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Road vehicles – Controller area network (CAN) – Part 2: High-speed medium access unit

Véhicules routiers – Controller area network (CAN) – Partie 2 : Unité d'accès au médium haute vitesse

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Contents

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.

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.

This part of ISO 11898 was prepared by Technical Committee ISO/TC 22 ***Road vehicles***, Sub-Committee 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***

Introduction

The ISO 11898 was firstly published 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 including the Logical Link Control (LLC) sublayer and the Medium Access Control (MAC) sublayer as well as the physical signalling (PLS sublayer), and

- part 2 defines the high-speed Medium Access Unit (MAU).

Part 1 and part 2 are equal to the “old” ISO 11898 standard.

Road vehicles – Controller area network (CAN) – Part 2 : High-speed medium access unit

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 (MAU) functions as well as some medium dependent interface (MDI) features according to ISO 8802-3.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 11898~~International Standard~~. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard 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 7637-3:1990, Road vehicles – Electrical disturbances by conduction and coupling – Part 3: Vehicles with nominal 12 or 24 V supply voltage – Electrical transient transmission by capacitive and inductive coupling via lines other than supply lines

ISO/IEC 8802-3:1993, Information technology - Local and metropolitan area networks - Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications.

ISO/CD 11898-1:1999, Road vehicles – Interchange of digital information on controller area network (CAN) – Part 1: data link layer and medium access control.

3 Terms and definitions

For the purpose of this part of ISO 11898, the following terms and definitions apply.

3.1
bus voltage
V_{CAN_L} and V_{CAN_H} denoting the voltages of the bus line wires CAN_L and CAN_H relative to ground of each individual CAN node

3.2
common mode bus voltage range
Boundary voltage levels of V_{CAN_L} and V_{CAN_H}, for which proper operation is guaranteed if up to the maximum number of CAN nodes are connected to the bus

3.3
differential internal capacitance, C_{diff} (of a CAN node)
Capacitance seen between CAN_L and CAN_H during the recessive state when the CAN node is disconnected from the bus

3.4
differential internal resistance, R_{diff} (of a CAN node)
Resistance which is seen between CAN_L and CAN_H during the recessive state when the CAN node is disconnected from the bus

3.5
differential voltage, V_{diff} (of CAN bus)
Differential voltage of the two-wire CAN bus, value $V_{diff} = V_{CAN\_H} - V_{CAN\_L}$

3.6
internal capacitance, C_{in} (of a CAN node)
Capacitance seen between CAN_L (or CAN_H) and ground during the recessive state when the CAN node is disconnected from the bus

3.7
internal delay time, t_{node} (of a CAN node)
Sum of all asynchronous delay times occurring on the transmitting and receiving path relative to the bit timing logic unit of the protocol IC of each individual CAN node disconnected from the bus

3.8
internal resistance, R_{in} (of a CAN node)
Resistance which is seen between CAN_L (or CAN_H) and ground during the recessive state when the CAN node is disconnected from the bus

3.9
physical layer
Electrical circuit realization (bus comparator and bus driver) that connects a CAN node to a bus, it consists of analogue circuitry and digital circuitry, interfacing between the analogue signals on the CAN bus and the digital signals inside the CAN node

Note - The total number of CAN nodes connected on a bus is limited by electrical loads on the bus.

3.10
physical media (of the bus)
Pair of parallel wires, shielded or unshielded, dependent on EMC requirements

Note - The individual wires are designated as CAN_L and CAN_H. The names of the corresponding pins of CAN nodes are also denoted by CAN_L and CAN_H respectively. 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.

4 Abbreviations

CAN Controller Area Network

IC Integrated Circuit

MDI Medium Dependent Interface

HS-MAU High-Speed Medium Access Unit

MAU Medium Access Unit

5 Functional description of Medium Access Unit (MAU)

5.1 General

The following description is valid for a two-wire differential bus. The values of the voltage levels, the resistances and the capacitances as well as the termination network are described in 7 and 8.

5.2 Physical medium attachment sublayer specification

5.2.1 General

As shown in figure 1 the bus line is terminated by termination network A and termination network B. These termination suppresses reflections. The locating of the termination within a CAN node should be avoided because the bus lines lose termination if this CAN node is disconnected from the bus line.

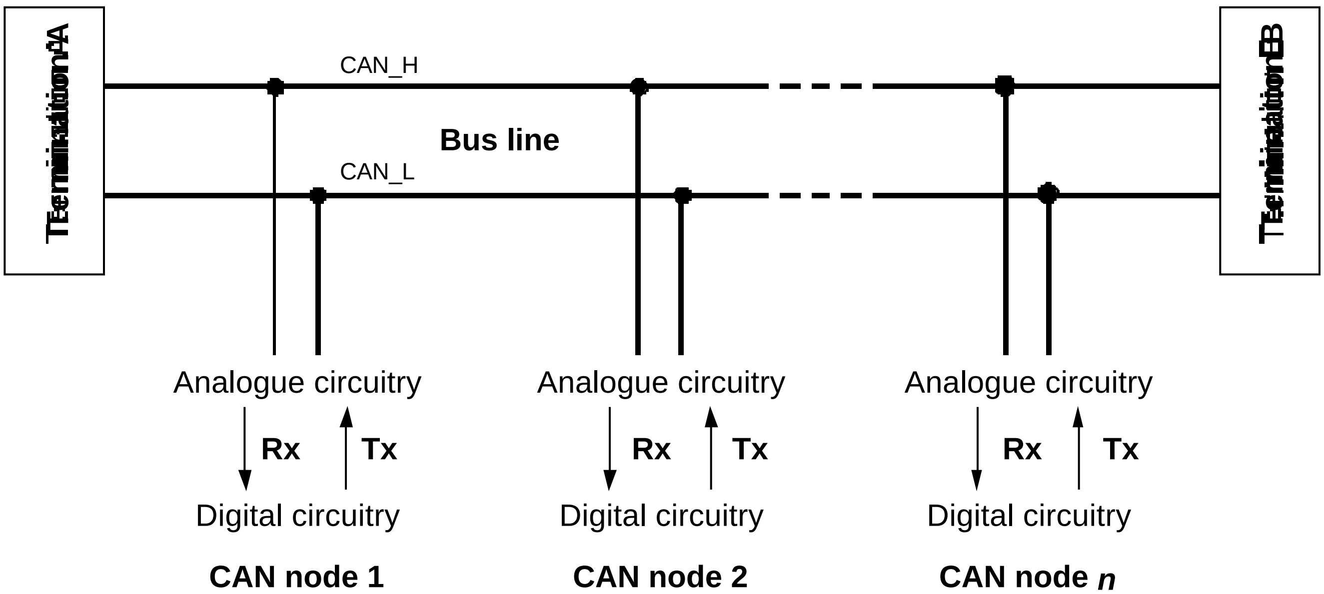


Figure 1 — Suggested electrical interconnection

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.

A »dominant« bit is sent to the bus if the bus drivers of at least one unit are switched on. This induces a current flow through the terminating resistors, and consequently a differential voltage between the two wires of the bus.

The dominant and recessive states are detected by transforming the differential voltages of the bus to the corresponding »recessive« and »dominant« voltage levels at the comparator input of the receiving circuitry.

5.2.2 Bus levels

5.2.2.1 The bus can have one of the two logical states: »recessive« or »dominant« (see figure 2).

In the recessive state, $V_{\text{CAN\_H}}$ and $V_{\text{CAN\_L}}$ 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.

The dominant state is represented by a differential voltage greater than a minimum threshold. The dominant state overwrites the recessive state, and is transmitted during a »dominant« bit.

5.2.2.2 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 operations means that the bus is driven by one CAN node only.

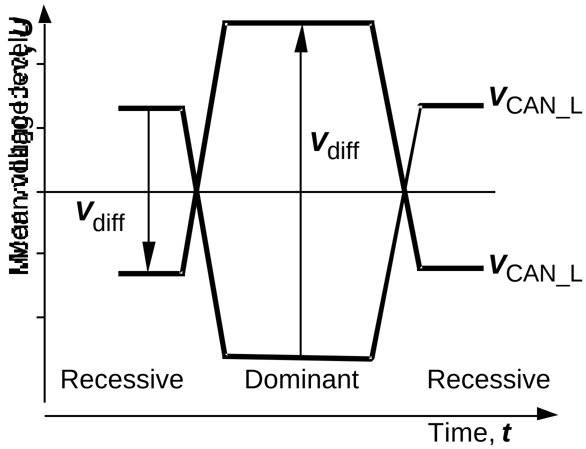


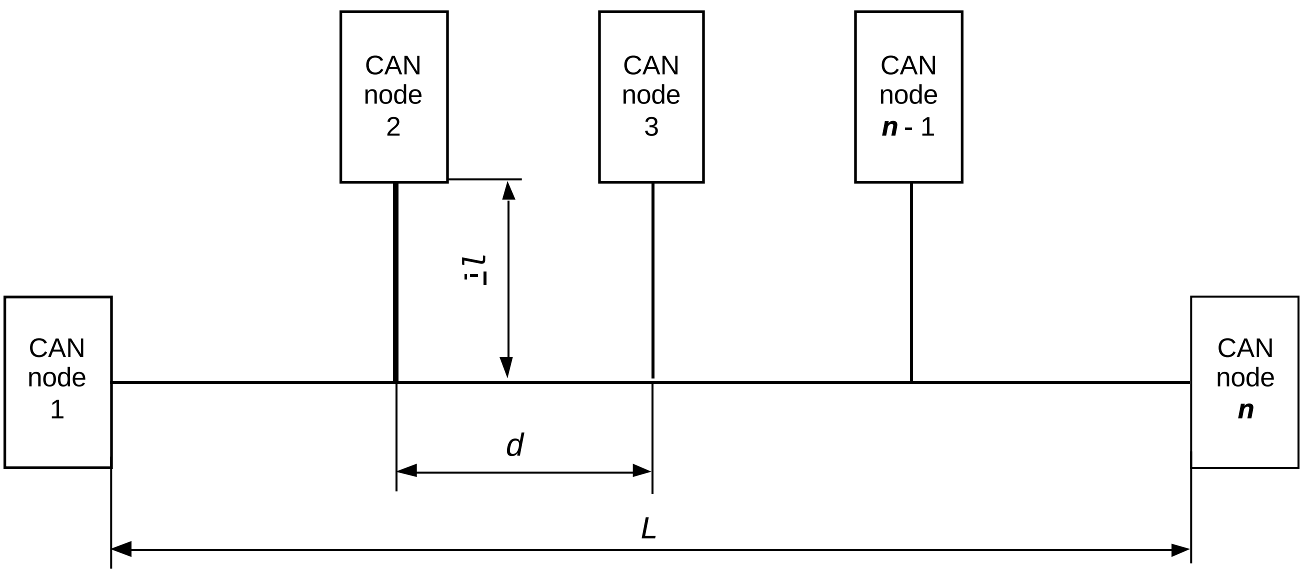
Figure 2 — Physical bit representation

5.3 Medium Dependent Interface (MDI) specification

A connector used to plug CAN nodes to the bus shall meet the requirements defined in the electrical specification. The aim of this specification is to standardize the most important electrical parameters and not to define mechanical and material parameters.

5.4 Physical medium specification

The wiring topology of a CAN network should be as close as possible to a single line structure in order to avoid cable- reflected waves. In practice, short stubs as shown in figure 3 are necessary to connect CAN nodes to the bus successfully.



Legend:

- L bus length
- l cable stub length
- d node distance

Figure 3 — Wiring network topology

6 Conformance tests

6.1 General

Figures 4 through 12 and the formulae shown indicate the principles how the electrical parameters specified in 7 may be verified.

6.2 Recessive output of CAN nodes

The recessive output voltages $\boldsymbol{V}_{\mathrm{CAN\_H}}$ and $\boldsymbol{V}_{\mathrm{CAN\_L}}$ shall be taken as shown in figure 4, they are measured unloaded while the bus is idle.

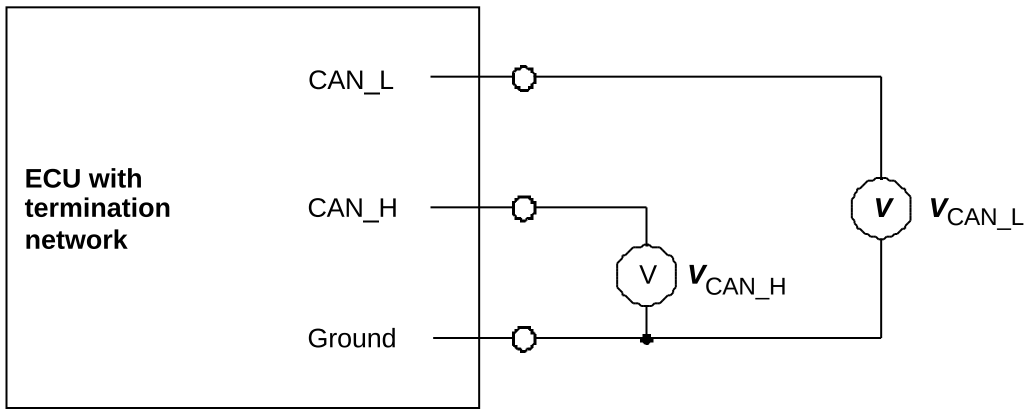


Figure 4 — Measurements of $\boldsymbol{V}_{\mathrm{CAN\_L}}$ and $\boldsymbol{V}_{\mathrm{CAN\_H}}$ during bus idle state

$\boldsymbol{V}_{\mathrm{CAN\_H}}$ and $\boldsymbol{V}_{\mathrm{CAN\_L}}$ are measured while the bus is idle. The corresponding value of $\boldsymbol{V}_{\mathrm{diff}}$ is given by:

$$\boldsymbol{V}_{\mathrm{diff}} = \boldsymbol{V}_{\mathrm{CAN\_H}} - \boldsymbol{V}_{\mathrm{CAN\_L}}$$

6.3 Dominant output of CAN node

6.3.1 General

The dominant output voltages $\boldsymbol{V}_{\mathrm{CAN\_H}}$ and $\boldsymbol{V}_{\mathrm{CAN\_L}}$ shall be taken as shown in figure 5 while the CAN node is transmitting a »dominant« bit.

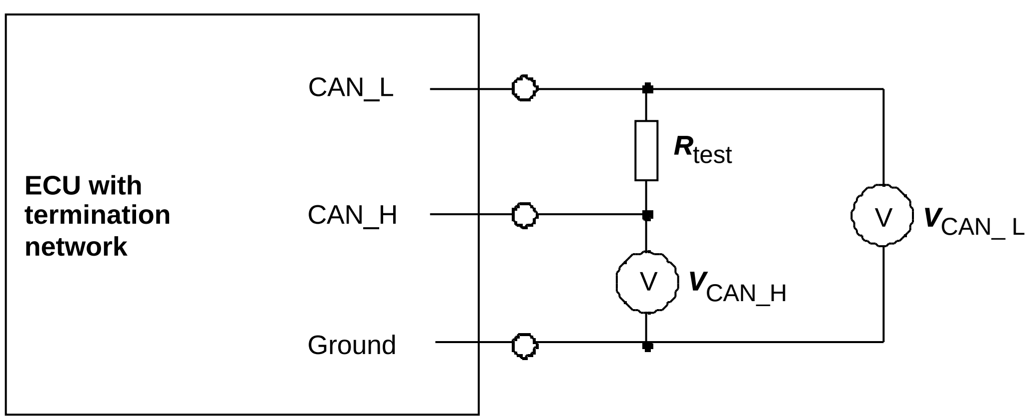


Figure 5 — Measurement of $\boldsymbol{V}_{\mathrm{CAN\_H}}$ and $\boldsymbol{V}_{\mathrm{CAN\_L}}$ while CAN node transmits »dominant« bit

$V_{\mathrm{CAN\_H}}$ and $V_{\mathrm{CAN\_L}}$ are measured during »dominant« bit transmission. The corresponding value of $\boldsymbol{V}_{\mathrm{diff}}$ is given by:

6.3.2 Recessive input threshold of CAN node

The input threshold for »recessive« bit detection of a CAN node shall be measured as shown in figure 6, with the CAN node protocol IC set to bus idle.

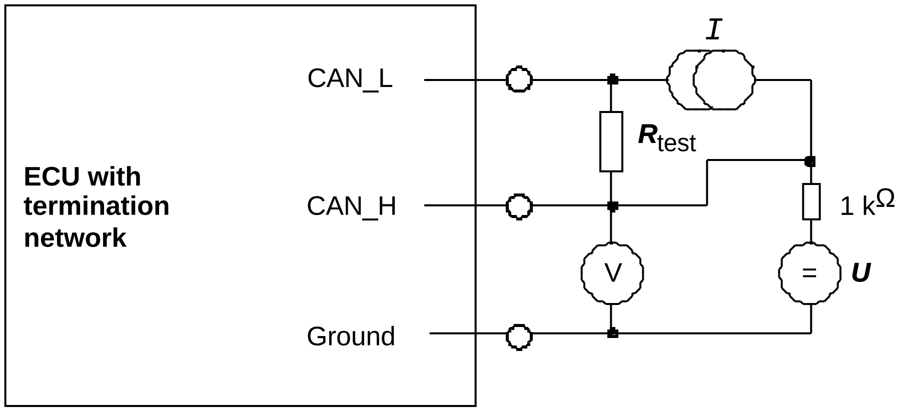


Figure 6 — Testing of input threshold for »recessive« bit detection

The current I is adjusted to a value which induces the upper threshold of the differential input voltage for detecting a »recessive« bit during the recessive state. Alternatively $\boldsymbol{U}$ is set to two values that produce

$\boldsymbol{V}$ = (minimum common mode voltage of $\boldsymbol{V}_{CAN\_H}$ in recessive state), and

$\boldsymbol{V}$ = (maximum common mode voltage of $\boldsymbol{V}_{CAN\_H}$ - maximum $\boldsymbol{V}_{diff}$ in recessive state),

during bus idle.

Under these conditions the CAN node shall leave the bus idle state. This indicates that every transmitted »recessive« bit is still detected as »recessive« by the protocol IC of the CAN node tested. The level of $\boldsymbol{V}_{diff}$ is nearly independent of $\boldsymbol{U}$.

6.4 Dominant input threshold of CAN node

The testing of the input threshold of a CAN node to detect a »dominant« bit shall be undertaken as shown in figure 7.

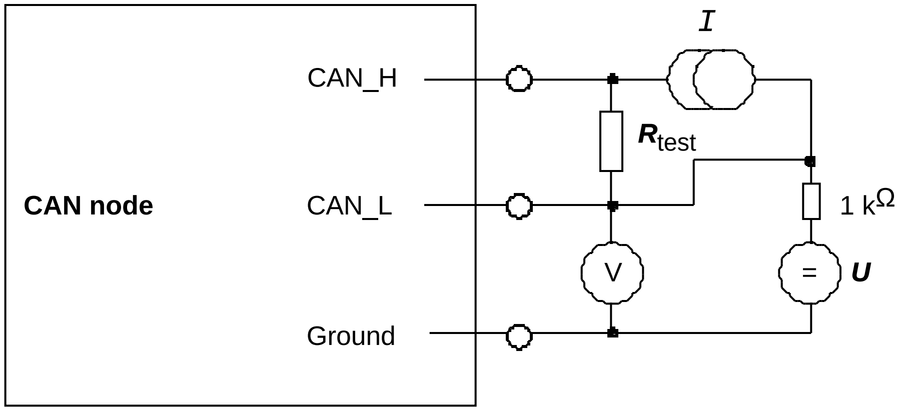


Figure 7 — Testing input threshold for »dominant« bit detection

The current I is adjusted to a value which induces the lower threshold of the differential input voltage, required to detect a »dominant« bit during recessive state. $\boldsymbol{U}$ is set to two values alternately that produce

$\boldsymbol{V}$ = (minimum common mode voltage of $\boldsymbol{V}_{CAN\_L}$ in dominant state), and

$\boldsymbol{V}$ = (maximum common mode voltage of $\boldsymbol{V}_{CAN\_L}$ - maximum $\boldsymbol{V}_{diff}$ in dominant state)

Under these conditions the CAN node shall stop transmitting the frame. This indicates that each »recessive« bit transmitted is detected as »dominant« by the protocol IC of the CAN node. The level of $\boldsymbol{V}_{\text{diff}}$ is nearly independent of $\boldsymbol{U}$.

6.5 Internal resistance of CAN_L and CAN_H

6.5.1 General

The ground-related internal termination resistance of CAN_L and CAN_H ($\boldsymbol{R}_{\text{in\_L}}$ and $\boldsymbol{R}_{\text{in\_H}}$) is measured as shown in figure 8, with the CAN node protocol IC set to bus idle.

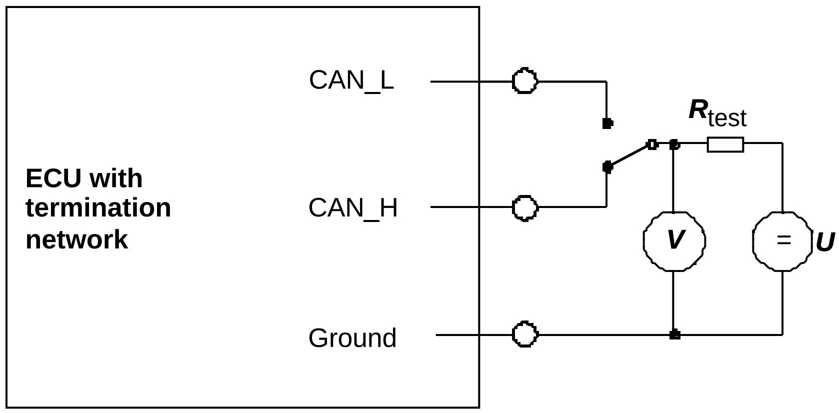


Figure 8 — Measurement of $\boldsymbol{R}_{\text{in}}$ while CAN node protocol IC is set to bus idle

$\boldsymbol{R}_{\text{in\_L}}$ and $\boldsymbol{R}_{\text{in\_H}}$ are determined for $\boldsymbol{R}_{\text{test}}$.

$\boldsymbol{R}_{\text{in\_L}}$ and $\boldsymbol{R}_{\text{in\_H}}$ are calculated by $\boldsymbol{R}_{\text{in\_L, H}} = \dfrac{\boldsymbol{R}_{\text{test}} \bullet (\boldsymbol{V}_{\text{CAN\_L,H}} - \boldsymbol{V})}{\boldsymbol{V} - \boldsymbol{U}}$

where $\boldsymbol{V}_{\text{CAN\_L}}$ and $\boldsymbol{V}_{\text{CAN\_H}}$ are the open circuit voltages according to figure 4.

6.5.2 Internal differential resistor

The measurements of $\boldsymbol{R}_{\text{diff}}$ while the CAN node protocol IC is set to idle shall be taken as shown in figure 9.

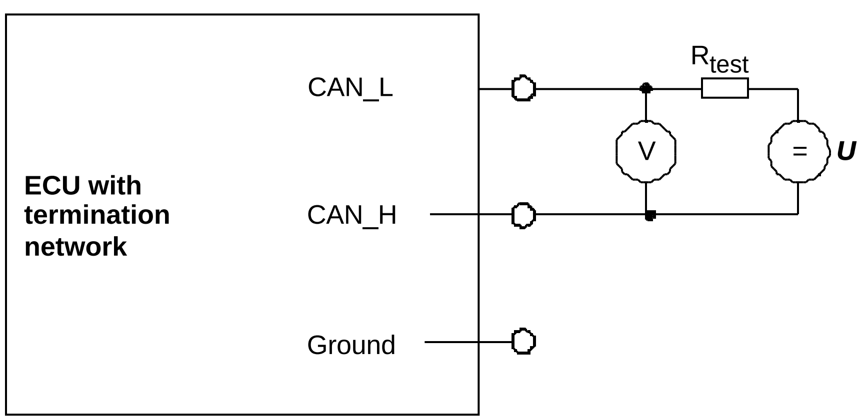


Figure 9 — Measurement of $\boldsymbol{R}_{\text{diff}}$ while CAN node protocol IC is set to bus idle

$\boldsymbol{R}_{\text{diff}}$ is determined for $\boldsymbol{R}_{\text{test}}$ during bus idle as:

$$\boldsymbol{R}_{\text{diff}} = \frac{\boldsymbol{R}_{\text{test}} \bullet [\boldsymbol{V}_{\text{diff}} - \boldsymbol{V}]}{\boldsymbol{V} - \boldsymbol{U}}$$

6.6 Input capacitances

In order to determine the input capacitances C_{in} and C_{diff}, it is necessary to perform two measurements:

¾ Measurement of C_{busin} (see figure 10),

¾ Measurement of C_{in} (see figure 11).

During the measurements a dominant bit shall not be transmitted. The value of the CAN node input capacitance is in the range of a few pF. Therefore, the measurement equipment itself shall have a negligible capacitance or its capacitance shall be compensated by an exact measurement.

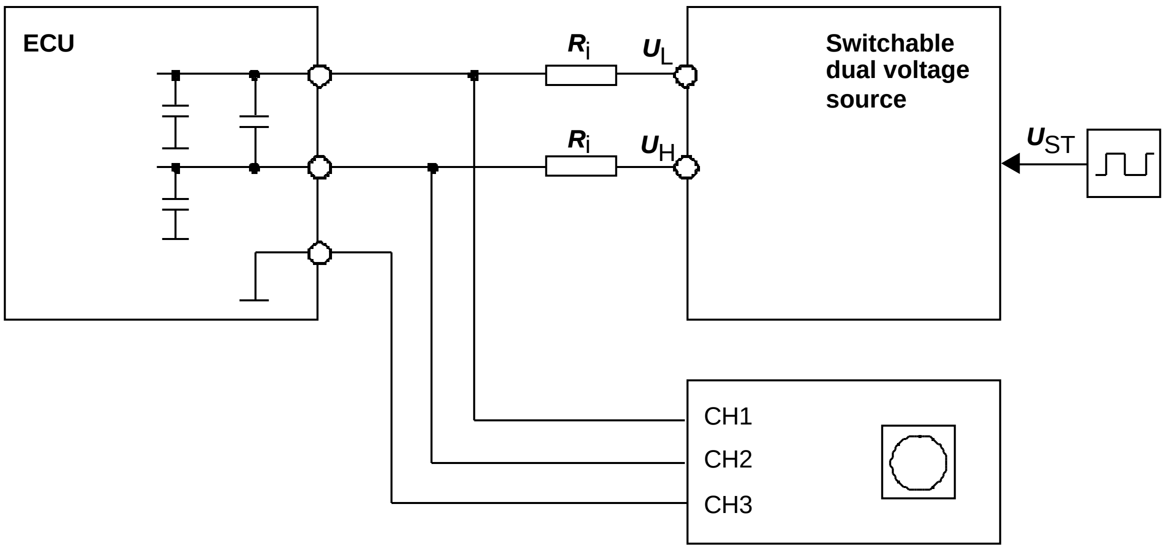


Figure 10 — Measurement of the input capacitance C_{busin} during the recessive state

$$C_{busin} = \frac{\tau}{R_i}$$

where τ is the time at which the differential voltage has reached 63 % of its final value.

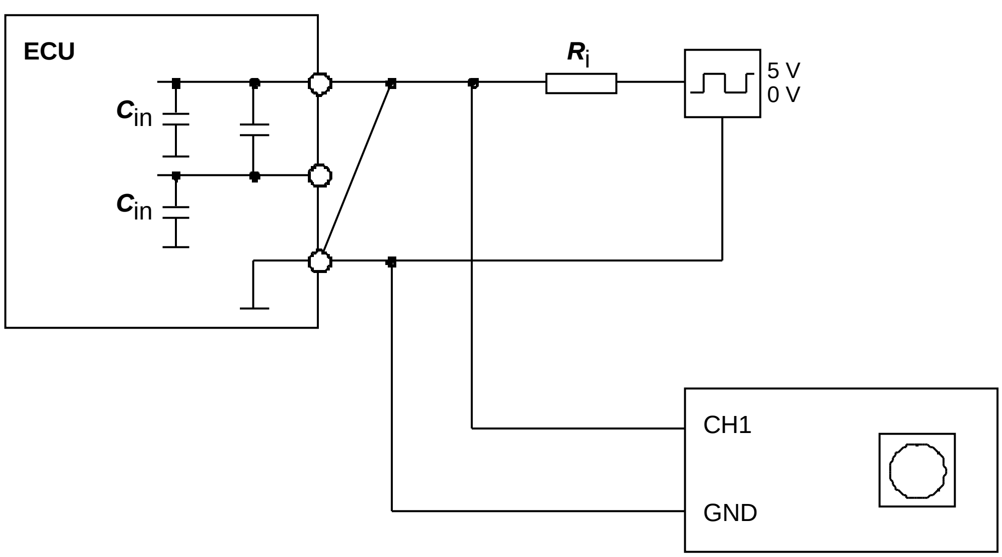


Figure 11 — Measurement of the input capacitance C_{in} of a CAN node at the recessive state

$$C_{in} = \frac{\tau}{2R_i}$$

where τ is the time at which the differential voltage has reached 63 % of its final value.

Then C_{diff} can be determined: $$C_{diff} = \frac{C_{busin} - C_{in}}{2}.$$

6.7 Measurement of the internal delay time

The measurement of the internal delay time t_{node} shall be undertaken by applying a »dominant« bit at the CAN bus inputs of an error active CAN node that is in idle state. The CAN node will regard the »dominant« bit as Start of Frame and will perform a hard synchronization. At the sixth »recessive« bit after the »dominant« bit, the CAN node will detect a stuff error and will respond with an active error flag. The time measured from the beginning of the externally applied »dominant« bit to the beginning of the »dominant« active error flag is $t_{edge\_to\_edge}$. The actual length of $t_{edge\_to\_edge}$ is composed of the internal delay time, of a multiple of the CAN bit time, and of the phase difference between the externally applied edge and the CAN node's clock. The phasing of the externally applied edge has to be adjusted in order to minimize $t_{edge\_to\_edge}$.

t_{node} is calculated by : $t_{node} = (t_{edge\_to\_edge})_{min.} - 7 \bullet$ nominal bit time.

The measurement of the input delay time part t_{input} of t_{node} shall be undertaken as shown in figure 12, i.e. during partly overwriting of the first »recessive« identifier bit (see hatched area in figure 12) by a dominant level until loss of arbitration.

The test unit shown in figure 12 synchronizes itself to the Start of Frame bit transmitted by the CAN node under test. Upon detection of the first »recessive« identifier bit, the test unit partly overwrites this »recessive« bit for a duration of t_{overw} by a dominant level (see hatched area). The duration of overwriting is increased until the CAN node under test loses arbitration and stops transmission. When this occurs, t_{overw} has just reached the limit $t_{overw} < (t_{Prop\_Seg} + t_{Phase\_Seg1} - t_{input})$ (see ISO 11898-1).

Using the maximum value of t_{overw} before the CAN node loses arbitration, the internal delay time t_{input} is calculated as:

$$t_{input} = t_{Prop\_Seg} + t_{Phase\_Seg1} - t_{overw}$$

The internal delay time t_{output} is calculated as:

$$t_{output} = t_{node} - t_{input}$$

The dominant and recessive voltage detection levels are set in the test unit to the corresponding threshold voltages for reception. This ensures a uniquely specified relation between voltage levels and internal delay time.

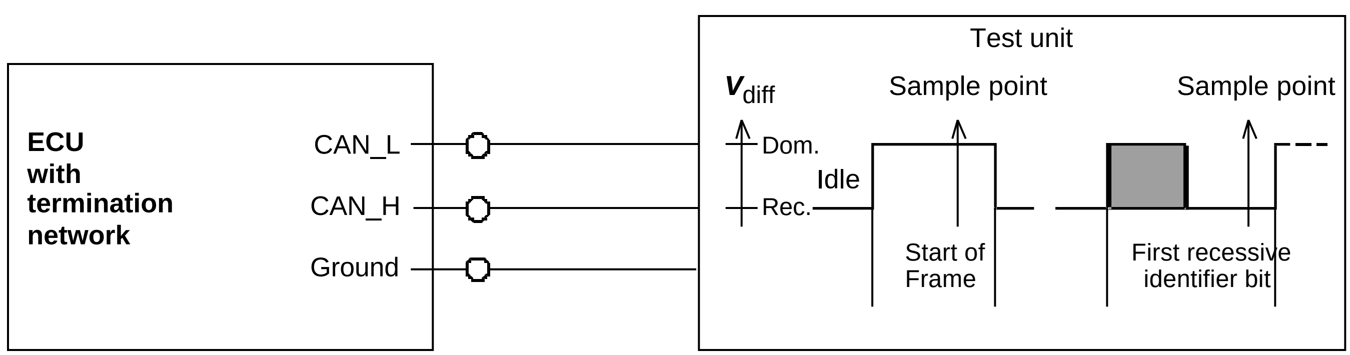


Figure 12 — Internal delay time measurement

7 Electrical specification of High-Speed Medium Access Unit (HS-MAU)

7.1 General

The following electrical specification is valid for a two-wire differential bus with transmission rates up to 1 Mbit/s. The termination shown in figure 1 and figure 13 is specified in table 10. It is not recommended to integrate the termination into a CAN node.

Figure 13 — Bus termination of the high-speed bus implementation

7.2 Physical medium attachment sublayer specification

7.2.1 General

All data given in tables 1 through 5 are independent of a specific physical layer implementation. The parameters specified in these tables shall be fulfilled throughout the operating temperature range of every CAN node. The parameters are chosen such that a maximum number of CAN nodes may be connected to the common bus.

7.2.2 Bus levels

7.2.2.1 Common mode voltages

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

Table 1 — Bus voltage parameters for recessive state

Parameter	Notation	Unit	Value			Condition
			min.	nom.	max.	
Common mode bus voltage	V_{CAN_H}	V		2,5	7,0	Measured with respect to the individual ground of each CAN node
	V_{CAN_L}	V	- 2,0	2,5		
Differential bus voltage[1)]	V_{diff}	mV	- 120	0	12	Measured at each CAN node connected to the bus.

1) 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 4). 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 — Bus voltage parameters for dominant state

Parameter	Notation	Unit	Value min.	Value nom.	Value max.	Condition
Common mode bus voltage[1)]	V_{CAN_H}	V		3,5	7,0	Measured with respect to the individual ground of each CAN node
	V_{CAN_L}	V	- 2,0	1,5		
Differential bus voltage[2)]	V_{diff}	V	1,2	2,0	3,0	Measured at each CAN node connected to the bus.

1) 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} .

2) 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.

7.2.2.2 Disturbance by coupling

The tolerated disturbances of CAN_H and CAN_L by coupling are defined in accordance with ISO7637-3:1990, test pulses 3a and 3b.

7.3 CAN node

7.3.1 General

The parameters given in table 3 shall be tested at the CAN_L and CAN_H pins of each CAN node, with the CAN node disconnected from the bus (see 6.2 and 6.3).

Table 3 — Maximum ratings of V_{CAN_L} and V_{CAN_H} of CAN node

Nominal battery voltage V	Notation	Voltage V min.	Voltage V max.
12	V_{CAN_H}	- 3,0	16,0
	V_{CAN_L}	- 3,0	16,0
24	V_{CAN_H}	- 3,0	32,0
	V_{CAN_L}	- 3,0	32,0

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 4 shall be tested at the CAN_L and CAN_H pins of each CAN node, according to conformance tests 6.2 to 6.7.

Table 4 — DC parameters for recessive output of CAN node

Parameter	Notation	Unit	Value min.	Value nom.	Value max.	Condition
Output bus voltage	V_{CAN_H}	V	2,0	2,5	3,0	no load
	V_{CAN_L}	V	2,0	2,5	3,0	
Differential output bus voltage	V_{diff}	mV	- 500	0	50	no load
Differential internal resistance	R_{diff}	kΩ	10		100	no load [1)]
Internal resistor[2)]	R_{in}	kΩ	5		50	
Differential input voltage[3)]	V_{diff}	V	- 1,0		0,5	[4) 5)]

1) The load is connected between CAN_H and CAN_L. For a CAN node without integrated terminating resistor R_L (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} (see 6.5.2).

2) R_{in} of CAN_H and CAN_L should have almost the same value (see 6.5.1). The deviation shall be less than 3 % relative to each other.

3) 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).

4) Threshold for receiving a »recessive« bit.

5) Reception shall be ensured within the common mode voltage range specified in table 1 and table 2 respectively.

Table 5 — DC parameters for dominant output of CAN node

Parameter	Notation	Unit	Value min.	Value nom.	Value max.	Condition
Output bus voltage	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	V_{diff}	V	1,5	2,0	3,0	load $R_L/2$
Differential input voltage[2)]	V_{diff}	V	0,9		5,0	load $R_L/2$ [3)]

1) 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}.

2) 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).

3) Threshold for receiving a »dominant« bit. Reception shall be ensured within the common mode voltage range specified in table 1 and table 2 respectively.

7.3.2 Illustration of voltage range

Load conditions are defined within the table 1 through table 5. Figures 14 to figure 17 illustrate the valid voltage ranges of V_{CAN_H} and V_{CAN_L}.

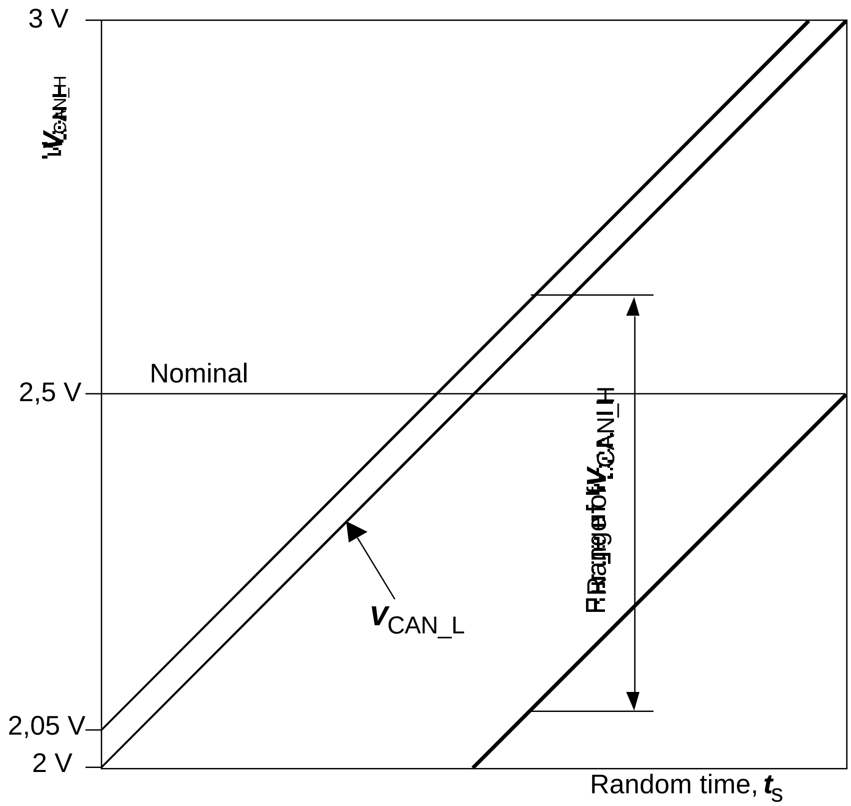


Figure 14 — Valid voltage range of V_{CAN_H} during recessive state of CAN node disconnected from bus, if V_{CAN_L} varies from min. to max. voltage level

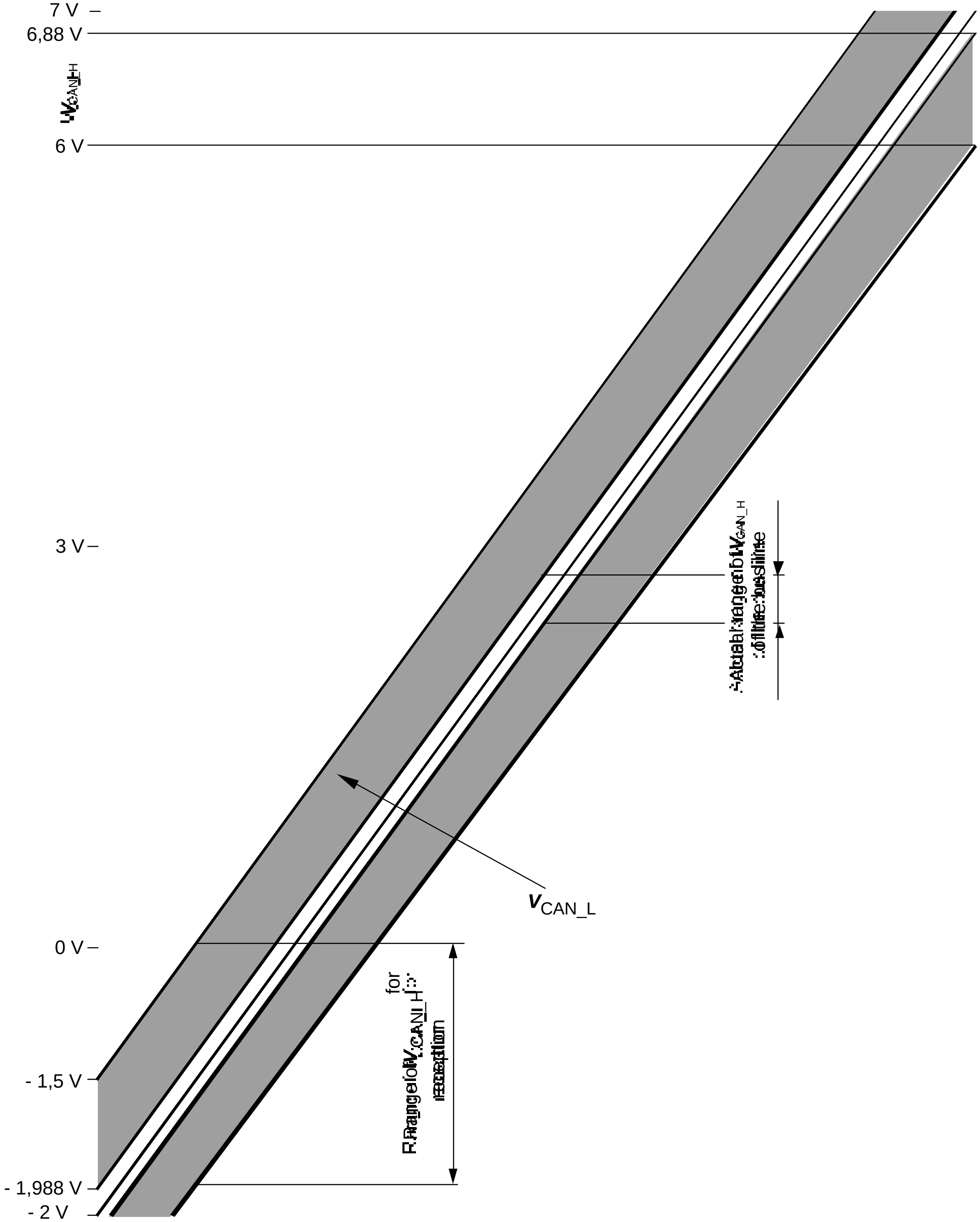


Figure 15 — Valid voltage range of V_{CAN_H} for monitoring recessive bus state, and for disconnected CAN node, if V_{CAN_L} varies from min. to max. common mode range of bus

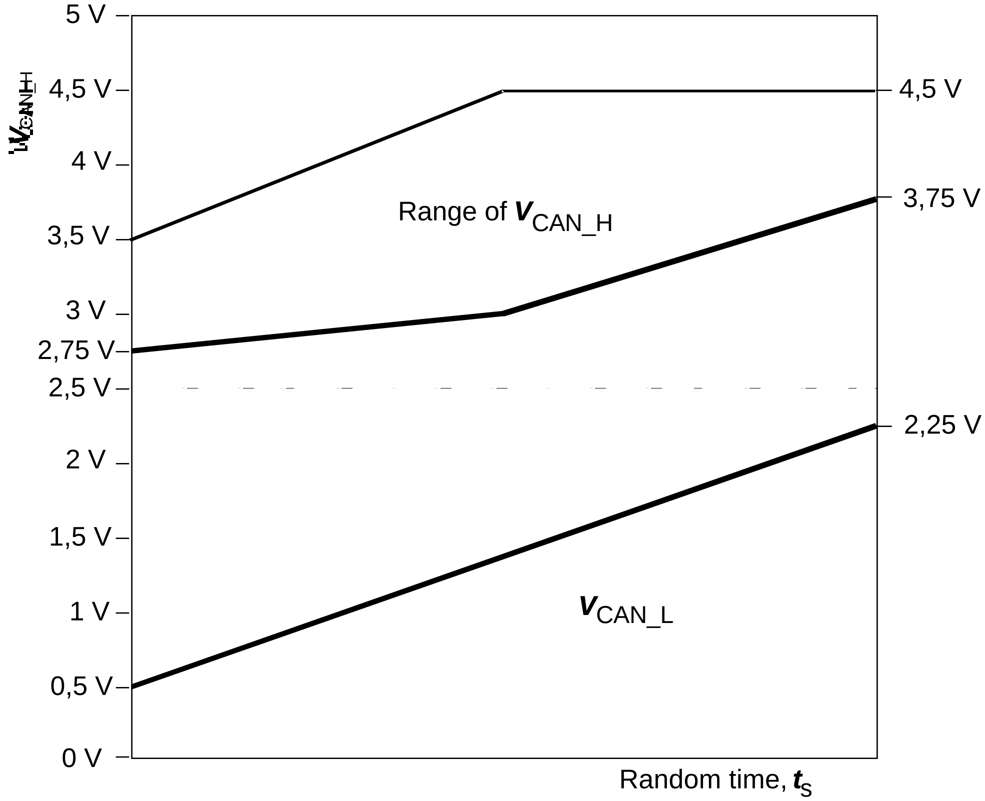


Figure 16 — Valid voltage range of V_{CAN_H} during dominant state of CAN node which is disconnected from bus, if V_{CAN_L} varies from min. to max. voltage level

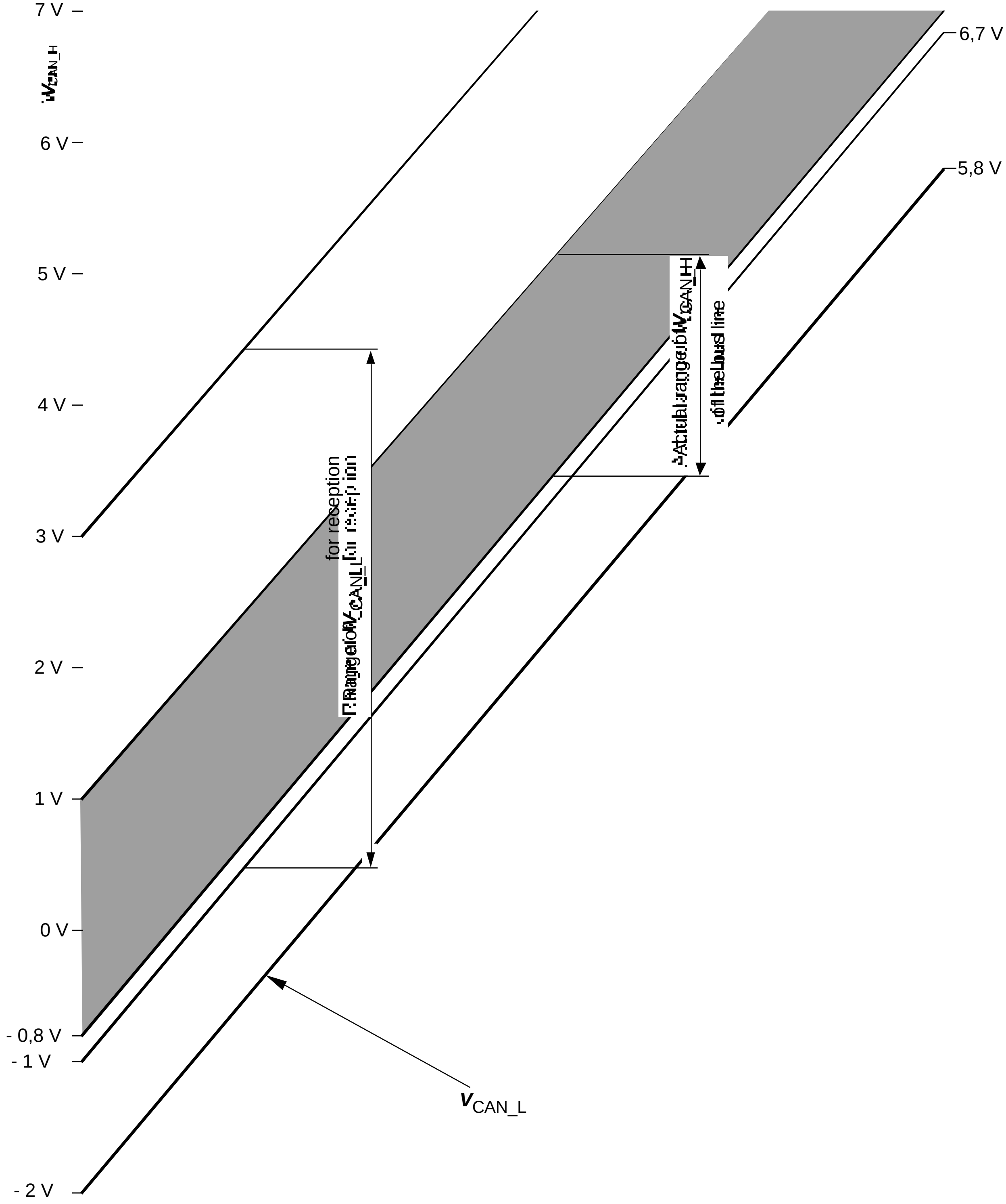


Figure 17 — Valid voltage range of V_{CAN_H} for monitoring dominant bus state, and for disconnected CAN node, if V_{CAN_L} varies from min. to max. common mode range of bus

The parameters given in table 6 shall be tested at the CAN_L and CAN_H pins of each CAN node, according to conformance tests 6.

Table 6 — AC parameters of CAN node disconnected from bus

Parameter	Notation	Unit	Value			Condition
			min.	nom.	max.	
Bit time	t_B	µs	1			1)
Internal capacitance	C_{in}	pF		20		3)
Differential internal capacitance[2]	C_{diff}	pF		10		1 Mbit/s

1) 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.

2) 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 C_{in} and C_{diff} may be zero. The max. tolerable values are determined by the bit timing and the network topology parameters l and d (see table 11, note 1). Proper functionality is guaranteed if occurring cable-reflected waves do not suppress the dominant differential voltage levels below V_{diff} = 0,9 V and do not increase the recessive differential voltage level above V_{diff} = 0,5 V at each individual CAN node (see table 4 and table 5).

3) 1 Mbit/s for CAN_H and CAN_L relative to HF ground.

The test voltages U_{ST} are defined in table 7.

Table 7 — Test voltages

Parameter	Unit	Test voltage at U_{ST}	
		1st voltage	2nd voltage
U_L	V	5	0
U_H	V	0	5

7.4 Medium Dependent Interface (MDI) specification, connector parameters

A connector used to plug CAN nodes to the bus shall meet the requirements specified in table 8.

Table 8 — Connector parameters

Parameter		Notation	Unit	Value		
				min.	nom.	max.
Voltage	V_{BAT} – 12 V	U	V			16
	V_{BAT} = 24 V	U	V			32
Current		I	mA	0	25	80
Peak current[1]		I_p	mA			500
Transmission frequency		f	MHz	25		
Transmission resistance[2]		R_T	mΩ		70	

1) Time restriction: $101 t_B$.

2) The differential voltage of the bus seen by the receiving CAN node depends on the line resistance between this and the transmitting CAN node. Therefore the transmission resistance of the signal wires is limited by the bus level parameters at each CAN node.

7.5 Physical medium specification

7.5.1 General

Cables for the bus shall be in accordance with the specifications of table 9.

Table 9 — Physical media parameters of a pair of wires (shielded or unshielded)

Parameter	Notation	Unit	Value			Condition
			min.	nom.	max.	
Impedance	Z	Ω	95	120	140	Measured between two signal wires.
Length-related resistance	r	mΩ/m		70		1)
Specific line delay		ns/m		5		2)

1) The differential voltage on the bus seen by a receiving CAN node depends on the line resistance between it and the transmitting CAN node. Therefore, the total resistance of the signal wires is limited by the bus level parameters of each CAN node.

2) The min. delay between two points of the bus may be zero. The max. value is determined by the bit time and the delay times of the transmitting and receiving circuitry.

7.5.2 Termination resistor

The termination resistor R_L used in Termination A and Termination B shall comply with the limits specified in table 10.

Table 10 — Termination resistor

Notation	Unit	Value			Condition
		min.	nom.	max.	
R_L 1)	Ω	100	120	130	Min. power dissipation: 220 mW.

1) Dependent on the topology, the Bit rate, and the slew rate deviations from 120 Ω may be possible. It is, however, necessary to check the applicability of other resistor values in each case.

Remark : The lower the termination resistor value is the smaller the number of nodes in a network is.

7.5.3 Topology

The wiring topology of a CAN network should be as close as possible to a single line structure in order to avoid cable- reflected waves.

Table 11 — Network topology parameters

Parameter	Notation	Unit	Value			Condition
			min.	nom.	max.	
Bus length	L	m	0		40	Bit rate: 1 Mbit/s 1)
Cable stub length	l	m	0		0,3	
Node distance	D	m	0,1		40	

1) At bit rates lower than 1 Mbit/s the bus length may be lengthened significantly. Depending on l, the bit rate and internal capacitances of the individual CAN nodes, other network topologies with changed lengths l and d may be used. In this case the influence of occurring cable resonator waves on the bit representation on the bus should be carefully checked by measurements of V_{diff} at each CAN node (see also table 4, note 3).