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Road vehicles — Controller area network (CAN) — Part 3: Fault tolerant medium access unit

Véhicules routiers — Gestionaire de réceau de communication (CAN) — Partie 3 : Titre de la partie

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Contents

Foreword

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

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: Fault tolerant medium access unit*

— *Part 4: Time tolerant CAN*

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

In addition to the high-speed CAN the development of the low-speed CAN, which is originally covered by ISO 115119-2:1994, gained new means like fault tolerant behaviour. Subject of this standard should be the definition and descriptions of requirements necessary to obtain a fault tolerant behaviour as well as the definition of fault tolerance itself. In particular it describes the MDI and parts of the MAU.

This part of ISO 11898 will replace ISO 11519-2:1994.

Road vehicles — Controller area network (CAN) — Part 3: Fault tolerant medium access unit

1 Scope

This part of ISO 11898 specifies characteristics of setting up an interchange of digital information between electronic control units (ECUs) of road vehicles equipped with the controller area network (CAN) at transmission rates above 40 kbit/s up to 500 kbit/s.

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

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

All other layers of the OSI model either do not have counterparts within the CAN protocol and are left to the discretion of users, or do not affect the fault tolerant behaviour of the low speed CAN physical layer and are therefore not specified in this part of ISO 11898.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 11898. 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 11898 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 7498:1984, *Information processing systems — Open System Interconnection — Basic Reference Model.*

ISO 7637-3:1995, *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.*

ISO 7637-3:1995/Cor.1:1995, *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, TECHNICAL CORRIGENDUM 1.*

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 part of ISO 11898, 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
Failures caused by a malfunction of the physical bus such as interruption, short circuits

3.3
bus value
One of two complementary logical values: “dominant” or “recessive”

NOTE The “dominant” value represents a logical “0” 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
V_{CAN_L} and V_{CAN_H} denote the voltages of the bus line wires CAN_L and CAN_H relative to ground of each individual CAN node

3.5
differential voltage
V_{diff}
Differential voltage of the two-wire CAN bus, value

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
internal transceiver loop time delay
Delay time of a transceiver sending a dominant bit on a bus with no significant capacitive load until the same transceiver device recognizes the established bit on the bus

3.9
low power mode
Operating mode with reduced power consumption

NOTE A node in low power mode shall not disturb communication between other nodes.

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

NOTE - A CAN node is a node communicating across a CAN network.

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 the bus wires and connectors seen by one or more node

3.13
physical layer
Electrical circuit realization 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
Node called receiver if it is not transmitter and the bus is not idle

3.16
transmitter
Device that transforms logical information or data signals to electrical signals so that these signals can be transmitted via the physical medium

3.17
transceiver
Node originating a data frame or remote frame, and stays transmitter until the bus is idle again or until the node loses arbitration

Die Abkürzungen, die nicht in dieser Norm aufgeführt sind, habe ich gestrichen. Die Abkürzungen MAU, GND, RTH und RTL, die im Text der Norm aufgeführt sind, habe ich hinzugefügt. Bitte die Bedeutung von GND prüfen und die von RTH und RTL hinzufügen.

4 Abbreviated terms

CAN	Controller Area Network	ECU	Electronic Control Unit
GND	Ground	LLC	Logical Link Control
MAC	Medium Access Control	MAU	Medium Access Unit
MDI	Medium Dependent Interface	OSI	Open System Interconnection
PLS	Physical Signalling	PMA	Physical Medium Attachment
RTH		RTL	

5 OSI reference model

According to the OSI reference model this part of ISO 11898 represents following two layers, see also figure 1:

— medium dependent interface;

— physical medium attachment.

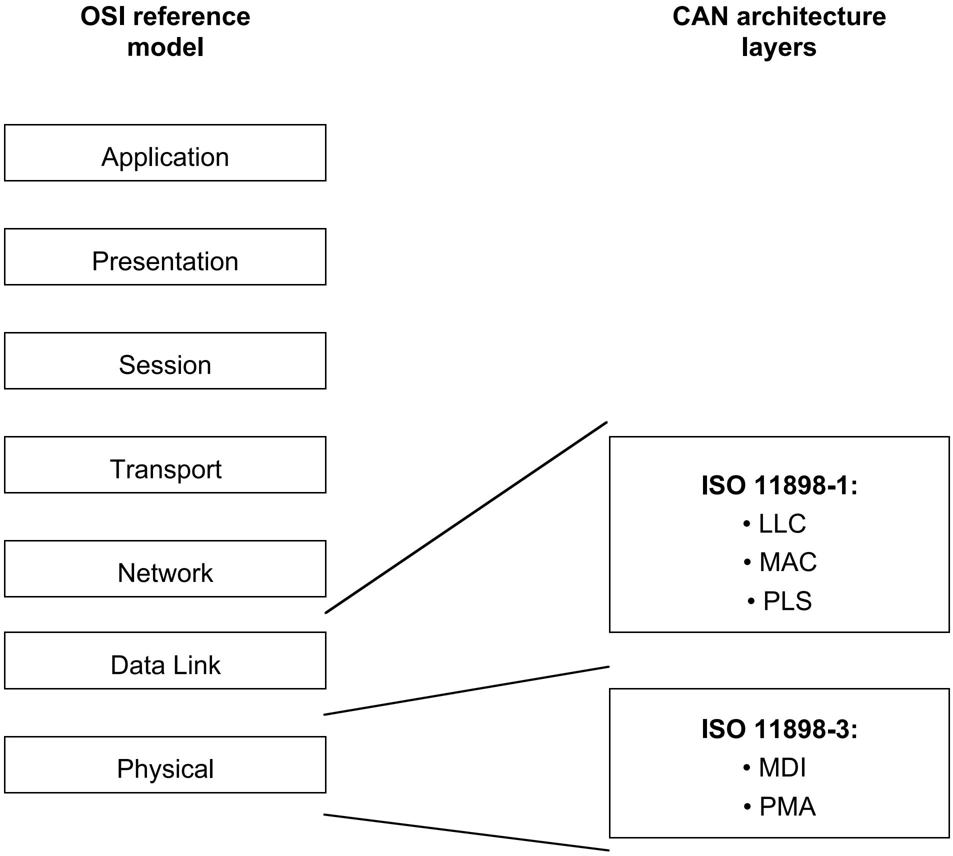


Figure 1 — OSI reference model versus CAN layered architecture

6 MDI specification

6.1 Physical medium

6.1.1 General

The physical media used for the transmission of CAN broadcasts shall be a pair of parallel (or twisted) wires, shielded or unshielded, dependent on EMC requirements. The individual wires are denoted as CAN_H and CAN_L.

In dominant state CAN_L has a lower voltage level than in recessive state and CAN_H has a higher voltage level than in recessive state.

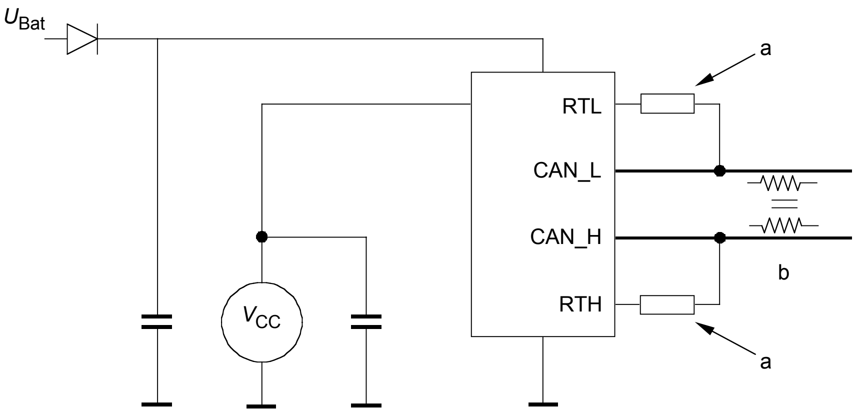
6.1.2 Node bus connection

The two wires CAN_H and CAN_L are terminated by a termination network, which shall be realized by the individual nodes itself.

The overall termination resistance of each line shall be greater or equal 100 _ .However, the termination resistor value of a designated node should not be below 500 _, due to the semiconductor manufacturers constraints.

To represent the recessive state, CAN_L shall be terminated to V_{CC}, and CAN_H shall be terminated to GND.

Figure 2 illustrates the termination of a designated bus node.



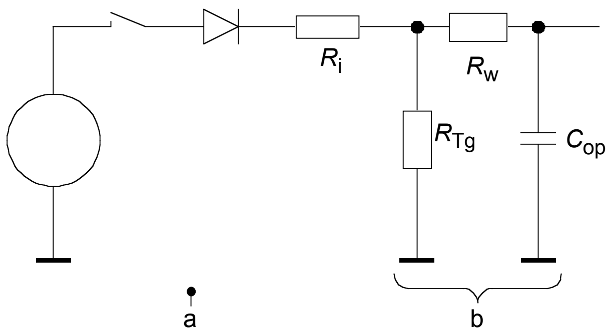
Key	a	Optional.
	b	Optional common mode choke coil.

Figure 2 — Termination of a single bus node

The termination resistors are denoted in figure 2 as optional, i.e. under certain conditions not all nodes need an individual termination, if the requirements of the overall termination are fulfilled.

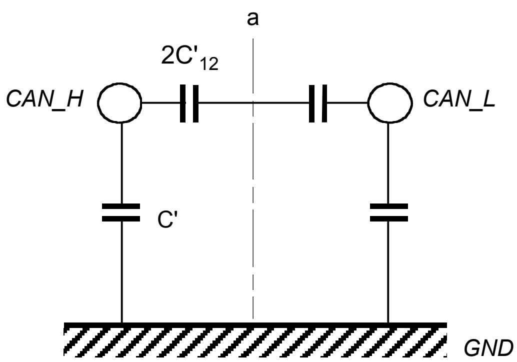
6.1.3 Medium capacitance

The following specifications shall be 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 6.4.1. The basic model shown in figure 3 and 4 shall be used for the calculations.



Key	a	Driver.	b	Wire.

Figure 3 — Substitute circuit for bus line



Key	a	Symmetric axis.	GND	Ground.

Figure 4 — Operating capacitance referring to network length l

The operating capacitance shall be calculated using equation 1.

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

where

C_{OP}	is the operating capacitance defined in 3.11.
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 a 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 is given by:

$$C'_{OP\ typ} = 120\ \frac{\text{pF}}{\text{m}}$$

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 to estimate the maximum allowed operating capacitance.

$$R_{term}\,C_{OP} = \tau_C = \frac{\dfrac{s_p}{f_{bit}} - 2\,t_l - t_{sync}}{\ln(V_0 + GND) - \ln V_{th}} \qquad [2]$$

where

R_{term}	is the overall network termination resistor (approx. 120 _);
C_{OP} is	the operating capacitance specified in 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 synchronization 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)

GND denotes the maximum allowed effective groundshift (max. 3 V)

EXAMPLE The calculation of τ_C leads to the graph shown in figure 5.

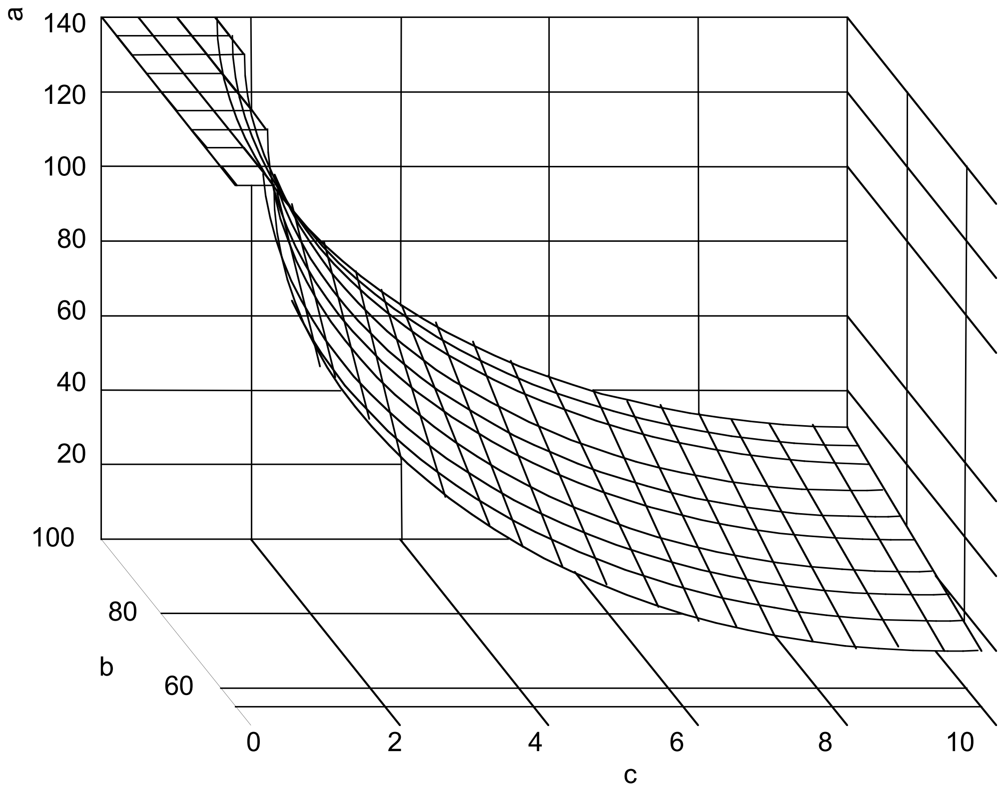
As an over the thump rule, the possible maximum time constant τ_C may be calculate using equation 3.

$$\tau_C \quad \frac{1}{6\, f_{bit}} \qquad [3]$$

where

τ_C is the time constant of bus wire;

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



Key	a	Communication speed in kBit/s	b	Sample point in %	c	τ_C in µs

NOTE Assumptions of the graph are:
V_0 = 5 V;
V_{th} = 0,2 V;
no groundshift;
total internal loop delay = 1,5 µs.

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

6.2 PLS specifications

The bus line may have one of the two logical states “recessive” and “dominant”, see figure 6. In order to distinguish between both states the differential voltage V_{diff} shall be used.

$$V_{diff} = V_{CAN\_L} - V_{CAN\_H} \quad [4]$$

where

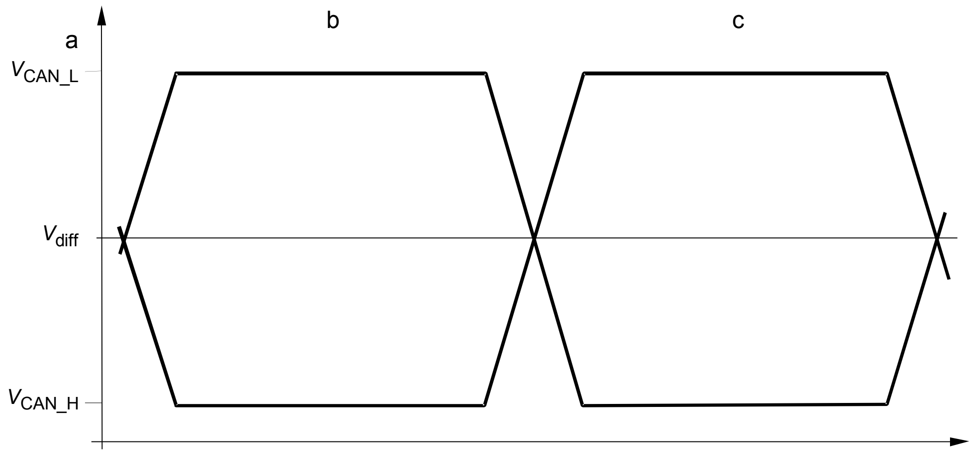
V_{diff} is the differential voltage;

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 shall have a higher voltage level than the CAN_H line. In general, this leads to an negative differential voltage V_{diff}. The recessive state shall be transmitted during bus idle as a “recessive” bit.

The dominant state shall be represented by a positive differential voltage V_{diff}, i.e. the CAN_H line shall have a higher voltage level, and the CAN_L line shall have a lower voltage level. The dominant state overrides a recessive state, and shall be transmitted as dominant bits.



Key	a	Bus line voltage	b	Recessive	c	Dominant

Figure 6 — Physical bit representation

6.3 Electrical specification

6.3.1 Voltage ratings for ECU

The voltage ratings given in table 1 shall be considered for ECUs operating with nominal 12 V supply.

Table 1 — Ratings of V_{CAN_L} and V_{CAN_H} of an ECU with nominal 12 V supply

Notation	Voltage	
	min.[a] V	max. V
V_{CAN_L}	-27,0	40,0
V_{CAN_H}	-27,0	40,0

[a] Possible if GND is disconnected or during jump start conditions

((Folgender Text war vorher in Tabelle 1. Da dieser jedoch Anforderungen enthält, wurde dieser aus der Tabelle genommen:))

ECUs with nominal 12 V supply, shall operate at ratings given in table 1, where

no destruction of transceiver may occurs;
transceiver shall not affect communication on the net;
voltage levels may be applied without time restrictions.

The common mode voltage of an undisturbed ECU in normal mode shall be within the ratings specified in table 2.

The common mode voltage shall be calculated by:

$$V_{COM} = \frac{V_{CAN\_L} + V_{CAN\_H}}{2} \qquad [5]$$

where

V_{COM} is the common mode bus voltage;

V_{CAN_L} is the CAN_L line voltage;

V_{CAN_H} is the CAN_H line voltage.

Table 2 — Common mode voltage of an undisturbed ECU in normal mode

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

6.3.2 DC parameters for physical signalling

DC parameters and limiting values for physical signalling are specified in tables 3 to 5.

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

Parameter	Notation	Unit	Value		
			min.	nominal	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 set to 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 the dominant state of an ECU connected to the termination network via bus line

Parameter	Notation	Unit	Value		
			min.	nominal	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 set to nominal 5 V.					

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

Parameter	Notation	Unit	Value		
			min.	nominal	max.
Bus voltage	V_{CAN_L}	V	V_{Bat} - 0,3 [a]	-	-
	V_{CAN_H}	V	-	-	0,3
Differential bus voltage	V_{diff}	V	-	-	-
[a] V_{Bat} is set to nominal 12 V.					

6.3.3 DC parameters for detection

DC parameters and limiting values for the detection are specified in tables 6 and 7.

Table 6 — DC threshold from dominant to recessive detection in normal mode, and vice versa

Parameter	Notation	Unit	Value		
			min.	nominal	max.
Single ended receiver detection	V_{CAN_L}	V	2,8	-	3,5
	V_{CAN_H}	V	1,5	-	2,3
Differential receiver	V_{diff}	V	- 3,5	-	- 2,6

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

Parameter	Notation	Unit	Value		
			min.	nominal	max.
Wake-up threshold	$V_{th(wake)L}$	V	2,5	3,2	3,9
	$V_{th(wake)H}$	V	1,1	1,8	2,5
Differential of wake-up threshold	ΔV_{diff}	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 and 8.

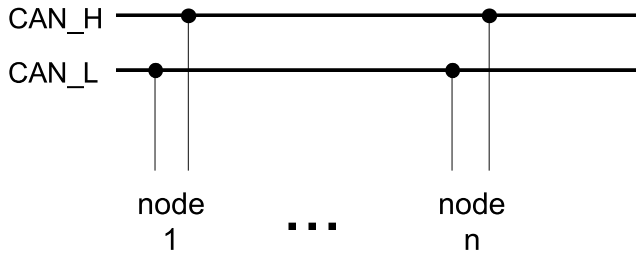


Figure 7 — Connecting model, bus topology with stub lines

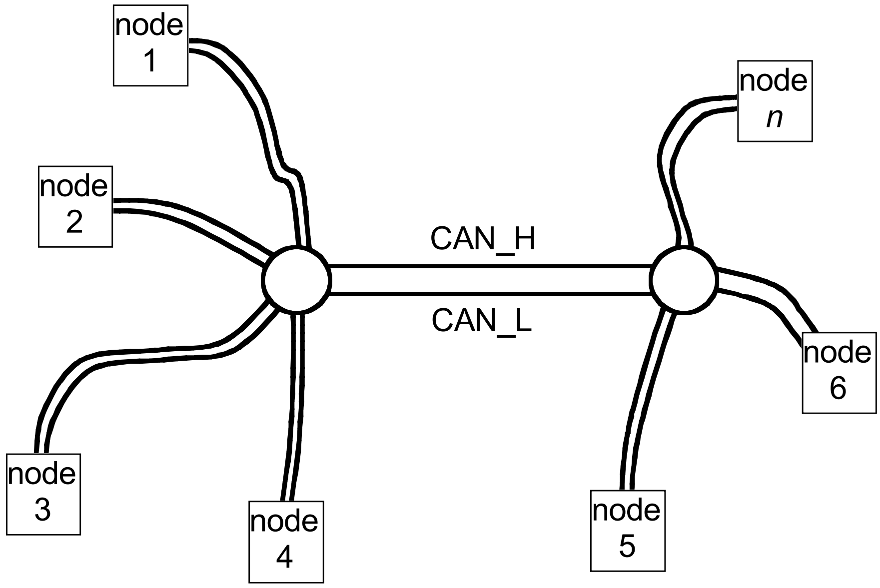


Figure 8 — Connecting model, star point topology

However, for any connecting model 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, see 6.4.2.

— The maximum possible number of participating nodes shall not be less than 20, at ***500 kbit/s*** and an overall network length of ***??40 m??***. The actual number of nodes varies due to communication speed, capacitive network load, overall line length, network termination topology, etc..

— To provide a maximum communication speed of ***500 kbit/s*** the overall network length shall not exceed 40 m. However, increased overall network length may be applied by reducing the actual communication speed.

For a star point topology following additional constraints shall be fulfilled:

— The individual nodes shall be connected to one ore more passive star points. Two or more passive star points shall be connected by bus topology.

— Some connecting lines (star connector to node) may be extended to several meters, no stub lines are recommended.

— Both the overall network length, i.e. all star point connection line lengths added, and the maximum node to node distance affect the network communication.

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

— star point connection method with two star points;

— network is terminated with an overall resistance of 100 Ω.

— node number is about 20.

— 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 requirements

The recessive bus level described in 6.2 shall be maintained by the bus termination.

Dominant bus level shall override recessive bus state.

Transition between the dominant to recessive levels may also be done by the termination. However, no termination network or circuit is designated.

Moreover, the termination shall be attached to most of the participating nodes.

6.4.2.2 Termination modes

Two major termination modes are specified:

— normal mode termination.

— low power mode termination.

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

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

In normal power mode, the CAN_L line shall be 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 shall be provided by connecting the CAN_L line to the RTL pins of the transceiver devices and by connecting the CAN_H line to the RTH pins, see figure 2.

By connecting the termination pins the following requirements shall 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 shall be at last 500 Ω, due to in circuit current limitations.

It is recommended, that every node provides its own termination resistors. A not well terminated node may be sensitive for 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.

Table 8 — Physical failures

Description of bus failure	Behavior of the network
One node becomes disconnected from the bus [a]	The remaining nodes continue communication.
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 [c]	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 +/- 1,5V.

[d] This failure is covered by the detection of the failure “CAN_L shorted to ground”.

7.2 Failure events

7.2.1 General

Transceiver device shall not react to the physical failures, but to the way they influence the bus wire system. These failures are called failure events which are subdivided 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 lost ground connection, or is affected by a groundshift to supply voltages above the specified limitations of ± 1,5 V, or a proper voltage supply (either V_{CC} or V_{Bat}), the 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 are specified in table 9.

Table 9 — Failure events

Event name [a]	Description
CANH2*U*BAT	Failure event when the CAN_H wire is short circuited to the battery voltage V_{Bat} .
CANH2VCC	Failure event when the CAN_H wire is short circuited to the supply voltage V_{CC} .
CANL2UBAT	Failure event when the CAN_L wire is short circuited to the battery voltage V_{Bat} .
CANL2GND	Failure event 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

PMA specification describes requirements which shall be fulfilled by ECU and especially the transceiver device participating at CAN network communication.

8.2 Timing requirements

8.2.1 Requirement

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

8.2.2 Constraints

Figure 9 shows the constraints of timing requirements.

Both transitions recessive to dominant" (rec. -> dom.) as well as dominant to recessive (dom. -> rec.) shall fulfill given timing requirements.

8.2.3 Measurement circuit

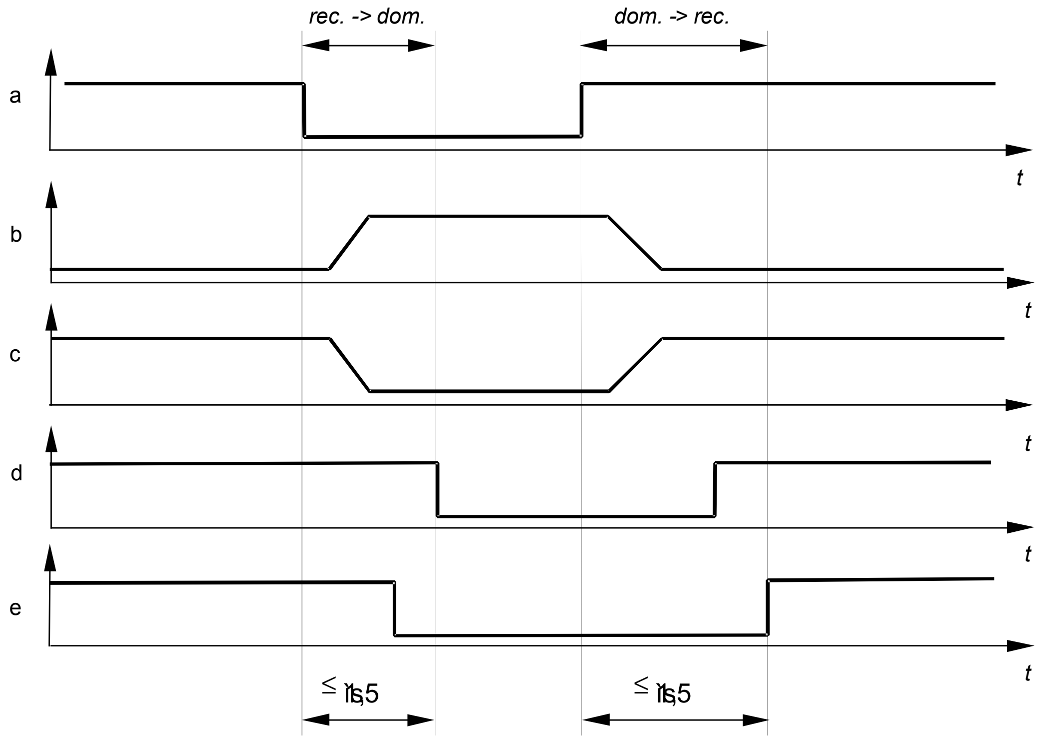
Figure 10 specifies the testing circuit which shall be used to check the timing requirements. The transceivers shall operate in the following three main states:

— differential driver and receiver (SW1 and SW2 open);

— single line driver and receiver for CAN_L line (SW1 closed and SW2 open);

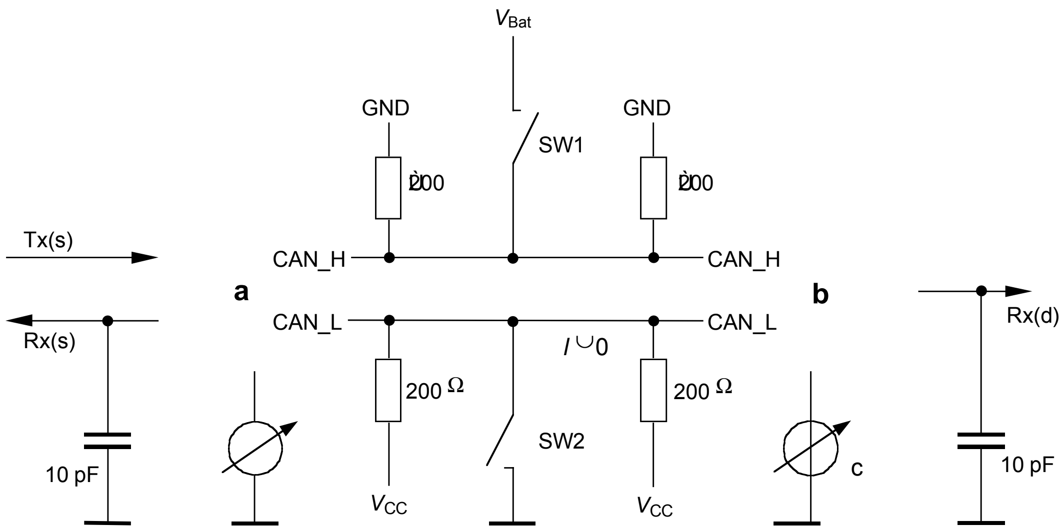
— single line driver and receiver for CAN_H line (SW1 open and SW2 closed).

In addition to these major operating states a ground shift of ± 1,5 V shall be applied to either node.



Key				
Key	a	Tx(s), the digital input signal of the sending node.	d	Rx(s), the digital output signal of the sending node (read back of bus line).
	b	CAN_H, the physical signal on CAN_H wire.		
	c	CAN_L, the physical signal on CAN_L wire.	e	Rx(d), the digital output signal of the destination node

Figure 9 — Timing requirements



Key	a	Source node	b	Destination node	c	Ground shift

Figure 10 — Test method for transceiver timing requirements

8.3 Failure management

8.3.1 Failure detection

To cope with the failures specified in 7, the normal mode event failure detection scheme listed in tables 10 and 11 shall be used.

Table 10 — Normal mode event failure detection scheme

Event[a]	State[b]	Threshold [V]	Timing ms
CANH2UBAT$_N$ [c]	D	CAN_H > 7,2 (6.5 < V_{th} < 8,0)	> 7 µs
	R	CAN:H < 7,2 (6.5 < V_{th} < 8,0)	> 125 µs
CANH2VCC$_N$	D	CAN_H > 1,8 (1.5 < V_{th} < 2,0)	> 1,6
	R	CAN_H < 1,8 (1.5 < V_{th} < 2,0)	> t_{bit} x 12
CANL2UBAT$_N$	D	CAN_L > 7,2 (6.5 < V_{th} < 8,0)	> 7 µs
	R	CAN_L < 7,2 (6.5 < V_{th} < 8,0)	> 125 µs
CANL2GND$_N$ [d]	D	V_{diff} > -3,2 and/or CANL < 3,2 (-3,9 < V_{th1} < -2,5; 2,5 < V_{th2} < 3,9)	> t_{bit} x 12 < 1,6
	R	V_{diff} < -3,2 or/and CANL > 3,2 (-3,9 < V_{th1} < -2,5; 2,5 < V_{th2} < 3,9)	> 7µs

[a] See table 9 for explanations.
[b] D means detection and R recovery.
[c] This failure may be considered as 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).

Table 11 — Low power mode event failure detection scheme

Event [a]	State[b]	Threshold V	Timing ms
CANH2UBAT$_{LP}$ [c]	D	CANH > 1,8 (1,1 < V_{th} < 2,5)	> 7 µs
	R	CANH < 1,8 (1,1 < V_{th} < 2,5)	> 125 µs
CANH2VCC$_{LP}$	D	CANH > 1,8 (1,1 < V_{th} < 2,5)	> 1,6
	R	CANH < 1,8 (1,1 < V_{th} < 2,5)	> t_{bit} x 12
CANL2UBAT$_{LP}$	D	*not detected*	
	R	*not detected*	
CANL2GND$_{LP}$ [d]	D	CANH > 1.8 and/or CANL < 3,2 (1,1 < V_{th1} < 2,5; 2,5 < V_{th2} < 3,9)	> 0,1 < 1,6
	R	CANH < 1.8 or/and CANL > 3,2 (1,1 < V_{th1} < 2,5; 2,5 < V_{th2} < 3,9)	> 7 µs

[a] See table 9 for explanations.
[b] D means “detection” and R “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).

8.3.2 Failure treatment

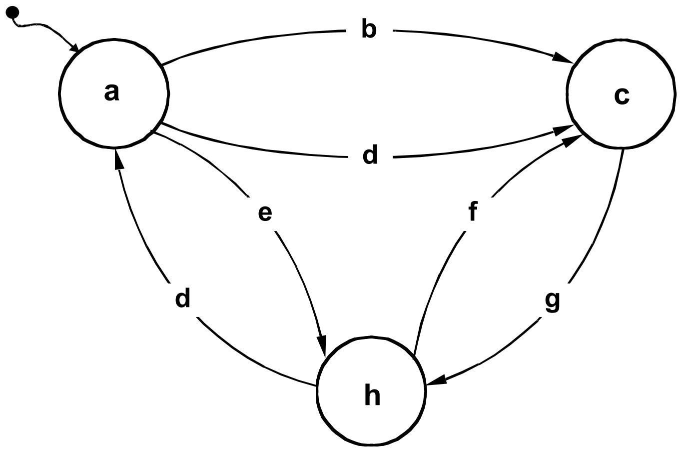
8.3.2.1 Power failures

No explicit internal states have been specified how to cope with power failures. A transceiver device shall react in such a way to fulfill the requirements of the operating modes in 8.3.3.

8.3.2.2 Bus wire failures

The treatment of bus wire failures shall be represented using an internal state machine. This does not mean that a transceiver device has to implement an internal state machine. However, the behaviour of this device shall fulfil the following specification.

Figure 11 shows the generally 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 fell back to low power mode afterwards.



Key	a	State 0: Normal operating state, no failure is detected, default state.	e	$CANH2VCC_{N/LP}$ or $CANH2UBAT_{N/LP}$
			f	NOT ($CANH2VCC_{N/LP}$ or $CANH2UBAT_{N/LP}$) and ($CANL2GND_{N/LP}$ or $CANL2UBAT_{N}$)
	b	$CANL2UBAT_{N}$ or $CANL2GND_{N/LP}$.		
	c	State E1: CAN_L failure detected.	g	$CANH2VCC_{N/LP}$ or $CANH2UBAT_{N/LP}$
	d	No failure.	h	State E2: CAN_H failure detected.

Figure 11 — Internal CAN transceiver states

According to the states specified in figure 11, the transceiver device shall switch its drivers, receivers and termination to different modes.

Tables 12 and 13 specify the internal treatment of the bus wire failures for either normal mode and low power mode.

Table 12 — 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 off (expect CANL2UBAT is detected).	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}

Table 13 — Low power mode state description

State	Driver	Receiver	Termination
0	All drivers are switched on	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

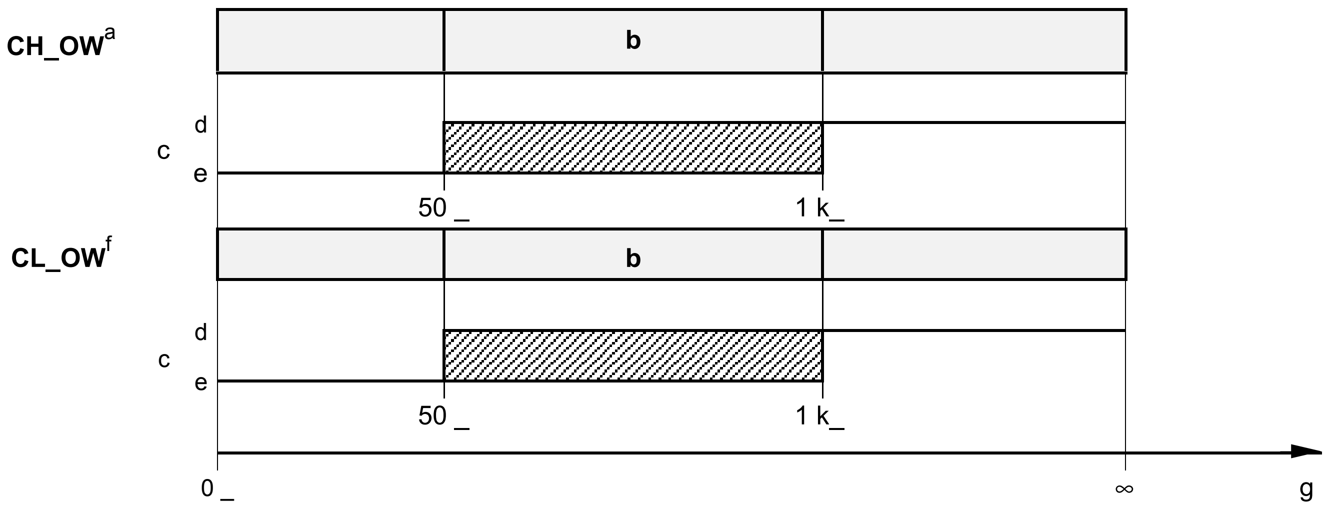
The operating modes shall be as specified in the exemplary network of 6.4.1. This subclause describe what a transceiver according to this part of ISO 11898 shall cope with. The operating modes shall be covered by the conformance test.

8.4.2 Open wire failures

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

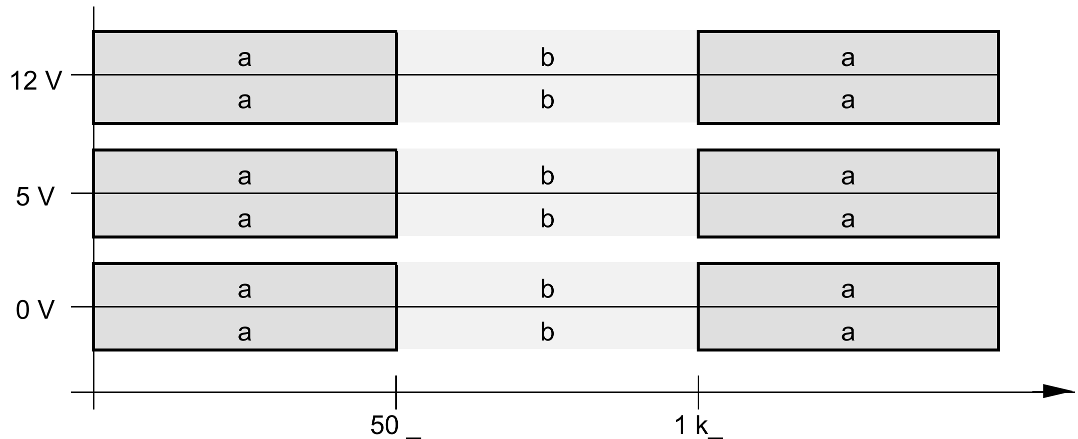
Figure 12 illustrates the operating modes for the both open wire failures.

A failure signalling of the transceiver device to its periphery is optional.



Key				
	a	CH_OW means CAN_H line is interrupted.	e	False no failure is detected.
	b	Fault free communication required within the shaded area.	f	CL_OW means CAN_L line is interrupted.
	c	Failure state.	g	Resistor range denotes that the interruption may occur at any given resistance.
	d	True, i.e. the failure is recognized and an appropriate reaction is performed.		

Figure 12 — Specification of open wire operation mode



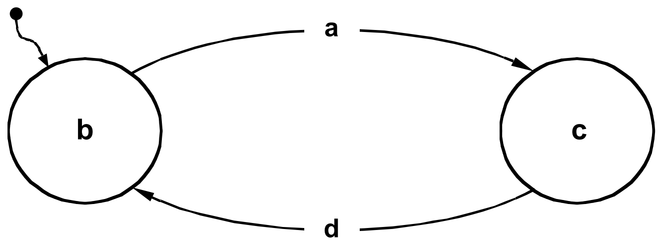
Key	a	Proper network operation required	b	Proper network operation not required.

Figure 13 — Specification of short circuit operating modes

8.4.3 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 shall participate in network communication.

Whenever a network communication is not possible due to power failures the transceiver device shall behave in such not disturbing the remainings of the network. Figure 14 illustrates the both power states and gives a general indication when a transceiver shall switch its mode.



Key				
Key	a	V_{Bat} or V_{CC} ≈ ≤ 4,6 V.	c	• No back current; • no active bus influence.
	b	Normal.	d	V_{Bat} or V_{CC} ≈ ≥ 4,6 V.

Figure 14 — Power operating mode specification