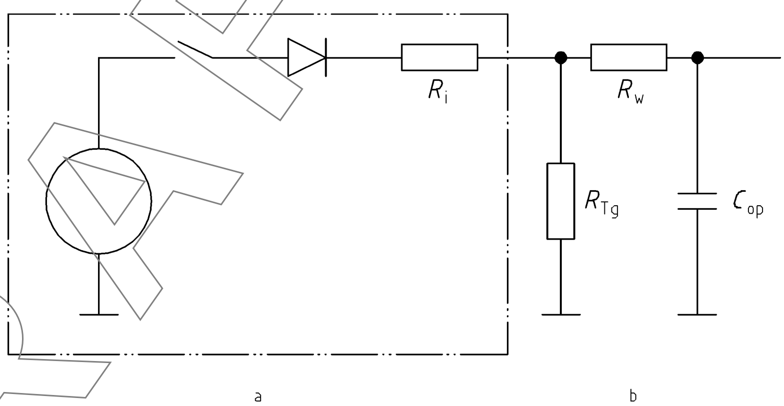
a Optional.

Figure 2 — Termination of a single bus node

In Figure 2 the termination resistors are denoted as optional. That means that under certain conditions not all nodes need an individual termination, if the requirements of proper overall termination are fulfilled.

6.1.3 Operating capacitance

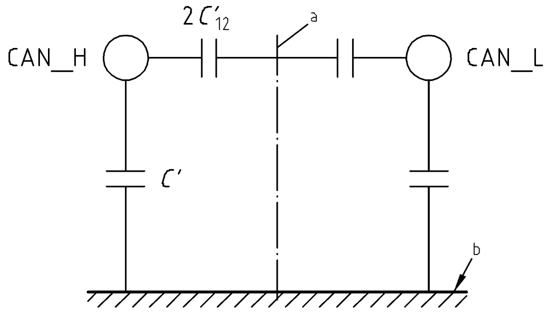
The following specifications are valid for a simple wiring model which in general is used in automotive applications. It consists of a pair of twisted copper cables which are connected in a topology described in Clause 6.4.1. The following basic model shown in Figures 3 and 4 is used for the calculations.



a Driver.

b Wire.

Figure 3 — Substitute circuit for bus line



a Symmetric axis
b Ground

Figure 4 — Operating capacitance in relation to network cable length, l

The operating capacitance is calculated using Equation 1:

$$C_{OP} = l(C' + 2C'_{12}) + n\, C_{node} + k\, C_{plug} \tag{1}$$

where

Cop is the operating capacitance defined in 3.12

C' is the capacitance between the lines and ground, referring to the wire length in metres (m);

C'_{12} is the capacitance between the two wires (which is assumed to be symmetrical), referring to the wire length in metres (m);

C_{node} is the capacitance of an attached bus node seen from the bus side;

C_{plug} is the capacitance of one connecting plug;

l is the overall network cable length;

n is the number of nodes;

k is the number of plugs.

EXAMPLE A typical value for the operating capacitance referring to the overall network cable length in respect to the exemplary network described below is given by

C_{OPtyp} = 120 [pF/m]

6.1.4 Medium timing

The maximum allowed operating capacitance is limited by network inherent parameters such as

— overall termination resistance, R_{term},

— wiring model and topology,

— communication speed,

— sample point and voltage thresholds,

— ground shift, etc.

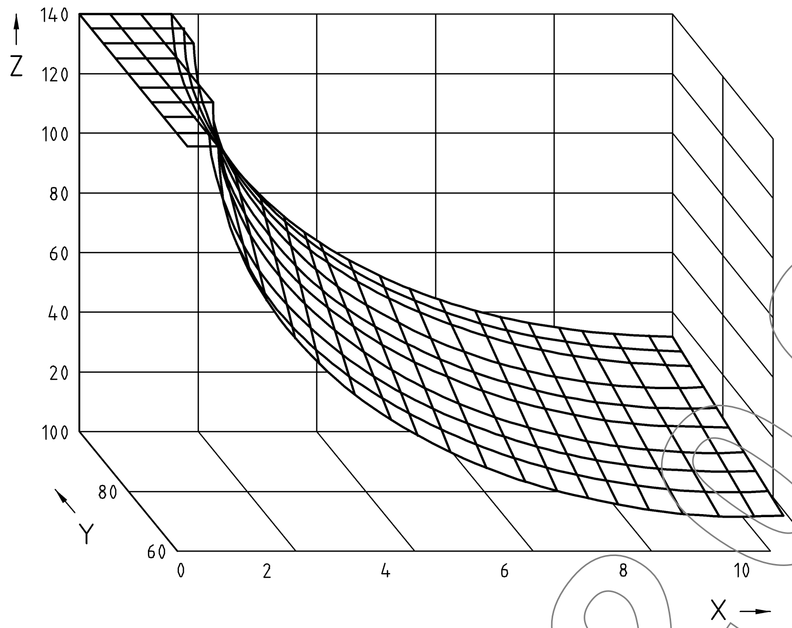
The following equation provides a method for estimating the maximum allowed operating capacitance:

$$R_{\text{term}} \times C_{\text{OP}} = \tau_{\text{C}} = \frac{\frac{s_{\text{p}}}{f_{\text{bit}}} - 2t_{\text{l}} - t_{\text{sync}}}{\ln\left(V_0 + V_{\text{GND}}\right) - \ln V_{\text{th}}} \qquad (2)$$

where

R_{term}	is the overall network termination resistor (approx. 120 Ω);
C_{OP}	is the operating capacitance according to Equation 1;
τ_{C}	is the time constant of bus wire;
s_{p}	is the sampling point within a bit, in percent (%);
f_{bit}	is the bit frequency or physical communication speed in bits per second (bit/s);
t_{l}	is the overall loop delay time of a transceiver device;
t_{sync}	is the maximum possible synchronisation delay between two nodes;
V_0	is the maximum voltage level of a bus line (approx. 5 V);
V_{th}	is the sampling voltage threshold (approx. < 0,5 V);
V_{GND}	is the maximum allowed effective ground shift (max. 3 V)

The calculation of τ_{C} leads to the graph shown by Figure 5.



Key

X τ_C, µs

Y sample point, %

Z communication speed, kBit/s

Conditions: V_0 is assumed to be 5 V;

V_{th} is assumed to be 0,2 V;

no ground shift is assumed;

the total internal loop delay is assumed to be 1,5 µs.

Figure 5 — Maximum communication speed versus τ_C and the sample point

As an over the thump rule the possible maximum time constant τ_C can be calculated using Equation 3.

$$\tau_C \le \frac{1}{6 f_{bit}} \quad (3)$$

where

τ_C is the time constant of bus wire

f_{bit} denotes the bit frequency or physical communication speed, in bit/s.

6.2 Physical signalling

The bus line can have one of the two logical states: *recessive* or *dominant* (see Figure 6). To distinguish between both states, a differential voltage is used:

$$V_{diff} = V_{CAN\_H} - V_{CAN\_L} \quad (4)$$

where

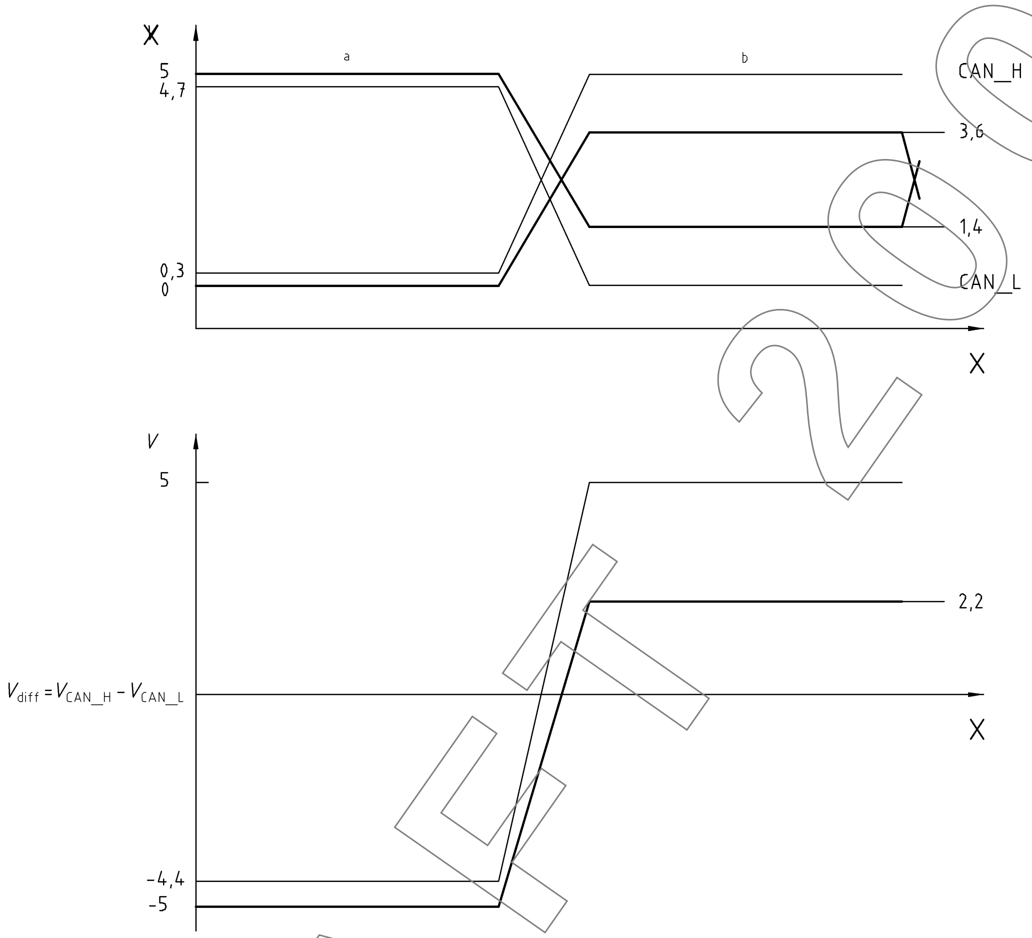
V_{diff} is the differential voltage;

V_{CAN_H} is the voltage level of the CAN_H wire;

V_{CAN_L} is the voltage level of the CAN_L wire.

In the *recessive* state, the CAN_L line is fixed to a higher voltage level than the CAN_H line. In general, this leads to a negative V_{diff}. The recessive state is transmitted during bus idle or during "recessive" bits.

The dominant state is represented by a positive V_{diff}, which means, that the CAN_H line is actively fixed to a higher voltage level and the CAN_L line is actively fixed to a lower voltage level. The *dominant* state overrides the *recessive* state and is transmitted during "*dominant*" bits.



a Recessive.

b Dominant.

Figure 6 — Physical bit representation

6.3 Electrical specification

6.3.1 Electrical boundary voltages for ECU

The parameters given in Table 1 should be valid for maximum node connecting voltages.

Table 1 — Ratings of $V_{\text{CAN\_L}}$ and $V_{\text{CAN\_H}}$ of ECU in 12 V and 42 V systems

Notation		Voltage V min.[a]	Voltage V max.
12V system	$V_{\text{CAN\_L}}$	– 27	40
12V system	$V_{\text{CAN\_H}}$	– 27	40
42V system	$V_{\text{CAN\_L}}$	– 58	58
42V system	$V_{\text{CAN\_H}}$	– 58	58

NOTE No destruction of transceiver occurs. The transceiver should not affect communication on the net. The voltage levels may be applied without time restrictions.

[a] Possible if V_{GND} is disconnected or during jump start conditions.

The common mode voltage is:

$$V_{\text{COM}} = \frac{V_{\text{CAN\_L}} + V_{\text{CAN\_H}}}{2} \qquad (5)$$

where

V_{COM} is the common mode bus voltage;

$V_{\text{CAN\_L}}$ is the CAN_L wire voltage level;

$V_{\text{CAN\_H}}$ is the CAN_H wire voltage level.

The common mode voltage for an undisturbed system in normal mode shall be within the ratings specified in Table 2.

Table 2 — Common mode voltage, for undisturbed system in normal mode

Parameter	Notation	Unit	Value min.	Value nom.	Value max.
Common mode voltage	V_{COM}	V	– 1	2,5	6

6.3.2 DC parameters for physical signalling

Table 3 — DC parameters for recessive state of ECU connected to termination network via bus line

Parameter	Notation	Unit	Value		
			min.	nom.	max.
Bus voltage	V_{CAN_L}	V	V_{CC} – 0,3[a]	—	—
	V_{CAN_H}	V	—	—	0,3
Differential bus voltage[b]	V_{diff}	V	– V_{CC}	—	– V_{CC} + 0,6

[a] V_{CC} is a nominal 5 V.

[b] The differential voltage is determined by the input load of all ECUs during the recessive state. Therefore, V_{diff} decreases slightly as the number of ECUs connected to the bus increases.

Table 4 — DC parameters for dominant state of ECU connected to termination network via bus line

Parameter	Notation	Unit	Value		
			min.	nom.	max.
Bus voltage	V_{CAN_L}	V	—	—	1,4
	V_{CAN_H}	V	V_{CC} – 1,4[a]	—	—
Differential bus voltage	V_{diff}	V	V_{CC} – 2,8	—	V_{CC}

[a] V_{CC} is nominal 5 V.

Table 5 — DC parameters for low-power mode of ECU connected to termination network via bus line

Parameter	Notation	Unit	Value		
			min.	nom.	max.
Bus voltage	V_{CAN_L}	V	5	—	—
	V_{CAN_H}	V	—	—	1

6.3.3 DC parameters for comparators

Table 6 — DC threshold of dominant recessive detection in normal mode and vice versa

Parameter	Notation	Unit	Value		
			min.	nom.	max.
Single-ended receiver	V_{CAN_L}	V	2,5	—	3,9
	V_{CAN_H}	V	1,5	—	2,3
Differential bus receiver	V_{thDIFF_N}	V	– 3,9	—	– 2,5
CAN_L to BAT detector	$V_{thLxBAT\_N}$	V	– 6,5	—	– 8,0
CAN_H to BAT detector	$V_{dthHxBAT\_N}$	V	– 6,5	—	– 8,0

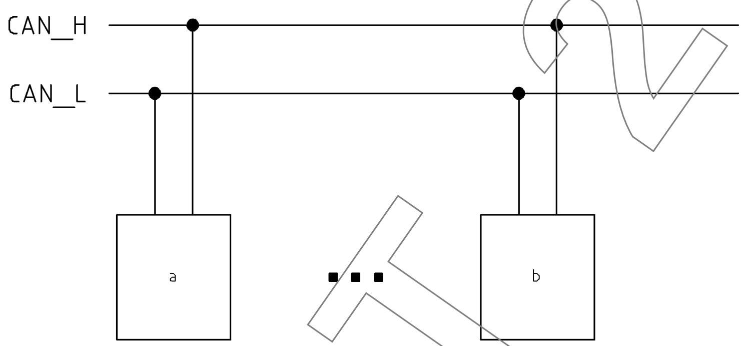
Table 7 — DC threshold for wake-up detection from low-power mode

Parameter	Notation	Unit	Value		
			min.	nom.	max.
Wake-up threshold	$V_{\text{th(wake)L}}$	V	2,5	3,2	3,9
	$V_{\text{th(wake)H}}$	V	1,1	1,8	2,5
Wake-up threshold difference	$\Delta V_{\text{th(wake)}}$	V	0,8	1,4	—

6.4 Network specification

6.4.1 Network topology

Individual CAN nodes may be connected to a communication network either by a bus or star topology (see Figures 7 or 8).



Key

a node *a*

n node *n*

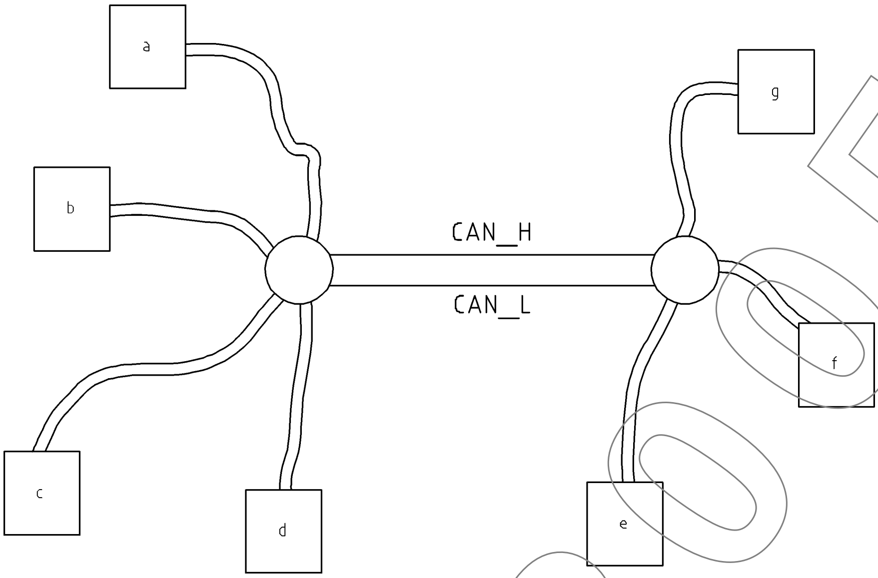
Figure 7 — Connecting model — Bus structure with stub lines

However, for any connecting concept, the following requirements shall be fulfilled, in order to provide the fault-tolerant means.

— The overall network termination resistor shall be in a range of about 100 Ω (but not less than 100 Ω). For a detailed description of the termination concept, refer to 6.4.2.

— The maximum possible number of participating nodes should not be less than 20 (at 125 kBit/s and a overall network length of 40 m). The actual number of nodes will vary according to communication speed, capacitive network load, overall line length, network termination concept, etc.

— To provide a maximum communication speed of 125 kBit/s, the overall network length should not exceed 40 m. However, it is possible to increase the overall network length by reducing the actual communication speed.



Key

n node *n*

NOTE Each number identifies a particular node.

Figure 8 — Connecting model — Star-point structure

For a star-point configuration, there are some additional constraints given by:

— the individual nodes are connected to one ore more “passive” star points, which are themselves connected via a normal bus structure;

— even some connecting lines (star connector to node) might be extended to several metres; no stub lines are recommended;

— both the overall network length (all star connection line lengths added) and the maximum node-to-node distance affect the network communication.

EXAMPLE For most of the exemplary values given in this part of ISO 11898, the following network topology is used:

— star point connection method with two star points;

— the network is terminated with an overall resistance of 100 Ω;

— the node number is about 20;

— the overall network length is about 40 m;

— the maximum node-to-node distance is 20 m;

— the wire capacitance related to the length is about 120 pF/m.

6.4.2 Network termination

6.4.2.1 General

The recessive bus level specified in 6.2 is maintained by the bus termination. The dominant bus level overrides actively this recessive bus state. The transition between the dominant to recessive level is done by the termination, too. However, there is no designated termination network or circuit. Moreover, the termination is attached to most of the participating nodes.

6.4.2.2 Termination modes

In principle, there are two major termination modes:

a) normal mode termination;

b) low-power mode termination.

Due to the failure management described in Clause 8.2 the actual bus termination depends on the actual failure mode a transceiver operates in.

To represent the *recessive* state, the CAN_H line is terminated to ground (using a pull-down resistor) in either modes (normal and low-power).

In normal mode, the CAN_L line is terminated to V_{CC}, using a pull-up resistor. In low power mode, however, the CAN_L line is terminated to V_{Bat} by transceiver internal switching of the “high” end of the termination resistor.

6.4.2.3 Termination concept

The termination is provided by connecting the CAN_L line to the RTL pins of the transceiver devices and the CAN_H line to the RTH pins (see Figure 2).

When connecting the termination pins the following requirements have to be considered:

— The overall network termination resistor of one line (all parallel resistors connected to RTL or RTH pins) shall be about 100 Ω, due to in circuit current limitations and CAN voltages.

— A single resistor connected to an individual transceiver device should not be below 500 Ω, due to in circuit current limitations.

It is recommended, that every node provides its own termination resistors. However this is note a strict requirement. A not well terminated node might be sensitive to false wake-up signals if a broken line error had occurred.

7 Physical medium failure definition

7.1 Physical failures

The physical failures specified in Table 8 shall be treated by a fault-tolerant transceiver device.

7.2 Failure events

7.2.1 General

The transceiver device does not react to the physical failures, but to the way they influence the bus wire system. These failure images are called "failure events". They can be divided into two major groups:

— power failures;

— bus wire failures.

In general, the detection of failure events causes the transceiver device to perform an internal state switch.

7.2.2 Power failures

If one node loses Ground connection (or is affected by a Ground shift greater than the defined limitations of ± 1,5 V), or a proper voltage supply (either V_{CC} or V_{Bat}), this failure is treated as power failure.

7.2.3 Bus wire failures

Not all bus wire failures (open and short failures in Table 8) can be distinguished by the transceiver device. Hence, a reduced set of failure events is specified (see Table 9).

Table 8 — Physical failures

Description of bus failure	Behaviour of network
One node becomes disconnected from the bus[a]	The remaining nodes continue communicating.
One node loses power[b]	The remaining nodes continue communicating, at least with reduced signal-to-noise ratio.
One node loses Ground[b]	The remaining nodes continue communicating, at least with reduced signal-to-noise ratio.
Open and short failures:	All nodes continue communicating, at least with reduced signal-to-noise ratio.
CAN_L interrupted	All nodes continue communicating, at least with reduced signal-to-noise ratio.
CAN_H interrupted	All nodes continue communicating, at least with reduced signal-to-noise ratio.
CAN_L shorted to battery voltage[c]	All nodes continue communicating, at least with reduced signal-to-noise ratio.
CAN_H shorted to Ground[c]	All nodes continue communicating, at least with reduced signal-to-noise ratio.
CAN_L shorted to Ground[ce]	All nodes continue communicating, at least with reduced signal-to-noise ratio.
CAN_H shorted to battery voltage[c]	All nodes continue communicating, at least with reduced signal-to-noise ratio.
CAN_L wire shorted to CAN_H wire[d]	All nodes continue communicating, at least with reduced signal-to-noise ratio.
CAN_L and CAN_H interrupted at the same location[a]	No operation within the complete system. Nodes within the remaining subsystems might continue communicating.

a Due to the distributed termination concept, these failures shall not affect the remaining communication and are not detectable by a transceiver device. Hence they are not treated and are not part of this standard.

b Both failures are treated together as power failures.

c All short-circuit failures might occur in coincidence with a Ground shift (seen between two nodes) in a range of ± 1,5 V.

d This failure is covered by the detection of the failure, CAN_L shorted to Ground.

e These failures do not cause any corrective action within the transeiver and are tolerated implicity.

Table 9 — Failure events

Event name[a]	Description
CANH2UBAT	Failure that typically occurs when the CAN_H wire is short circuited to the battery voltage V_{Bat}.
CANH2VCC	Failure that typically occurs when the CAN_H wire is short circuited to the supply voltage V_{CC}.
CANL2UBAT	Failure that typically occurs when the CAN_L wire is short circuited to the battery voltage V_{Bat}.
CANL2GND	Failure that typically occurs when the CAN_L wire is short circuited to Ground

a The failure event names may occur with the indices N (for normal mode) and LP (for low-power mode).

8 PMA specification

8.1 General

The physical medium attachment specification describes requirements an ECU and especially the transceiver device participating in the CAN network communication should provide.

8.2 Timing requirements

8.2.1 General

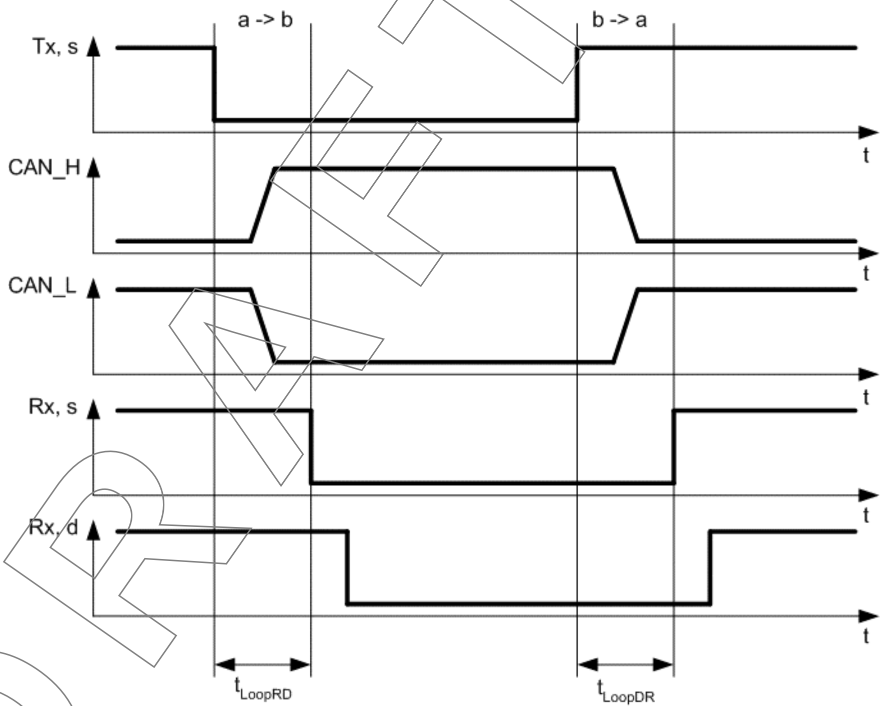
To enable maximum communication speed at maximum line length the internal loop time of a transceiver device is limited. Hence, a transceiver device shall fulfil given constraints under all possible failure conditions.

8.2.2 Constraints

Figure 9 shows the necessary timing requirements. Where

— *T*x(s) denotes the digital input signal of the sending node;
— *R*x(s) denotes the digital output signal of the sending node (read back of bus line);
— *R*x(d) denotes the digital output signal of the destination node;
— CAN_L and CAN_H denote the physical signal on the wire.

Both transitions “recessive” to “dominant” (a -> b) as well as “dominant” to “recessive” (b -> a) have to fulfil certain timing requirements.



Key

t times, µs

a Recessive.

b Dominant.

Figure 9 — Timing example, differential operation without GND shift

8.2.3 Measurement circuit, loop delay

A transceiver has to guarantee a maximum loop delay for signals, which are applied to the TX input. The loop delay is defined by the times t_{LoopRD} and t_{LoopDR} according to Figure 9 and is measured according to Figure 10.

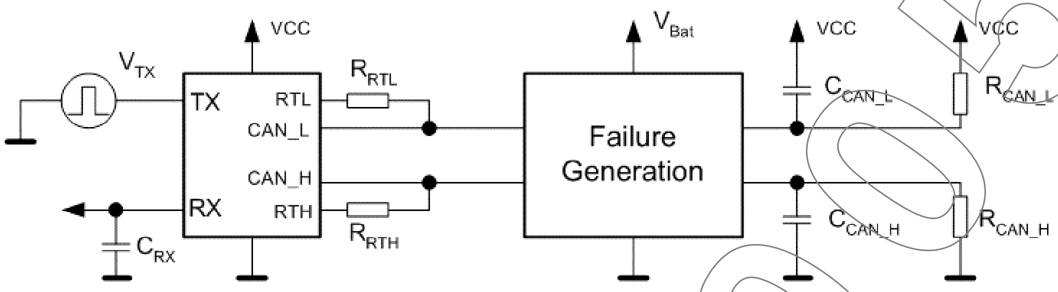


Figure 10 — Test method for transceiver timing measurement

Table 10 — Loop delay of a single transceiver

Failure case	**t_{LoopRD} ; t_{LoopDR}**	**Condition**
no failure	MAX 1,5µs	V_{TX} rectangular signal with 50kHz and 50% duty cycle, slope time <10ns, C_{RX}=10pF, R_{RTL}=R_{RTH}=500Ω, C_{CAN_L}=C_{CAN_H}=1nF, R_{CAN_L}= R_{CAN_H} = 125Ω
all failures except CAN_L shorted to CAN_H	MAX 1,9µs	
CAN_L shorted to CAN_H	MAX 1,9µs	V_{TX} rectangular signal with 50kHz and 50% duty cycle, slope time <10ns, C_{RX}=10pF, R_{RTL}=R_{RTH}=500Ω, C_{CAN_L}=C_{CAN_H}=1nF, R_{CAN_H}= 125Ω; R_{CAN_L} >1MΩ

8.2.4 Measurement circuit, GND shift capability

Figure 11 illustrates the functional test circuit, which is used to check the ground shift requirements. The test circuit allows applying different cases in combination with a local GND shift in positive and negative direction. The wiring harness between the nodes has to stay as short as possible and must not exceed 1 m in total. Depending on the applied failure case, the transceiver operations in three main states.

a) differential driver and receiver;

b) single-line operation on CAN_L line;

c) single-line operation on CAN_H line;

According the set-up shown in figure 11 following bus failure cases have to be applied in combination with a GND shift of up to ±1,5V:

— no failure

— CAN_L wire interrupted

— CAN_H wire interrupted

— CAN_L shorted to V_{Bat}

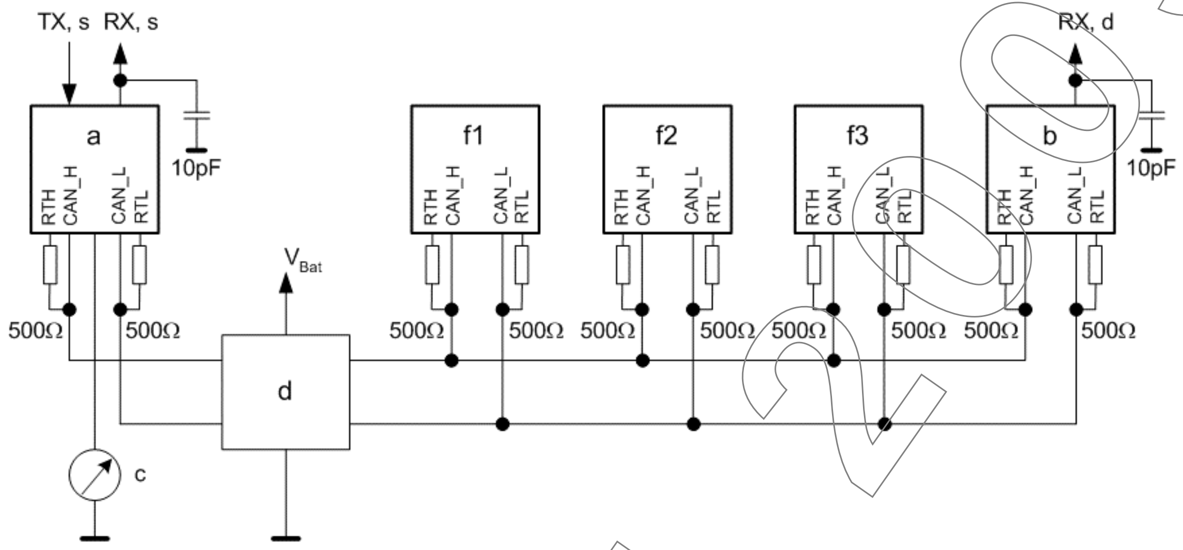
— CAN_H shorted to GND

— CAN_L shorted to GND

— CAN_H shorted to V_{Bat}

— CAN_L shorted to CAN_H

Independently from the applied bus failure and ground shift scenario, all R*x* signals have to represent the driven T*x* pattern correctly.



a Source node

b Destination node

c Ground shift

d Switch No. 1

e Switch No. 2

Figure 11 — Test method for transceiver ground shift requirements

8.3 Failure management

8.3.1 Failure detection

To cope with the failures specified in Clause 7, the scheme listed in Tables 11 and 12 is used.

Table 11 — Normal mode failure event detection scheme

Event	State[a]	Threshold	Timing[d]
$CANH2UBAT_N$[b]	D	CAN_H > $V_{thHxBAT\_N}$	> 7 µs
	R	CAN_H < $V_{thHxBAT\_N}$	> 125 µs
$CANH2VCC_N$	D	CAN_H > $V_{thCAN\_H\_N}$	> 1,6 ms
	R	CAN_H < $V_{thCAN\_H\_N}$	> t_{bit} x 12 ms
$CANL2UBAT_N$	D	CAN_L > $V_{thLxBAT\_N}$	> 7 µs
	R	CAN_L < $V_{thLxBAT\_N}$	> 125 µs
$CANL2GND_N$[c]	D	$V_{diff} > V_{thDiff\_N}$ and/or CAN_L < $V_{thCAN\_L\_N}$	> t_{bit} x 12 < 1,6 ms
	R	$V_{diff} < V_{thDiff\_N}$ or/and CAN_L > $V_{thCAN\_L\_N}$	> 7µs
$CANL2UBAT\_VER_N(1)$[e]	D	TX dominant and CAN_L > $V_{thCAN\_L\_N}$	3µs < t < 40µs
$CANL2UBAT\_VER_N(2)$[f]	D	Max 2 TX dominant to recessive edges with CAN_L > $V_{thCAN\_L\_N}$	-

[a] D denotes “detection” and R denotes “recovery”.

[b] This failure may be considered to be optional, because the major error handling is possible by detecting the CANH2VCC failure.

[c] This failure detection also covers the CANH2CANL failure (mutually short circuit of both lines).

[d] Analogue failure detection and recovery timer implementations have to react upon consecutive input conditions only. The sample rate of digital timer implementations has to be faster than 4 micro seconds.

[e] Implementation variant 1 for verification of $CANL2UBAT_N$ failure

[f] Implementation variant 2 for verification of $CANL2UBAT_N$ failure

Table 12 — Low-power mode failure event detection scheme

Event[a]	State[b]	Threshold	Timing[e]
$CANH2UBAT_{LP}$[c]	D	CANH > $V_{th(wake)H}$	> 7 µs
	R	CANH < $V_{th(wake)H}$	> 125 µs
$CANH2VCC_{LP}$	D	CANH > $V_{th(wake)H}$	> 1,6 ms
	R	CANH < $V_{th(wake)H}$	> t_{bit} x 12 ms
$CANL2UBAT_{LP}$	D	Not detected	
	R	Not detected	
$CANL2GND_{LP}$[d]	D	CAN_H > $V_{th(wake)H}$ and/or CAN_L < $V_{th(wake)L}$	> 0,1 < 1,6 ms
	R	CAN_H < $V_{th(wake)H}$ or/and CAN_L > $V_{th(wake)L}$	> 7 µs

[a] See Table 9 for explanations

[b] D denotes “detection” and R denotes “recovery”.

[c] This failure may be considered to be optional, because the major error handling is possible by detecting the CANH2VCC failure.

[d] This failure detection also covers the CANH2CANL failure (mutually short circuit of both lines).

[e] Analogue failure detection and recovery timer implementations have to react upon consecutive input conditions only. The sample rate of digital timer implementations has to be faster than 4 micro seconds.

8.3.2 Failure treatment

8.3.2.1 Power failures

There are no explicit internal states for coping with power failures. A transceiver device should react in such a way as to fulfil the requirements of the operating modes in Clause 8.3.

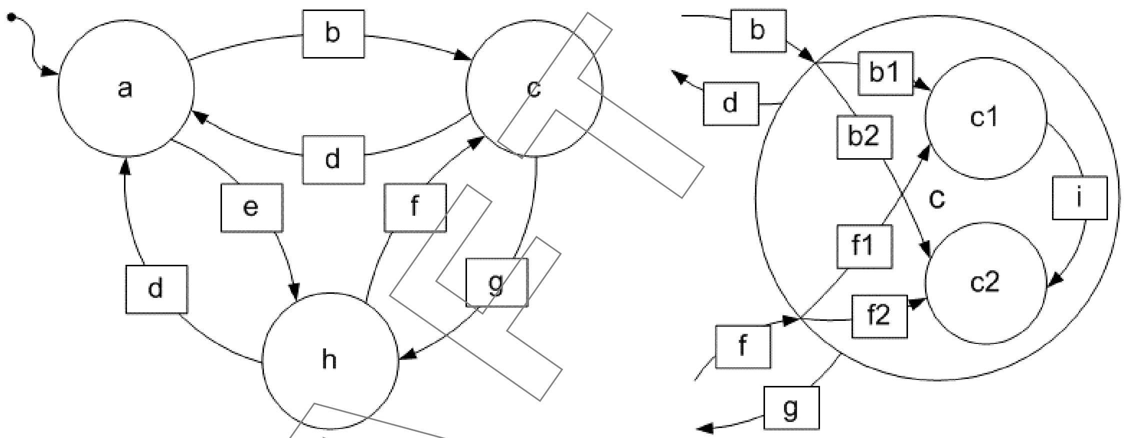
8.3.2.2 Bus wire failures

The treatment of bus wire failures is represented using an internal state machine. There is no necessity for a transceiver device to implement an internal state machine. However, the behaviour of the device shall be in agreement to the following specification.

Figure 12 shows the general used state diagram. The transitions are valid for normal and low power mode as they are denoted. However it is possible that a transceiver device which is actually in low power mode wakes up into normal mode to perform a state transition if it felled back to low power mode afterwards.

Following state conventions are used in Figure 12:

— State 0: Normal operating state, no failure is detected, default state.
— State E1: CAN_L failure expected / detected.
— State E2: CAN_H failure detected.



Key:

a State 0: Normal operating state, no failure is detected, default state

b CANL2UBAT$_N$ or CANL2GND$_{N/LP}$

b1 CANL2UBAT$_N$

b2 CANL2GND$_{N/LP}$

c State E1: CAN_L failure expected / detected

c1 State E1a : No CAN_L failure

c2 State E1b : CAN_L failure detected

d No failure

e CANH2VCC$_{N/LP}$ or CANH2UBAT$_{N/LP}$

f **NOT** (CANH2VCC$_{N/LP}$ or CANH2UBAT$_{N/LP}$) and (CANL2GND$_{N/LP}$ or CANL2UBAT$_N$).

f1 **NOT** (CANH2VCC$_{N/LP}$ or CANH2UBAT$_{N/LP}$) and CANL2UBAT$_N$

f2 **NOT** (CANH2VCC$_{N/LP}$ or CANH2UBAT$_{N/LP}$) and CANL2GND$_{N/LP}$

g CANH2VCC$_{N/LP}$ or CANH2UBAT$_{N/LP}$

h State E2: CAN_H failure detected

i CANL2UBAT_VER$_N$(1) or CANL2UBAT_VER$_N$(2)

Figure 12 — Internal CAN transceiver states

According to the states in Figure 12 the transceiver device switches its drivers, receivers and termination to different modes.

Tables 13 and 14 list the internal treatment of the bus wire failures for either normal mode and low power mode.

Table 13 — Normal mode state description

State	Drivers	Receivers	Termination
0	All drivers are switched on	Differential receivers on	CAN_H terminated to GND CAN_L terminated to V_{CC}
E1	Driver CAN_L is switched on or off	Single ended CAN_H receiver	CAN_H terminated to GND CAN_L weak V_{CC}
E1a	Driver CAN_L is switched on	Single ended CAN_H receiver OR Differential receiver OR CANH / CANL Single ended receivers	CAN_H terminated to GND CAN_L weak V_{CC} [a]
E1b	Driver CAN_L is switched off	Single ended CAN_H receiver	CAN_H terminated to GND CAN_L weak V_{CC}
E2	Driver CAN_H is switched off	Single ended CAN_L receiver	CAN_H weak GND CAN_L terminated to V_{CC}
[a] After a mode change from LP it is also allowed to terminate CAN_L to V_{CC}.			

Table 14 — Low-power mode state description

State	Drivers	Receivers	Termination
0	All drivers are switched off	Reduced to failure recognition	CAN_H terminated to GND CAN_L terminated to V_{Bat}
E1	All drivers are switched off	Reduced to failure recognition	CAN_H terminated to GND CAN_L floating
E2	All drivers are switched off	Reduced to failure recognition	CAN_H floating CAN_L terminated to V_{Bat}

8.4 Operating modes

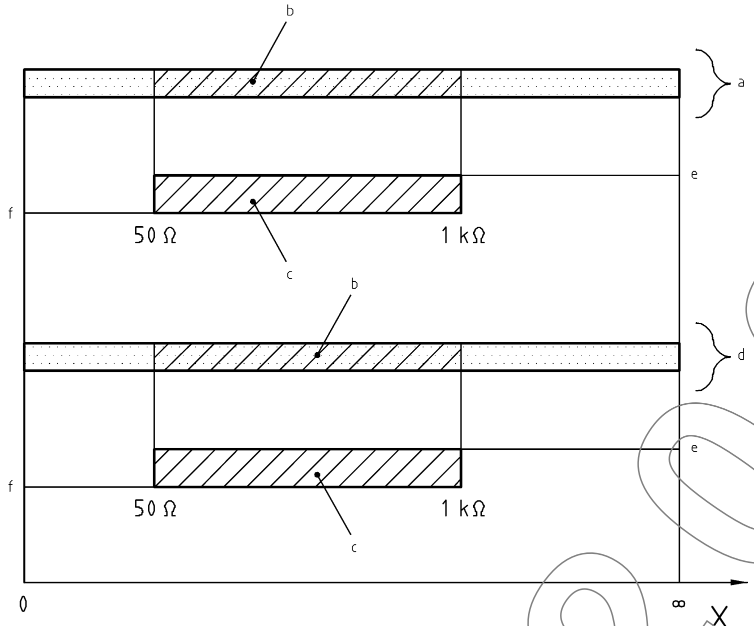
8.4.1 General

The operating modes are specified according to the exemplary network in 6.1.4. They describe what a transceiver following this part of ISO 11898 shall cope with. These operating modes will be covered by the conformance test.

8.4.2 Open wire failures

A transceiver according to this standard should be able to cope with open wire failures under all conditions. That means, the communication should continue whether or not there is a detectable failure.

Figure 13 illustrates the operating modes for the both open wire failures, and the failure states.



Key:

a CH_OW, i.e. the CAN_H line is interrupted).

b Fault free communication required.

c Failure state

d CL_OW, i.e. the CAN_L line is interrupted.

e True, i.e. the failure is recognised and an appropriate reaction is performed.

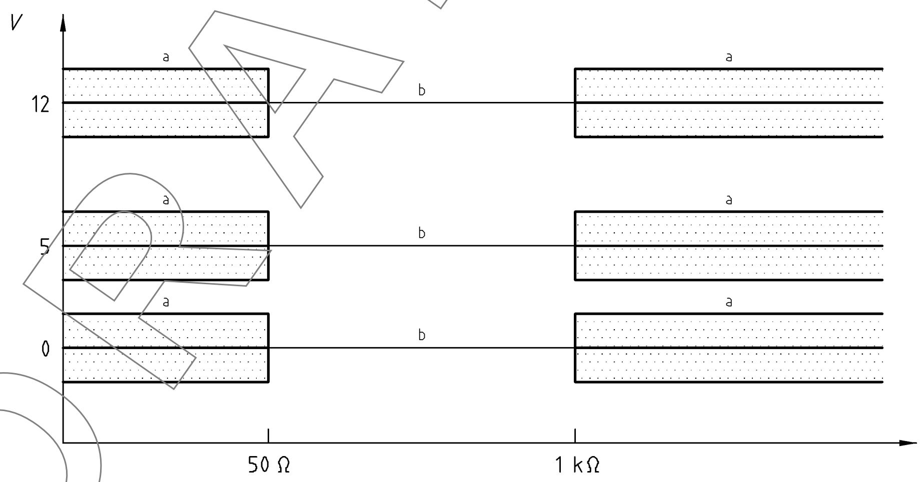
f False, i.e. no failure is detected.

X Resistor range, in ohms (Ω), denotes interruption might occur at any given resistance.

Figure 13 — Open wire operating mode

8.4.3 Short circuit failures

The single-line short circuit failures are two dimensional failures. On the one hand, the voltage level at which a short circuit occurs can vary. On the other hand, a different resistance between bus wire and external voltage level is possible. Figure 14 shows the short circuit operating areas. Due to Ground shift, the operating areas (shaded areas) vary in a range of at least ± 1,5 V. The battery voltage level is a nominal voltage level and may vary in a wide range temporarily, e.g. from 6,5 V to 27 V (12 V-systems) or from 21 V to 58 V (42 V-systems).



a Proper network operation required.

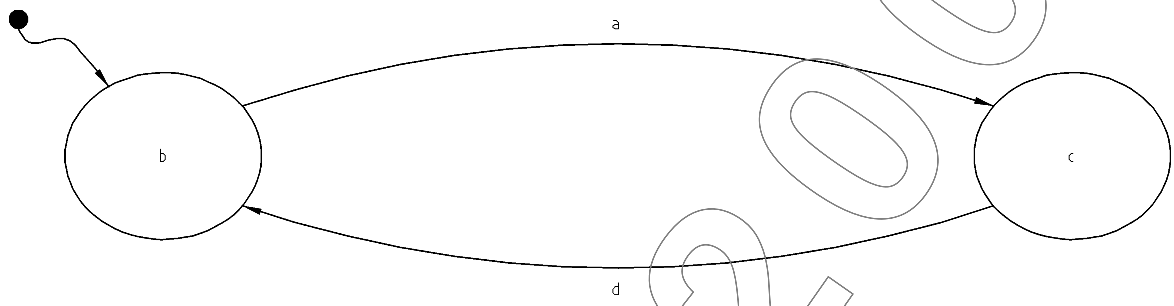
b Proper network operation *not* required.

Figure 14 — Definition of short circuit operating modes

8.4.4 Power failures

Failures related to a proper power supply of the ECU, such as loss of Ground, loss of V_{CC} or V_{Bat}, shall be treated in a common way. As long as the outer conditions enable a communication, a node with a power failure should participate in network communication.

Whenever a network communication is not possible due to power failures, the transceiver device should behave in such a way as to not disturb the rest of the network. Figure 15 illustrates both power states and gives a rough indication of when a transceiver should switch its mode.



Key	a	V_{Bat} or $V_{CC} \leq 4{,}6$ V.	c	No back current, no active bus influence.
	b	Normal.	d	V_{Bat} or $V_{CC} \geq 4{,}6$ V

Figure 15 — Power operating modes

Bibliography

[1] ISO 7498:1984, *Information processing systems — Open System Interconnection — Basic Reference Model*

[2] ISO 7637-3, *Road vehicles — Electrical disturbance by conduction and coupling — Part 3: Vehicles with nominal 12 V or 24 V supply voltage — Electrical transient transmission by capacitive and inductive coupling via lines other than supply lines*

[3] ISO 8802-2:1989, *Information processing systems — Local area networks — Part 2: Logical link control*

[4] ISO 11898:1993, *Road vehicles — Interchange of digital information — Controller area network (CAN) for high-speed communication*