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Road vehicles — Controller area network (CAN) — Part 6: High-speed medium access unit with selective wake-up functionality

Véhicules routiers — Gestionnaire de réseau de communication (CAN) — Partie 6: Unité d'accès au medium haute vitesse avec fonctionnalité de réveil sélectif

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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.

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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.

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ISO 11898-6 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC , .

This second/third/... edition cancels and replaces the first/second/... edition (), [clause(s) / subclause(s) / table(s) / figure(s) / annex(es)] of which [has / have] been technically revised.

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*

— *Part 5: High-speed medium access unit with low-power mode*

— *Part 6: High-speed medium access unit with selective wake-up functionality*

Introduction

ISO 11898 was first published as one document in 1993. It covered the CAN data link layer as well as the high-speed physical layer.

In the reviewed and restructured ISO 11898 series:

— Part 1 describes the data link layer including the logical link control (LLC) sub layer and the medium access control (MAC) sub layer as well as the physical signalling (PHS) sub layer;

— Part 2 defines the high-speed medium access unit (MAU);

— Part 3 defines the low-speed fault-tolerant medium access unit (MAU);

— Part 4 defines the time-triggered communication;

— Part 5 defines the power modes of the high-speed medium access unit (MAU);

— Part 6 defines the selective wake-up functionality of the high-speed medium access unit (MAU).

Road vehicles — Controller area network (CAN) — Part 6: High-speed medium access unit with selective wake-up functionality

1 Scope

This part of ISO 11898 specifies the CAN physical layer for transmission rates up to 1 Mbit/s for use within road vehicles. It describes the medium access unit functions.

This part of ISO 11898 represents an extension of ISO 11898-2 and ISO 11898-5, dealing with new functionality for systems requiring a selective wake-up via configurable CAN frames.

Physical layer implementations according to this part of ISO 11898 are compliant with all parameters of ISO 11898-2 and ISO 11898-5, but are defined differently within this part of ISO 11898. Implementations according to this part of ISO 11898, ISO 11898-5 and ISO 11898-2 are interoperable and can be used at the same time within one network.

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 11898 (all parts), *Road vehicles — Controller area network (CAN)*

ISO 16845-2, *Road vehicles — Controller area network (CAN) — Part 2: High-speed medium access unit with selective wake-up functionality - Conformance test plan*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 11898 parts 1 to 5 and the following apply. Note that some terms in this document are differently defined as they are in ISO 11898-1 due to different focus of consideration.

3.1
bias unit
a sub part of the transceiver with selective wake-up function which provides the biasing voltage

NOTE Figure 1 depicts the functional sub parts of a transceiver.

3.2
bit rate
number of bits per time during transmission, independent of bit representation

3.3
CAN bus node
a communication participant of the CAN system which contains typically a physical layer, a CAN controller and an application

3.4
CAN controller
part of a CAN bus node which is responsible for the implementation of the CAN protocol part, also known as Data link layer which is addressed in the OSI layer 2

3.5
control unit
a sub part of the transceiver with selective wake-up function which controls all functions and functional sub parts of a transceiver

NOTE Figure 1 depicts the functional sub parts of a transceiver.

3.6
decoding unit
a sub part of the transceiver with selective wake-up function which analyzes the CAN communication to detect wake-up frames

NOTE Figure 1 depicts the functional sub parts of a transceiver.

3.7
partial networking
a system state in a CAN system where some nodes are sleeping while other nodes are communicating. A sleeping node with configured selective wake-up function shall be woken-up by dedicated valid CAN wake-up frames or by the overflowing error counter

3.8
physical layer
refers to the OSI reference model layer 1, consists of the transceiver, the cabling, connectors, bus termination and further bus connection components

3.9
selective wake-up
selective wake-up describes the new functionality of a transceiver to make the operation of a CAN system with partial networking possible

3.10
receiver
a sub part of the transceiver which is responsible to transform bus signals to logical signals and provides them to the CAN controller

NOTE Figure 1 depicts the functional sub parts of a transceiver.

3.11
transceiver
device that adapts logical signals to the physical layer and vice versa

NOTE Figure 1 depicts the functional sub parts of a transceiver.

3.12
transmitter
a sub part of a transceiver which is responsible to transform logical signals to bus signals and sets them on the bus

NOTE Figure 1 depicts the functional sub parts of a transceiver.

3.13
wake-up filter time (of a CAN node)
t_{Wake}
duration of a dominant signal on the bus lines CAN_H and CAN_L for forcing a wake-up to the CAN node

3.14
wake-up frame
CAN data frame which will cause a wake-up of the CAN node after analyzing the frame in the CAN frame decoder of the transceiver

3.15
wake-up pattern
two dominant bus levels for at least t_{Wake}, each separated by a recessive bus level of at least t_{Wake}

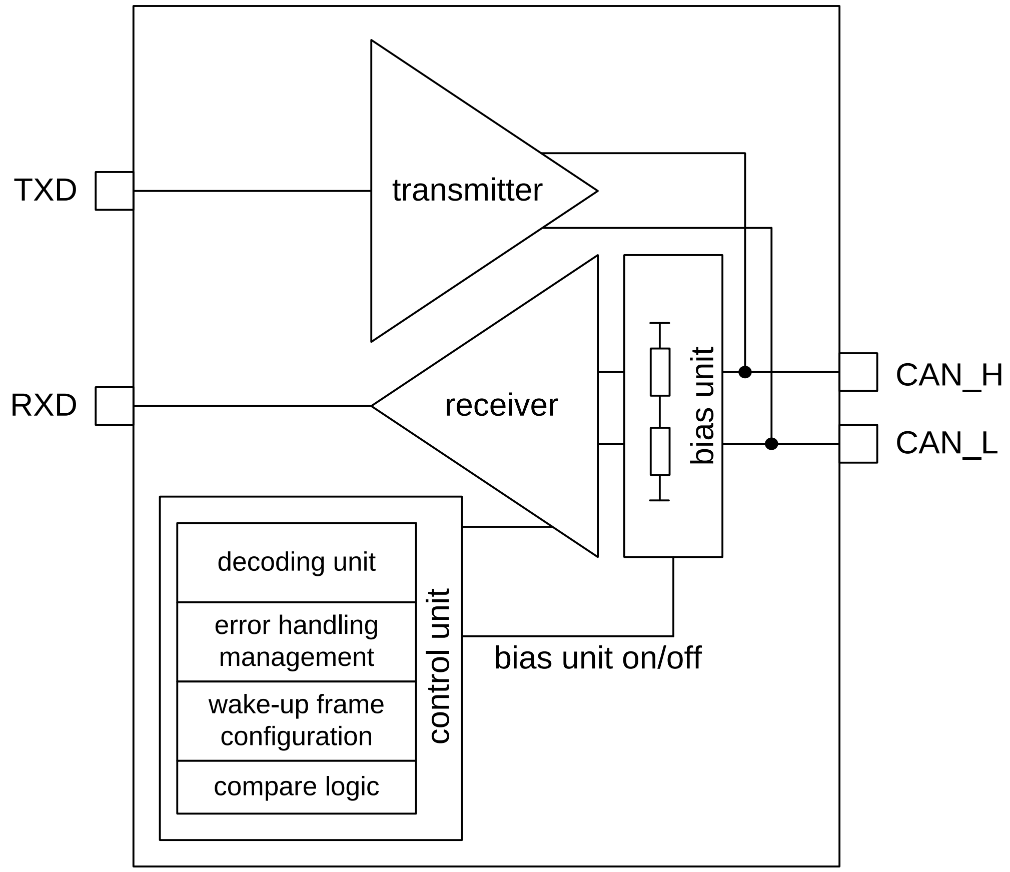


Figure 1 — Functional blocks of a transceiver

4 Symbols and abbreviated terms

ACK	Acknowledge	OSI	Open system interconnection
CAN	Controller area network	PHS	Physical signalling
CRC	Cyclic redundancy check	PL	Physical layer
DLC	Data length code	PMA	Physical medium attachment
EOF	End of frame	SOF	Start of frame
ID	Identifier	WUF	Wake-up frame
MAC	Medium access control	WUP	Wake-up pattern

5 Functional description of medium access unit (MAU) with selective wake-up functionality

5.1 General

A CAN bus system using standard transceiver can have only two bus system states. All nodes are in active state or all nodes are in low-power state. A new partial networking state can be realized, if CAN transceivers with selective wake-up function are used in some or all nodes. It is possible to define a sub-network (partial network) of nodes, which only changes to active state, if they receive a configured wake-up frame.

CAN transceiver with the new selective wake-up function are used to build up such partial networks. CAN transceiver with selective wake-up function change the node state from low-power to active, only if they have received the configured wake-up frame.

CAN transceiver with selective wake-up function are able to recognise and decode CAN messages by an internal CAN decoder. An enhanced voltage biasing function at the CAN bus pins is used in CAN transceiver with selective wake-up function.

Compliance classes

— **Compliant to ISO 11898-6**
A CAN transceiver, which fulfils at least all mandatory requirements out of this document, is in compliance with ISO 11898-6. The compliance shall be approved by the associated conformance test ISO 16845-2.

— **Enhanced voltage biasing compliant to ISO 11898-6**
A CAN transceiver, which fulfils only the requirements of the enhanced voltage biasing at the CAN bus pins, shall be declared with the supplement "Enhanced voltage biasing at the CAN bus according to ISO 11898-6". The compliance of the enhanced voltage biasing function shall be approved by the associated conformance test ISO 16845-2.

This specification discloses the respective hardware functionalities for CAN high speed transceivers with selective wake-up capability.

The transceivers with this capability are fully interoperable with CAN transceivers according to ISO 11898 parts 2 and 5.

5.2 Physical medium attachment sub layer specification

5.2.1 General

As shown in Figure 2 the bus line is terminated by termination network A and termination network B. These terminations are intended to suppress reflections.

Besides this reflection-optimised termination structure, centralised single terminations are possible at limited bit rates and topologies.

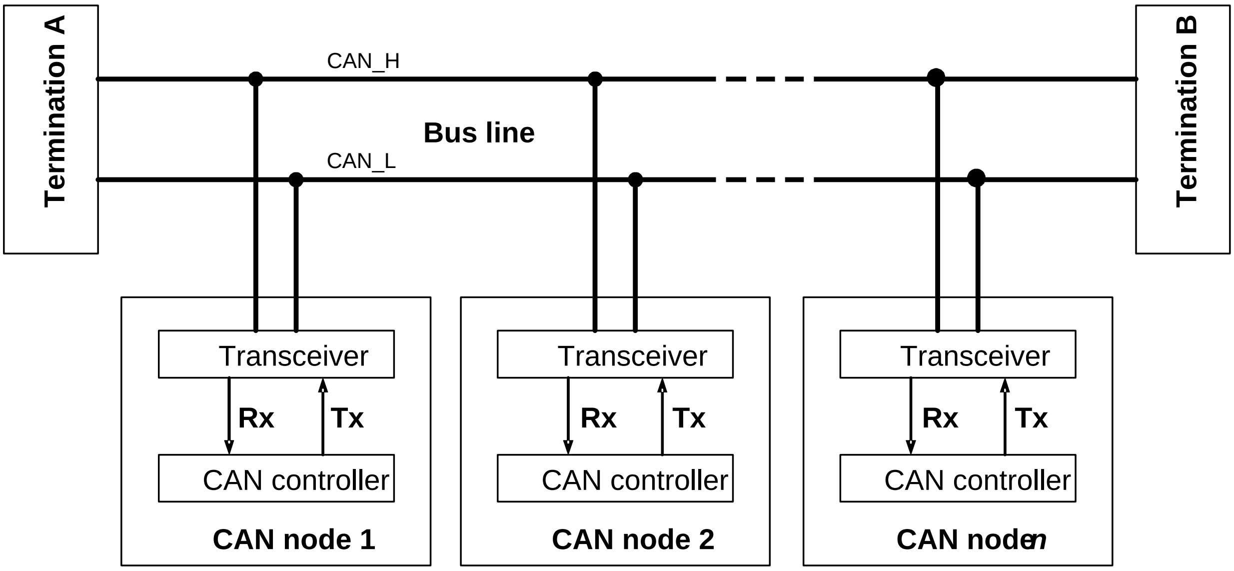


Figure 2 — Suggested electrical interconnection

Two different termination models are recommended within the high-speed medium access unit according to Figure 3:

— Termination with single resistor between CAN_H and CAN_L

— Split termination dividing the single resistor into two resistors with same value in series connection, while the centre tap is connected to a grounding capacitor and optionally to a dedicated split supply.

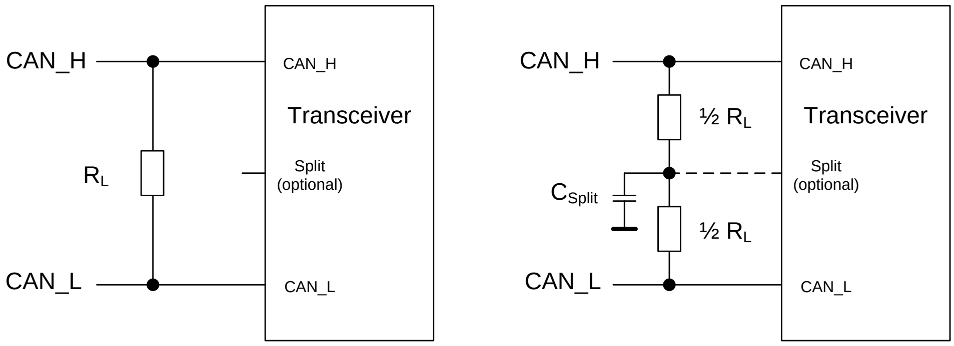


Figure 3 — Termination variants, single resistor termination and split termination

In order to support low-power functionality, two different modes of operation are defined as follows:

— Normal mode The behaviour during normal mode is described within ISO 11898-2

— Low-power mode The low-power mode is split into two sub categories as follows.

  — Without selective wake-up function Described within this document and in ISO 11898-5

  — With selective wake-up function Described within this document

5.2.2 Bus levels during normal mode

The bus can have one of the two logical states: recessive or dominant (see Figure 4).

The bus is in the recessive state, if the bus drivers of all CAN nodes are switched off. In this case the mean bus voltage is generated by the termination and by the high internal resistance of each CAN node's receiving circuitry. In the recessive state, V_{CAN_H} and V_{CAN_L} are fixed to mean voltage level, determined by the bus termination. V_{diff} is less than a maximum threshold. The recessive state is transmitted during bus idle or a recessive bit. Please note that Figure 4 illustrates the maximum allowed differential recessive bus voltage. Typically the differential voltage is about zero volts.

Optionally the recessive bus state may become stabilised making use of a dedicated split termination voltage (V_{Split}). This optional output voltage of physical layer implementations according to ISO 11898-5 may be optionally connected to the center tap of the split termination resistors. Whenever the receiver of a physical layer is not actively biasing towards 2,5 V, the optional V_{Split} shall become floating.

A dominant bit is sent to the bus, if the bus driver of at least one unit is switched on. This induces a current flow through the terminating resistors, and consequently a differential voltage between the two wires of the bus. A differential voltage greater than a minimum threshold represents the dominant state. The dominant state overwrites the recessive state, and is transmitted during a dominant bit.

The dominant and recessive states are detected by transforming the differential voltages of the bus to the corresponding recessive and dominant voltage levels within the receive comparator.

During arbitration, various CAN nodes may simultaneously transmit a dominant bit. In this case V_{diff} exceeds the V_{diff} seen during a single operation. Single operation means that the bus is driven by one CAN node only.

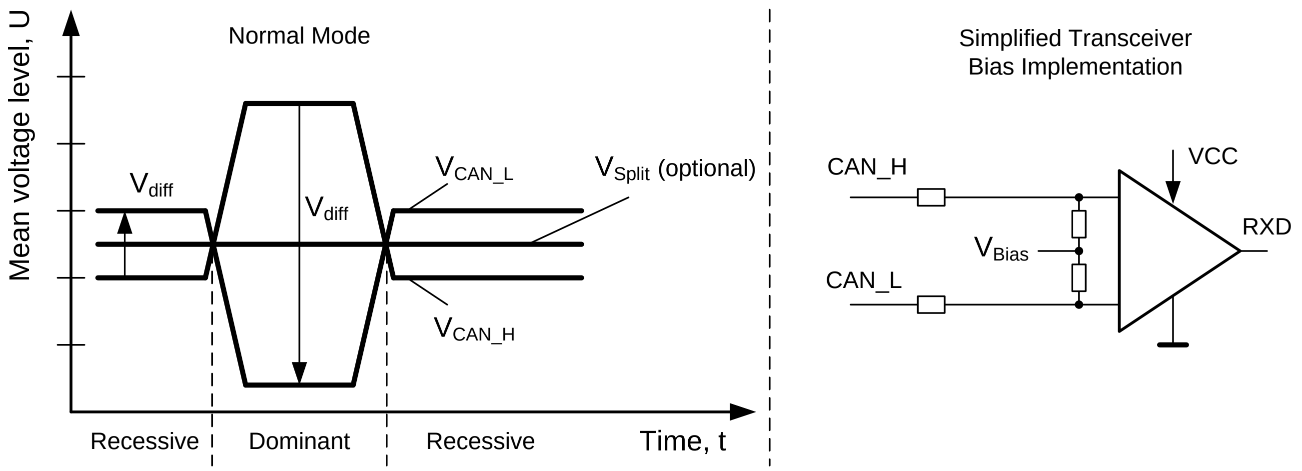


Figure 4 — Physical bit representation and simplified bias implementation

5.2.3 Bus levels during low-power mode

During low-power mode the transmitter is entirely disabled. Within low-power mode of a transceiver, it shall not be possible to actively drive a differential level to the bus lines.

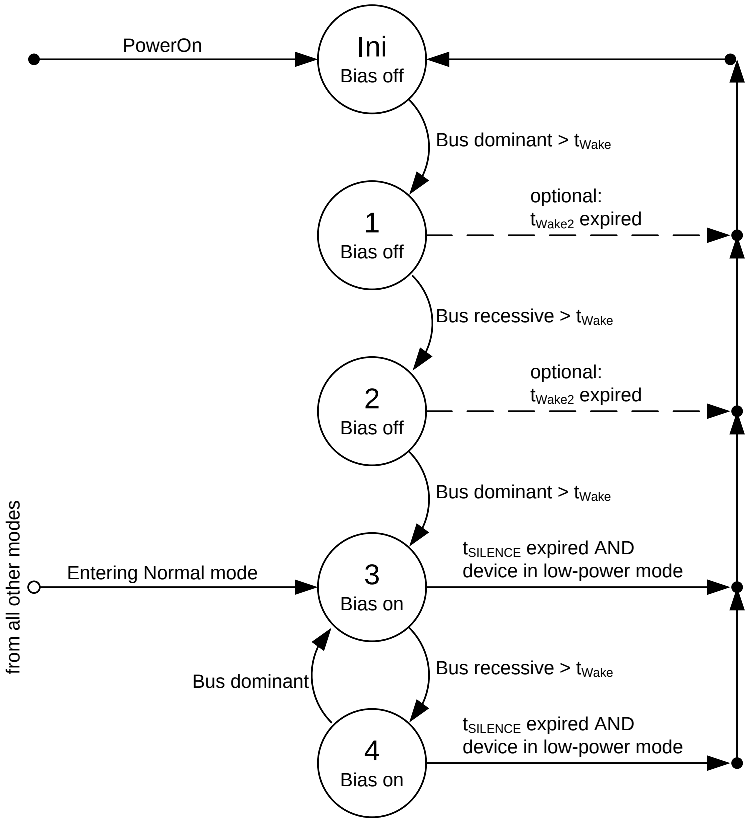
Enhanced voltage biasing in low power mode

Compared to the low-power mode behaviour described in ISO 11898-5, the voltage biasing in low-power mode has changed.

If there has been no activity on the bus for longer than $t_{SILENCE}$, the bus wires shall be biased towards 0V via the internal receiver input resistors R_{IN}.

If wake-up activity on the bus has been detected (WUP definition according to ISO 11898-6), the bus shall be biased to 2,5 V via internal receiver input resistors R_{IN}. The biasing is activated at least after t_{Bias}.

Voltage biasing of the bus lines shall be possible, if the battery supply is connected to the transceiver (even without active VCC supply available).



NOTE The transition from state Ini over 1, 2 to 3 describes a wake-up pattern detection following the definition in ISO 11898-5

Figure 5 — WUP detection and Bias control

The detection of “bus dominant” and “bus recessive” depends on whether the device is in normal mode or low-power mode; in low-power mode the filter time t_{Wake} is applied. When entering states 1 or 2 the optional timer t_{Wake2} is reset and restarts, when entering states 3 or 4 the timer $t_{SILENCE}$ is reset and restarts. The wake-up scenario in Figure 5 shows the biasing behaviour for all operation modes.

From physical point of view there are only the two defined operating conditions possible: Nominal 2,5 V biasing whenever bus communication takes place and with GND biasing whenever the bus communication becomes inactive.

The optional split termination voltage (V_{Split}) is disabled here and shall behave high-ohmic (floating) in order not to increase the current consumption unnecessarily.

5.2.4 Transition from normal to low-power mode

During the transition from normal to low-power mode no wake-up frame shall be lost, if selective wake-up function is enabled.

5.2.5 Wake-up out of low-power mode

5.2.5.1 Wake-up pattern

During low-power mode, a transceiver shall monitor the bus lines CAN_H and CAN_L for wake-up patterns (WUPs). Implementations shall make use of a differential bus comparator monitoring the bus lines.
A WUP is signalled on the bus by two consecutive dominant bus levels for at least t_{Wake}, each separated by a recessive level for at least t_{Wake}. A bus wake-up shall be performed, if the selective wake-up function is disabled or is not supported and a WUP has been received (i.e. being in state 3 or 4, see figure 5).

According to the target bit rate of the system, the individual time thresholds of an implementation can be adapted, but shall stay within the defined minimum and maximum timings as defined in Table 11.

5.2.5.2 Wake-up frame

5.2.5.2.1 General

All CAN frames as they are mentioned below shall follow the definitions in the ISO 11898-1.

A transceiver with selective wake-up function shall monitor the bus lines CAN_H and CAN_L for wake-up frames (WUFs). Implementations supporting this feature shall make use of a differential bus comparator monitoring the bus lines. A bus wake-up shall be performed, if selective wake-up function is enabled and a "valid WUF" has been received. The transceiver may ignore up to four (or up to eight in case of data rate > 500kBaud) consecutive CAN data frames that start after switching on the bias.

A received frame shall be considered as a valid frame in case all of the following conditions are met:

The section 12.4 of the ISO 11898-1 shall not be considered. Instead, the following described physical layer effects including the transmitter baud rate tolerance influencing the bit reception shall be considered. The maximum transmitter baud rate tolerance that can be accepted is device specific. Figure 6 depicts physical layer effects influencing the bit reception under the consumption of 10 consecutive bits containing only one recessive to dominant edge (worst case bit sequence for resynchronisation).

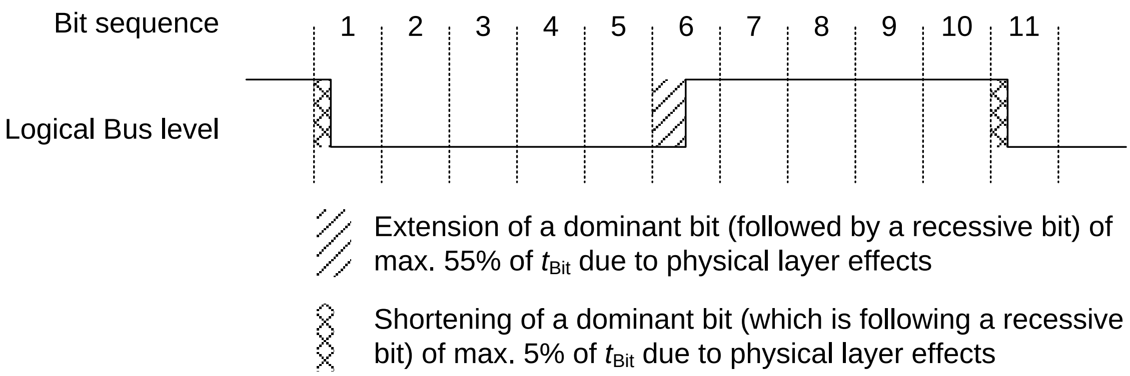


Figure 6 — worst case timings for bit reception

The two explained physical layer effects depicted in Figure 6 may occur independently of each other.

The maximum shortening of a dominant bit (which is following a recessive bit) described in Figure 6 is constant (except the ACK bit) for and each dominant bit (which is following a recessive bit) in one frame (without loss of arbitration).

A received frame is a “valid WUF” in case all of the following conditions are met:

— The received frame is a “valid frame” according to the definition above.

— The ID (as defined in sub clause 8.4.2.2 in ISO 11898-1) of the received frame is exactly matching a configured ID in the relevant bit positions. The relevant bit positions are given by an ID mask. The ID and the ID mask might have either 11 bits or 29 bits.

— The DLC (as defined in sub clause 8.4.2.3 in ISO 11898-1) of the received frame is exactly matching a configured DLC.

— In case DLC is greater than 0, the data field (as defined in sub clause 8.4.2.4 in ISO 11898-1) of the received frame has at least one bit set in a bit position, where also in the configured data mask in the corresponding bit position the bit is set.

— No error exists according to sub clause 10.9 in ISO 11898-1 excepting errors which are signalled in the ACK field and EOF field. Figure 7 depicts the bits which are seen as don’t care.

— The frame is not a remote frame (RTR Bit = 0)

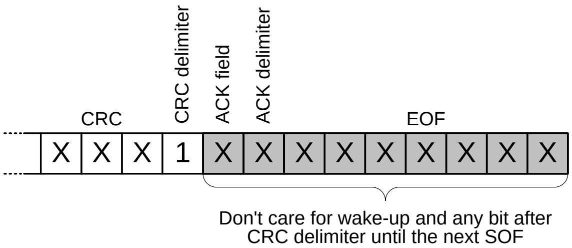


Figure 7 — Don't care bits for frame decoding

5.2.5.2.2 Frame error counter mechanism

A counter for erroneous frames shall be set to zero, on enabling the selective wake-up function and on expiration of $t_{SILENCE}$. The initial value of the counter is zero. This counter shall be incremented by one, when a bit stuffing, CRC or form error according to ISO 11898-1 is detected. If a frame has been received that is valid according to the definition in 5.2.5.2.1 and the counter is not zero, then the counter shall be decremented by one. Errors between CRC delimiter and end of intermission may be ignored. If the counter has reached a value of 31, the following actions shall be performed on the next increment of this counter: selective wake-up function shall be disabled and bus wake-up shall be performed.

Up to four consecutive CAN data frames that start after switching on the bias might be either ignored (no error counter increase in case of failure) or judged as erroneous (error counter increase even in case of no error).

On each increment or decrement of the counter the decoder unit in the transceiver shall wait for at least 6 and at most 10 recessive bits before considering a dominant bit as a new start of frame. Figure 8 depicts the position of the mandatory SOF detection in case of a received CAN data frame and in case of an error scenario.

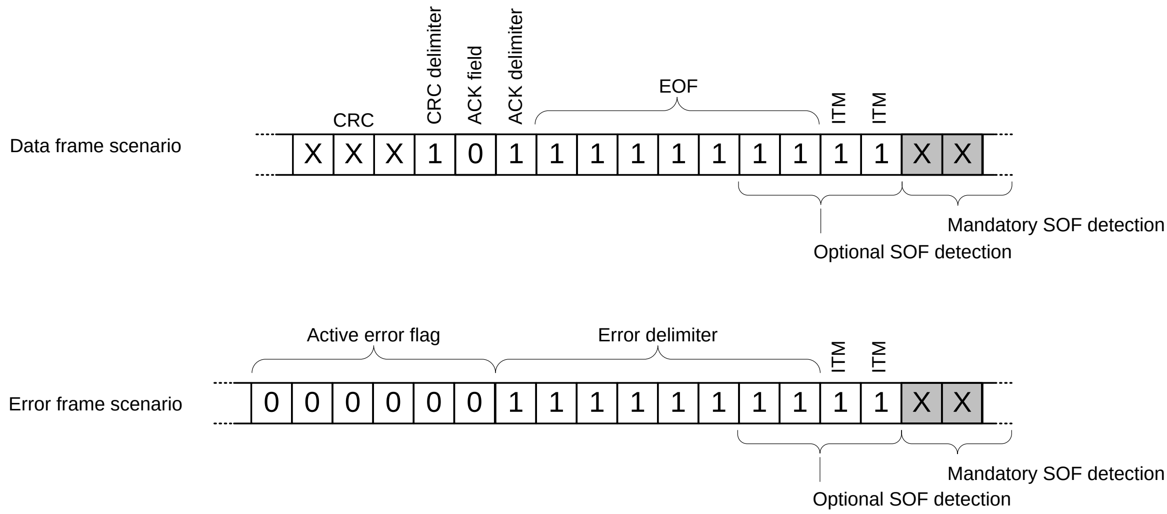


Figure 8 — Mandatory SOF detection after CAN data frame and error scenario

5.2.5.2.3 WUF ID evaluation

The transceiver shall support standard and extended CAN IDs to be configured as WUF. An additional CAN-ID mask mechanism shall be supported to exclude ID-bits from comparison.

All masked ID bits except "do not care" have to match exactly programmed ID bits. If the masked ID bits are programmed as "do not care" then both "1" or "0" will be accepted inside the ID.

"1" or "0" are acceptable as "do not care" in the mask register.

Figure 9 shows an example for valid WUF IDs correspond to the ID Mask register.

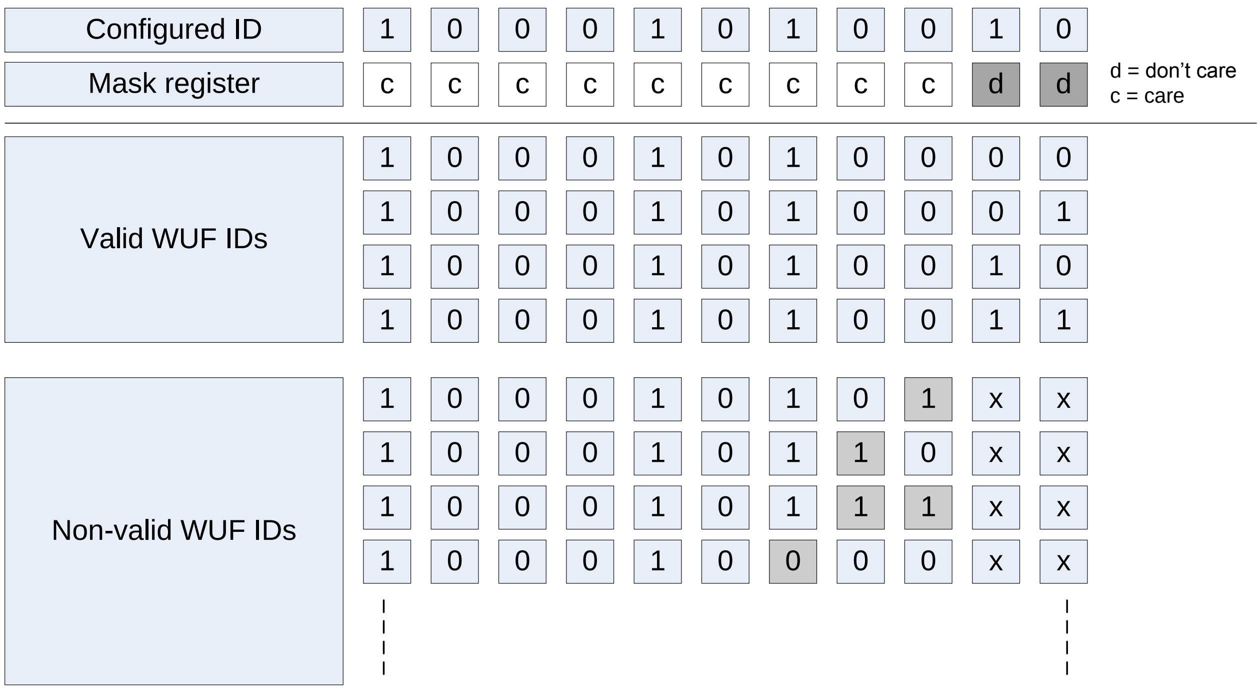


Figure 9 — Example for ID masking mechanism

5.2.5.2.4 WUF DLC evaluation

A frame can only be a valid WUF, in case the DLC of the received frame matches exactly the configured DLC.

5.2.5.2.5 WUF data field evaluation

A frame can only be a valid WUF if at least one logic “1” bit within the data field of the received WUF matches to a logic “1” of the data field within the configured WUF.

Figure 10 shows an example with a none-matching and a matching ID field.

	Byte 7	Byte 6	......	Byte 0
Configured data field	1 1 0 1 0 0 0 0	1 1 0 1 0 0 0 0	......	1 1 0 1 0 0 0 0
WUF data fields — matching	0 0 0 1 0 0 0 0	0 0 0 0 0 0 0 0	......	0 0 0 0 0 0 0 0
WUF data fields — None matching	0 0 0 0 0 1 1 1	0 0 0 0 0 1 1 1	......	0 0 0 0 0 1 1 1

Figure 10 — Example of the data field within the received CAN frame

With this mechanism it is possible to wake-up up to 64 independent groups of transceivers with only one wake-up frame.

5.2.6 Systems with unpowered nodes

In order to allow undisturbed CAN communication in systems, which have a couple of nodes intentionally unpowered (e.g. ignition key controlled modules) while other nodes continue to communicate normally, it is important that these unpowered nodes do affect the bus levels as little as possible. This requires that transceivers, which are temporarily unpowered, show a lowest possible leakage current to the bus lines inside the still communicating system. The lower the leakage current in unpowered case, the better the system performance in the permanently supplied part of the network.

Depending on the target application (permanently supplied or temporarily unsupplied) the max. leakage parameter according to Table 4 can be tolerated (permanently supplied nodes) or should be reduced as far as possible (temporarily unsupplied nodes).

Note: In contrast to a low-power mode, where the device is still supplied, unpowered means a physical disconnection from the power supply.

6 Conformance tests

The conformance test case definition and measurement setups to derive the parameter are defined in ISO ISO16845-2 [cp. chapter 2].

7 Electrical specification of high-speed medium access unit (HS-MAU)

7.1 Physical medium attachment sub layer specification

7.1.1 General

All data given in Table 1 through Table 10 are independent of a specific physical layer implementation. The parameters specified in these tables shall be fulfilled throughout the operating temperature range as specified for every individual CAN node.

7.1.2 Bus levels

7.1.2.1 Common mode voltages

The parameters specified in Table 1 to Table 6 apply when all CAN nodes are connected to a correctly terminated bus.

Table 1 — System bus voltage parameters for reception of recessive state, biasing on

Parameter	Notation	Unit	Value			Condition
			min.	nom.	max.	
Common mode bus voltage	V_{CAN_H}	V		2,5	12,0	Measured with respect to the individual ground of each CAN node
	V_{CAN_L}	V	- 12,0	2,5		
Differential bus voltage [a]	V_{diff}	mV	- 120	0	12	Measured at each CAN node connected to the bus.

[a] The differential bus voltage is determined by the output behaviour of all CAN nodes during the recessive state. Therefore V_{diff} is approximately zero (see Table 8). The min. value is determined by the requirement that a single bus driver shall be able to represent a dominant bit by a min. value of V_{diff} = 1,2 V

Table 2 — System bus voltage parameters for reception of dominant state, biasing on

Parameter	Notation	Unit	Value			Condition
			min.	nom.	max.	
Common mode bus voltage [a]	V_{CAN_H}	V		3,5	12,0	Measured with respect to the individual ground of each CAN node
	V_{CAN_L}	V	- 12,0	1,5		
Differential bus voltage [b]	V_{diff}	V	1,2	2,0	3,0	Measured at each CAN node connected to the bus.

[a] The min. value of V_{CAN_H} is determined by the min. value of V_{CAN_L} plus the min. value of V_{diff}. The max. value of V_{CAN_L} is determined by the max. value of V_{CAN_H} minus the min. value of V_{diff}.

[b] The bus load increases as CAN nodes are added to the network, by R_{diff}. Consequently, V_{diff} decreases. The min. value of V_{diff} determines the number of CAN nodes allowed on the bus. The max. value of V_{diff} is specified by the upper limit during arbitration.

Table 3 — System bus voltage parameters for low-power mode, biasing off

Parameter	Notation	Unit	Value			Condition
			min.	nom.	max.	
Common mode bus voltage	V_{CAN_H}	V		0	12,0	Measured with respect to the individual ground of each CAN node
	V_{CAN_L}	V	- 12,0	0		
Differential bus voltage[a)]	V_{diff}	mV	- 120	0	12	Measured at each CAN node connected to the bus.

[a)]The differential bus voltage is determined by the output behaviour of all CAN nodes during the low-power mode. Therefore V_{diff} is approximately zero (see Table 8). The min. value is determined by the requirement that a single bus driver shall be able to represent a dominant bit by a min. value of V_{diff} = 1,2 V.

7.1.2.2 Disturbance by coupling

The tolerated disturbances of CAN_H and CAN_L by coupling are defined in accordance with ISO 7637-3:1990, test pulses 3a and 3b.

7.2 CAN Transceiver

7.2.1 General

Table 4 — Transceiver input current, unpowered device

Parameter	Notation	Unit	Value			Condition
			min.	nom.	max.	
Input leakage current	I_{CAN_H}	µA	0	-	10	U_{BUS} = 5 V, U_{Supply} = 0 V [a)]
	I_{CAN_L}	µA	0	-	10	

[a)] In case of multiple supply inputs provided by the implementation, all supply inputs shall carry 0 V with respect to GND.

Table 5 — Transceiver's driver symmetry, normal mode

Parameter	Notation	Unit	Value			Condition
			min.	nom.	max.	
Driver Symmetry $V_{CAN\_H} + V_{CAN\_L}$	V_{SYM}	VCC	0,9	1,0	1,1	R_L = 120 Ω / tol .< 1 %, C_{Split} = 4,7 nF / 5 %, f_{TXD} = 250kHz, input impedance of oscilloscope: $\leq$20 pF / $\geq$ 1 MΩ

7.2.2 Transceiver input and output levels

Table 6 — Transceiver split pin output voltage, optional

Parameter	Notation	Unit	Value min.	Value nom.	Value max.	Condition
Split output voltage, normal mode Loaded Condition	V_{Split_l}	VCC	0,3	0,5	0,7	-500µA < I_{Split} < +500 µA
Split output voltage, normal mode Unloaded Condition	V_{Split_u}	VCC	0,45	0,5	0,55	$R_{Measure} \geq 1$ MΩ
Split leakage current, low-power mode	I_{Split}	µA	-	0	5	-12V < U_{Split} < +12 V

Table 7 — Transceiver maximum ratings of V_{CAN_L}, V_{CAN_H} and optional V_{Split}

Nominal battery voltage *V*	Notation	Voltage *V* min.	Voltage *V* max.
14	V_{CAN_H}	- 27,0	+40,0
	V_{CAN_L}	- 27,0	+40,0
	V_{Split}	- 27,0	+40,0
28	V_{CAN_H}	- 58,0	+58,0
	V_{CAN_L}	- 58,0	+58,0
	V_{Split}	- 58,0	+58,0
42	V_{CAN_H}	- 58,0	+58,0
	V_{CAN_L}	- 58,0	+58,0
	V_{Split}	- 58,0	+58,0
Notes to the ratings: — undisturbed operation does not have to be guaranteed; — no destruction of bus driver circuit; no time limit.			

The parameters given in Table 8 to Table 10 shall be tested at the CAN_L and CAN_H pins of each CAN node, according to the conformance tests as specified in Clause 6 of the ISO 11898-5 and chapter 6 of the ISO 11898-2.

Table 8 — Transceiver DC parameters for recessive state

Parameter	Notation	Unit	Value min.	Value nom.	Value max.	Condition
Output bus voltage, normal mode and low-power mode before $t_{SILENCE}$ has expired	V_{CAN_H}	V	2,0	2,5	3,0	no load [d)]
	V_{CAN_L}	V	2,0	2,5	3,0	
Output bus voltage, low-power mode after $t_{SILENCE}$ has expired	V_{CAN_H}	V	-0,1	0	0,1	no load
	V_{CAN_L}	V	-0,1	0	0,1	

Parameter	Notation	Unit	Value			Condition
			min.	nom.	max.	
Differential output bus voltage	V_{diff}	mV	- 500	0	50	no load
Differential input voltage, normal mode [a)]	V_{diff_N}	V			0,5	[b) c)]
Differential input voltage, low-power mode [c)]	V_{diff_LP}	V			0,4	[b) c)]

[a)] The threshold for receiving the dominant and recessive bits ensures a noise immunity of 0,3 V and 0,5 V respectively. The lower value for the dominant state is motivated by the fact that a lower load resistance between CAN_H and CAN_L is seen (the capacitance of the supply voltage source is the reason that the internal resistance of the bus driver driving the dominant bit is connected in parallel to the bus load resistance).

[b)] Range for receiving a recessive bit.

[c)] Reception shall be ensured within the common mode voltage range specified in Table 1 and Table 2 respectively.

[d)] Due to EMC requirements a certain matching between CAN_H and CAN_L is required (see also Table 5). Thus, the min. value on one CAN wire cannot appear in the same time with a max. value on the other CAN wire.

Table 9 — Transceiver bus input resistance

Parameter	Notation	Unit	Value			Condition
			min.	nom.	max.	
Differential internal resistance	R_{diff}	kΩ	10		100	normal mode, no load [a)]
Differential internal resistance	R_{diff}	kΩ	10		200	low-power mode, no load [a)]
Internal resistor [b)]	R_{in}	kΩ	5		50	normal mode
Internal resistor [b)]	R_{in}	kΩ	5		100	low-power mode

[a)] For CAN nodes with an integrated terminating resistor, R_L is seen between CAN_H and CAN_L instead of R_{diff}.

[b)] R_{in} of CAN_H and CAN_L should have almost the same value. The deviation shall be less than 3 % relative to each other.

Table 10 — Transceiver DC parameters for dominant state

Parameter	Notation	Unit	Value			Condition [a]
			min.	nom.	max.	
Output bus voltage, normal mode [d]	V_{CAN_H}	V	2,75	3,5	4,5	load $R_L/2$
	V_{CAN_L}	V	0,5	1,5	2,25	
Differential output voltage, normal mode	V_{diff}	V	1,5	2,0	3,0	load $R_L/2$
Differential input voltage, normal mode [b]	V_{diff}	V	0,9			load $R_L/2$ [c]
Differential input voltage, low-power mode	V_{diff}	V	1,15			load $R_L/2$ [c]

[a] The load is connected between CAN_H and CAN_L. For a CAN node without integrated terminating resistor (normal use), this resistor is a $R_L/2$ resistor. For CAN nodes with an integrated terminating resistor, this is a R_L resistor. In this case, R_L is seen between CAN_H and CAN_L instead of R_{diff}.

[b] The threshold for receiving the dominant and recessive bits ensures a noise immunity of 0,3 V and 0,5 V respectively. The lower value for the dominant state is motivated by the fact that a lower load resistance between CAN_H and CAN_L is seen (the capacitance of the supply voltage source is the reason that the internal resistance of the bus driver driving the dominant bit is connected in parallel to the bus load resistance).

[c] Range for receiving a dominant bit. Reception shall be ensured within the common mode voltage range specified in Table 1 and Table 2 respectively.

[d] Due to EMC requirements a certain matching between CAN_H and CAN_L is required (see also Table 5). Thus, the min. value on one CAN wire cannot appear in the same time with a max. value on the other CAN wire.

7.2.3 Illustration of voltage range

Load conditions are defined within the Table 1 through Table 10. Figure 11 to Figure 14 illustrate the valid voltage ranges of V_{CAN_H} and V_{CAN_L}.

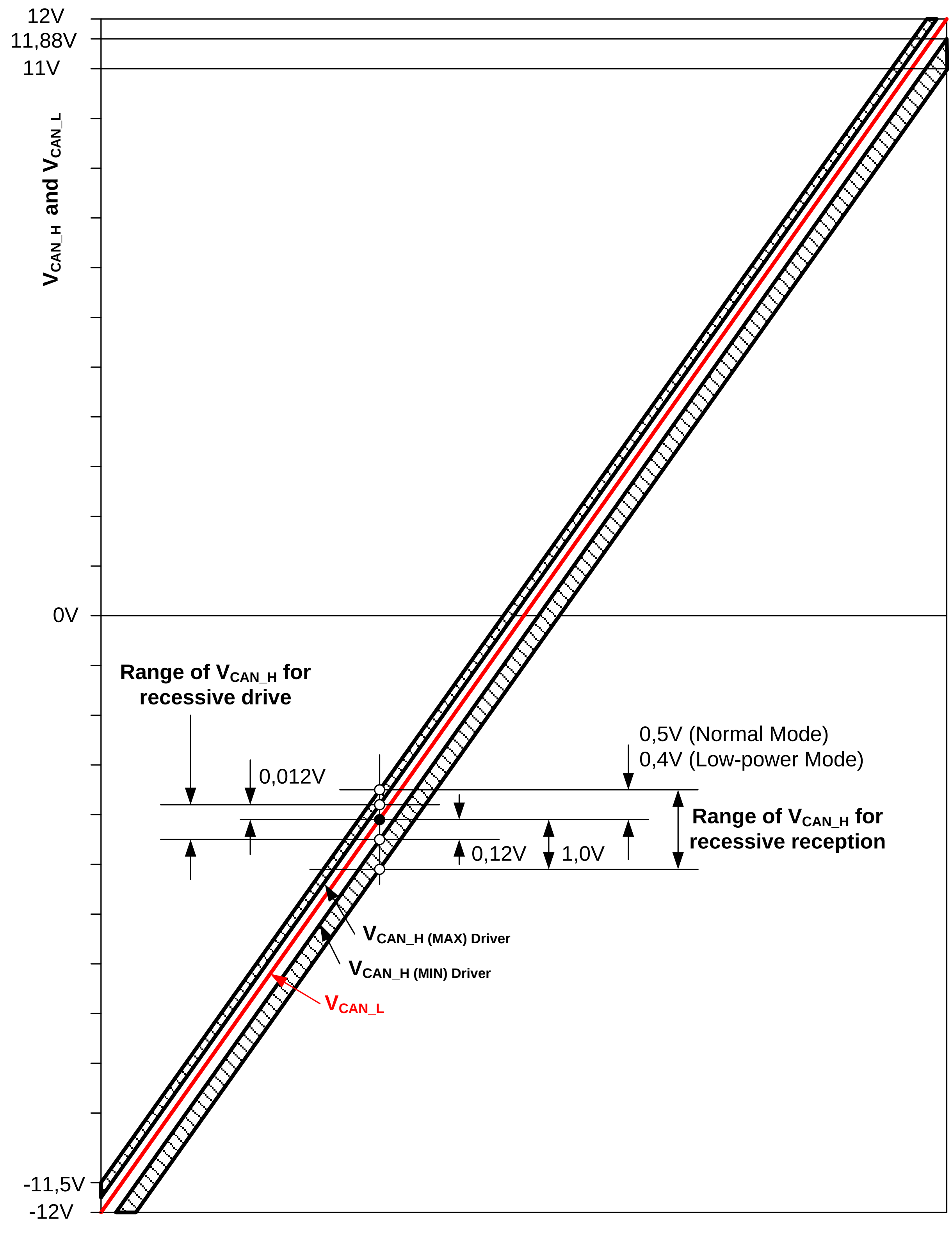


Figure 11 — Valid voltage range of V_{CAN_H} for monitoring recessive bus state and for disconnected CAN node, if V_{CAN_L} varies from min. to max. common mode range of bus

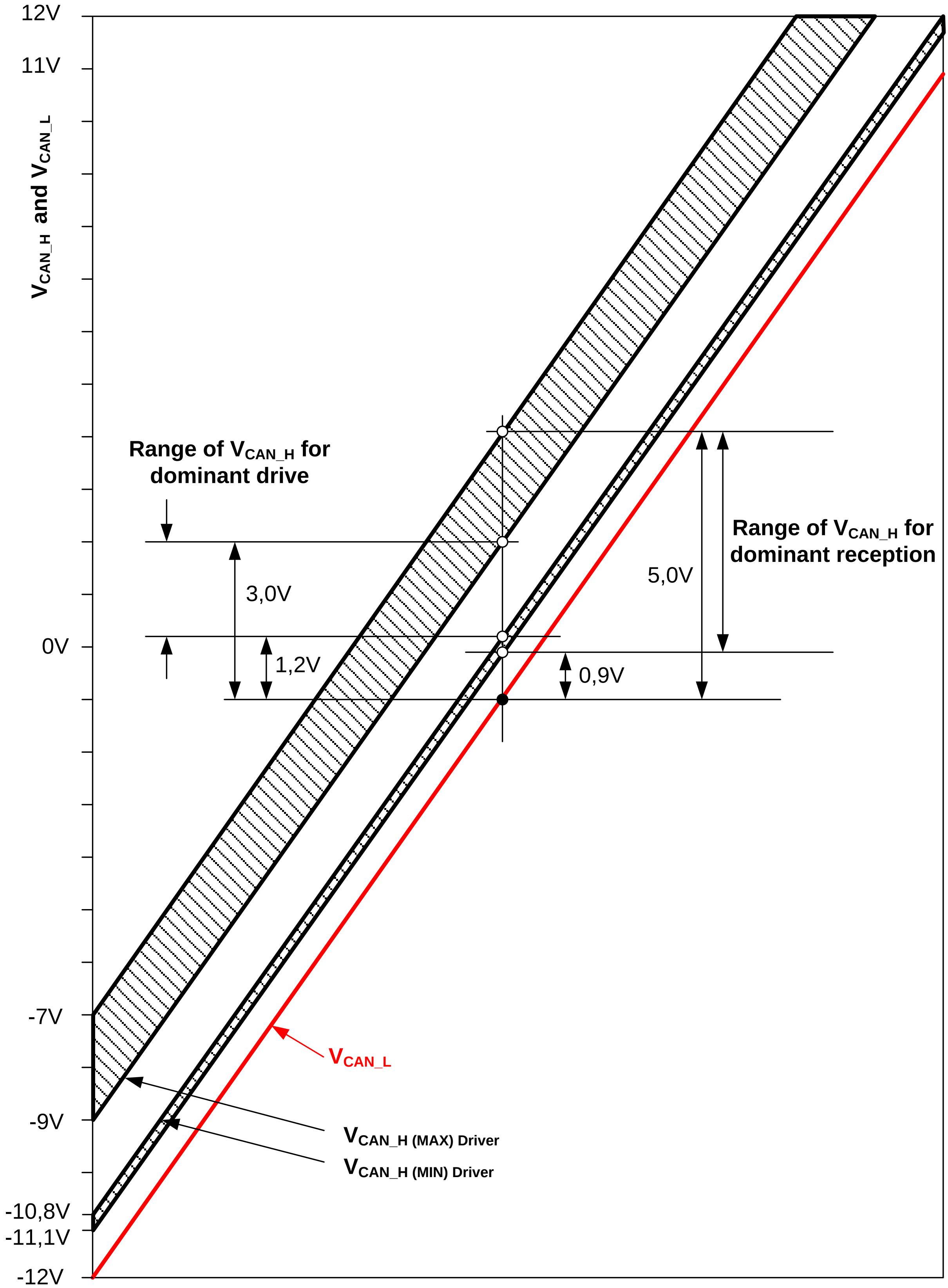


Figure 12 — Valid voltage range of V_{CAN_H} for monitoring dominant bus state and for disconnected CAN node, if V_{CAN_L} varies from min. to max. common mode range of bus during normal mode

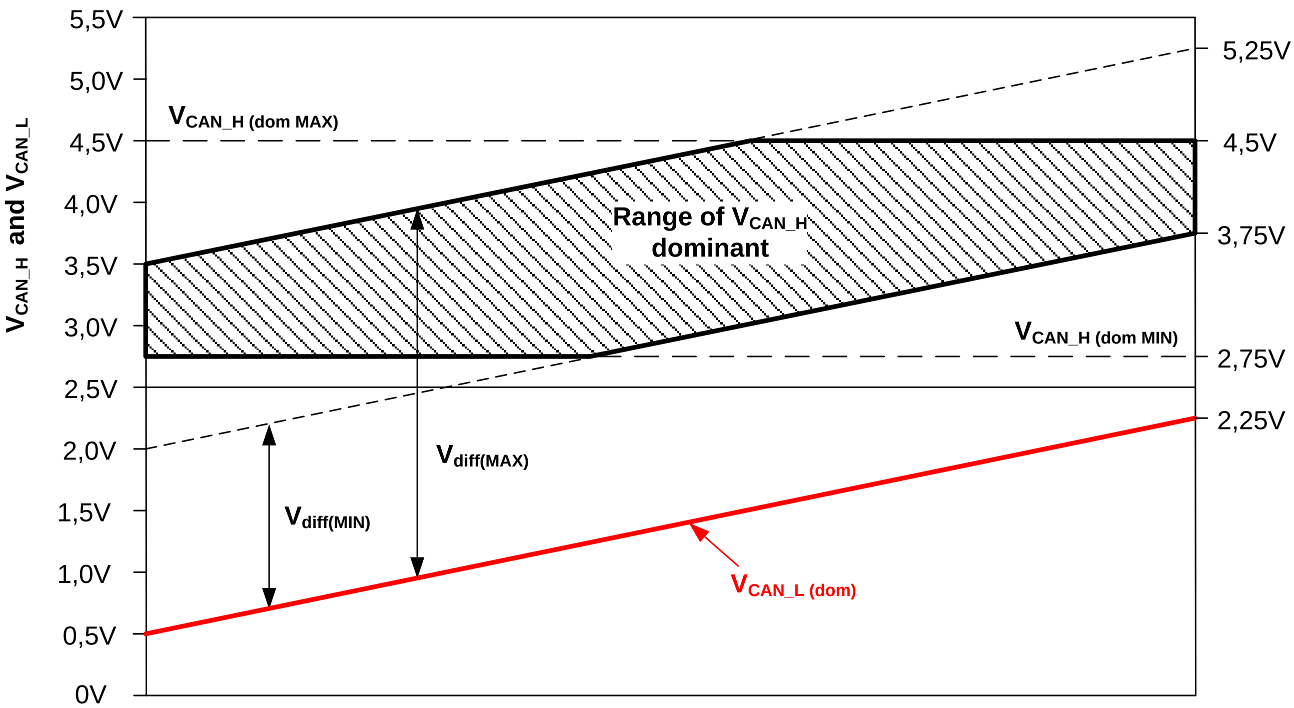


Figure 13 — Valid voltage range of V_{CAN_H} during dominant state of CAN node which is disconnected from bus, if V_{CAN_L} varies from min. to max. voltage level during normal mode

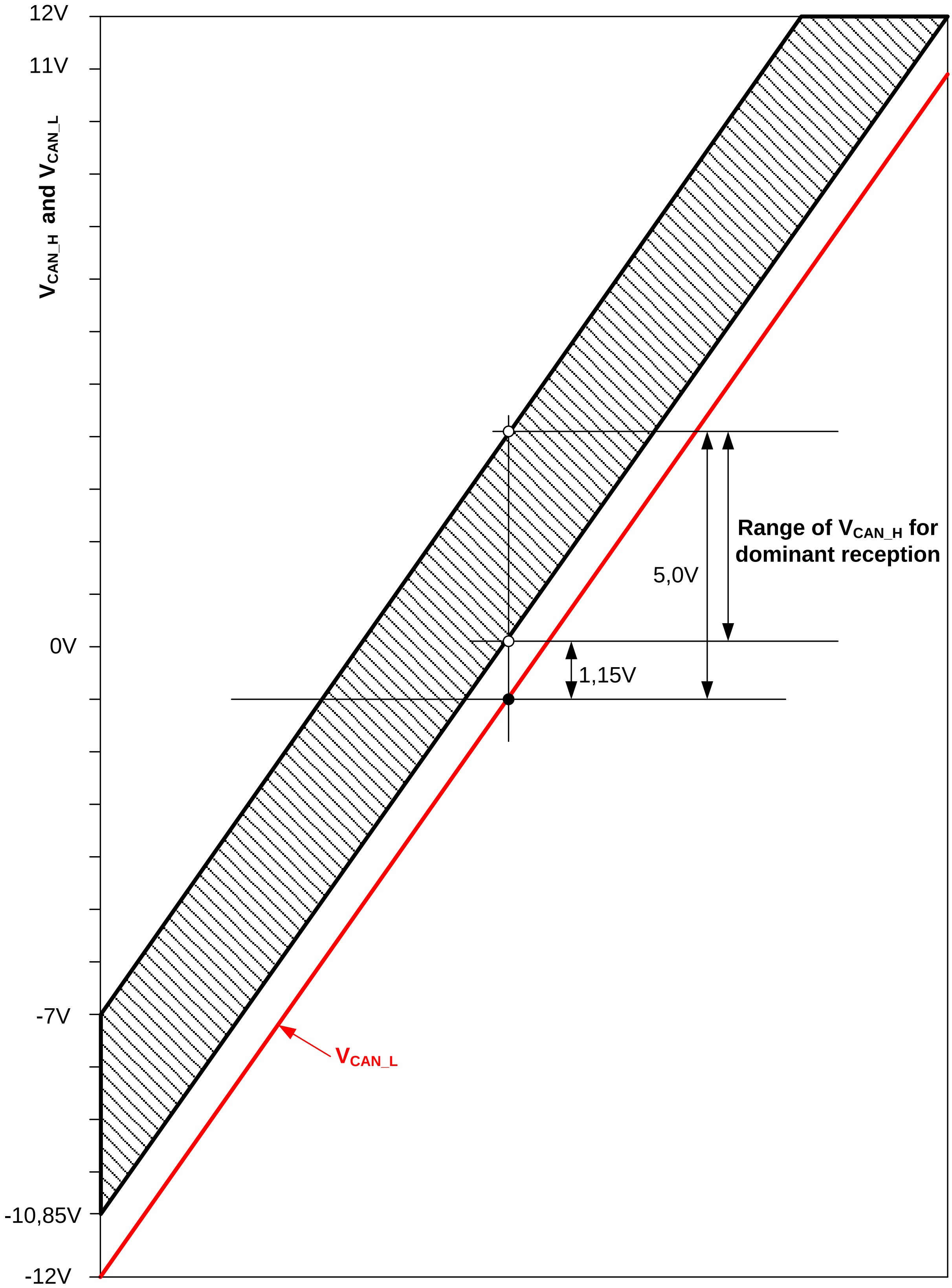


Figure 14 — Valid voltage range of V_{CAN_H} for monitoring dominant bus state and for disconnected CAN node, if V_{CAN_L} varies from min. to max. common mode range of bus during low-power mode

7.2.4 AC Parameters

The parameters given in Table 11 shall be tested at the CAN_L and CAN_H pins of each CAN node, according to conformance tests 6.6 within ISO 11898-2, 6.5 and 6.6 described within ISO 11898-5.

Table 11 — Transceiver AC parameters

Parameter	Notation	Unit	Value			Condition
			min.	nom.	max.	
Bit time	t_B	µs	1			[a]
Propagation delay TXD to RXD rec. to dom. / dom. to rec. [d]	t_{Prop}	ns	-		255	normal mode, load R_L = 120 Ω, C_L = 100 pF, C_{RXD} = 15 pF, f_{TXD} = 250 kHz
Wake-up filter time, dominant bus	t_{Wake}	µs	0,5		5 [e]	low-power mode, R_L = 120 Ω, U_{CM} according Table 2 (min and max. common mode bus voltage), / has to guarantee a differential dominant voltage according to Table 2 with a variable pulse length $t_{Pulse} = t_{Wake(min)} \dots t_{Wake(max)}$
Bias reaction time	t_{Bias}	µs			200	load R_L = 120 Ω, C_L = 100 pF, C_{GND} = 100 pF
Wake-up time out	t_{Wake2}	ms	0,5		10	This parameter is optional.
Timeout for bus inactivity	$t_{SILENCE}$	s	0,6		1,2	
Internal capacitance	C_{in}	pF		20		1 Mbit/s [c]
Differential internal capacitance[b]	C_{diff}	pF		10		1 Mbit/s

[a] The min. bit time corresponds to a max. bit rate of 1 Mbit/s. The lower end of the bit rate depends on the protocol IC or an optional permanent dominant detection circuitry preventing a permanently dominant clamped bus.

[b] In addition to the internal capacitance restriction, a bus connection should also have as low an inductance as possible. This is particularly important for high bit rates. The min. values of Cin and Cdiff may be zero. The max. tolerable values are determined by the bit timing and the network topology parameters. Proper functionality is guaranteed if occurring cable-reflected waves do not suppress the dominant differential voltage levels below Vdiff = 0,9 V and do not increase the recessive differential voltage level above Vdiff = 0,5 V at each individual CAN node (see Table 8 and Table 10).

[c] measured at CAN_H and CAN_L referring to ground

[d] Can only be checked directly, if there is access to the TXD / RXD interface. Within integrated CAN nodes, this parameter has to be measured indirectly. C_L is chosen to emulate a typical transceiver loading caused by a typical bus cable and thus, is suitable for representative propagation measurements.

[e] It should be noted that the max. filter time has an impact to the suitable wake-up messages, especially at high baud rates. For e.g. a 500kBit/s system a message needs to carry at least 3 similar bit levels in a row in order to safely pass the wake-up filter. Shorter filter time implementations might increase the risk for unwanted bus wake-ups due to noise. The specified range is a compromise between robustness against unwanted wake-ups and freedom in message selection.