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Road vehicles — Controller area network (CAN) —

Part 2:
High-speed medium access unit

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

Partie 2: Unité d'accès au support à grande vitesse

Reference number
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Contents

Page

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

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.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 11898-2 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 3, *Electrical and electronic equipment*.

This first edition of ISO 11898-2, together with ISO 11898-1, replaces ISO 11898:1993, which has been technically revised. Whereas the replaced International Standard covered both the CAN DLL and the high-speed PL, ISO 11898-2 specifies the high-speed MAU, while ISO 11898-1 specifies the DLL, including LLC and MAC sublayers.

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*

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Road vehicles — Controller area network (CAN) —

Part 2:
High-speed medium access unit

1 Scope

This part of ISO 11898 specifies the high-speed (transmission rates of up to 1 Mbit/s) medium access unit (MAU), and some medium dependent interface (MDI) features (according to ISO 8802-3), which comprise the physical layer of the controller area network (CAN): a serial communication protocol that supports distributed real-time control and multiplexing for use within road vehicles.

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 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/IEC 8802-3, *Information technology — Telecommunications and information exchange between systems — Local and metropolitan area networks — Specific requirements — Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications*

ISO 16845, *Road vehicles — Controller area network (CAN) — Conformance test plan*

3 Terms and definitions

For the purposes of this document, 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

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

3.5
differential voltage (of CAN bus)
V_{diff}
differential voltage of the two-wire CAN bus:

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

3.6
internal capacitance (of a CAN node)
C_{in}
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 (of a CAN node)
t_{node}
sum of all asynchronous delay times occurring on the transmitting and receiving paths relative to the bit timing logic unit of the protocol IC of each individual CAN node disconnected from the bus

3.8
internal resistance (of a CAN node)
R_{in}
resistance 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, consisting of analog circuitry and digital circuitry, interfacing between the analog 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 electromagnetic compatibility (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.

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4 Abbreviated terms

CAN	controller area network
ECU	electronic control unit
HS-MAU	high-speed medium access unit
IC	integrated circuit
MAU	medium access unit
MDI	medium dependent interface
NBT	nominal bit time
SOF	start of frame

5 Functional description of MAU

5.1 General

The following description is valid for a two-wire differential bus. The values of the voltage levels, resistances and capacitances, as well as the termination network, are given in Clauses 6 and 7.

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. This 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.

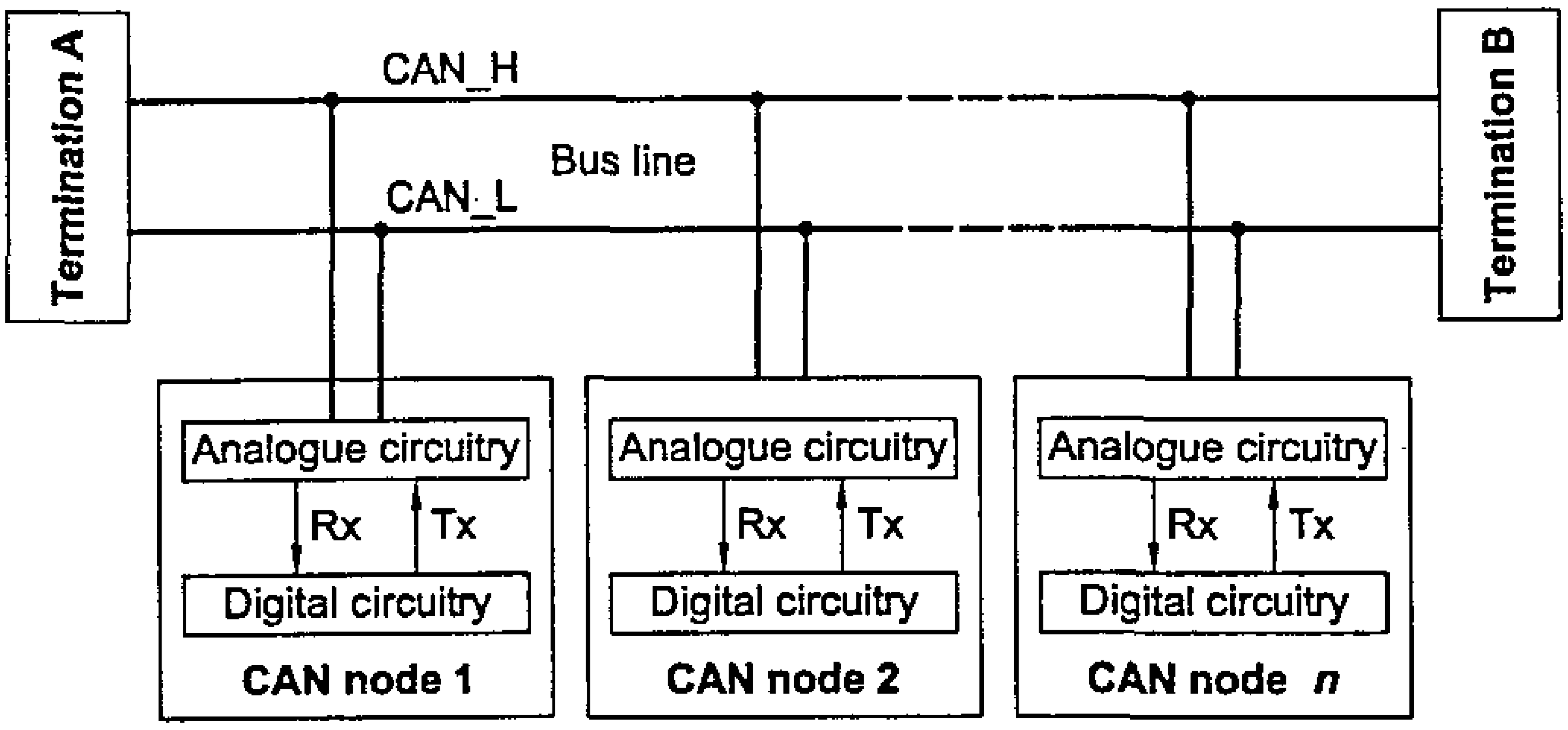

Figure 1 — Suggested electrical interconnection

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.

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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 into the corresponding recessive and dominant voltage levels at the comparator input of the receiving circuitry.

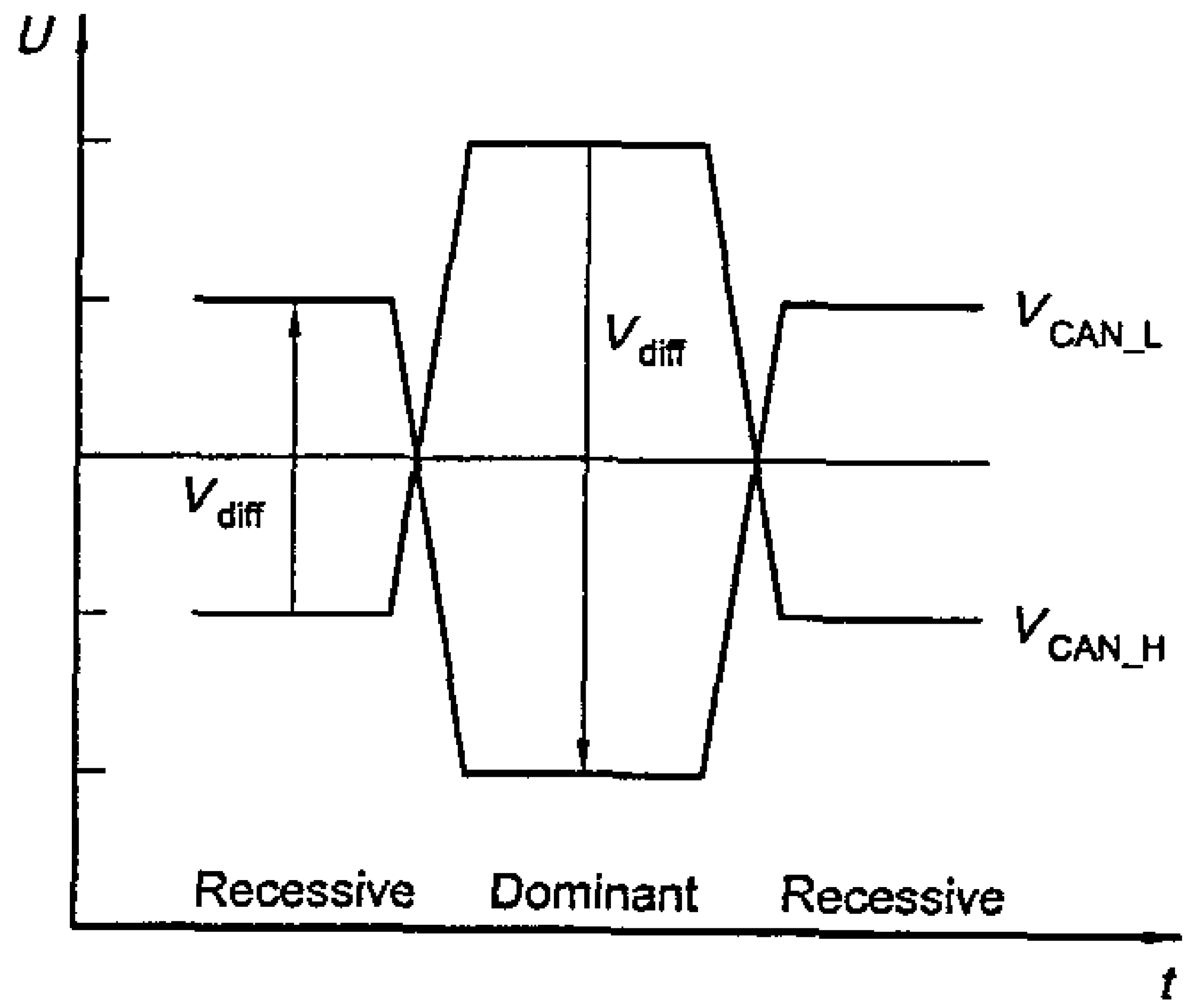
5.2.2 Bus levels

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_{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.

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 could simultaneously transmit a dominant bit. In this case V_{diff} exceeds the V_{diff} seen during a single operation. Single operations mean that the bus is driven by one CAN node only.



Key

U mean voltage level

t time

Figure 2 — Physical bit representation

5.3 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.

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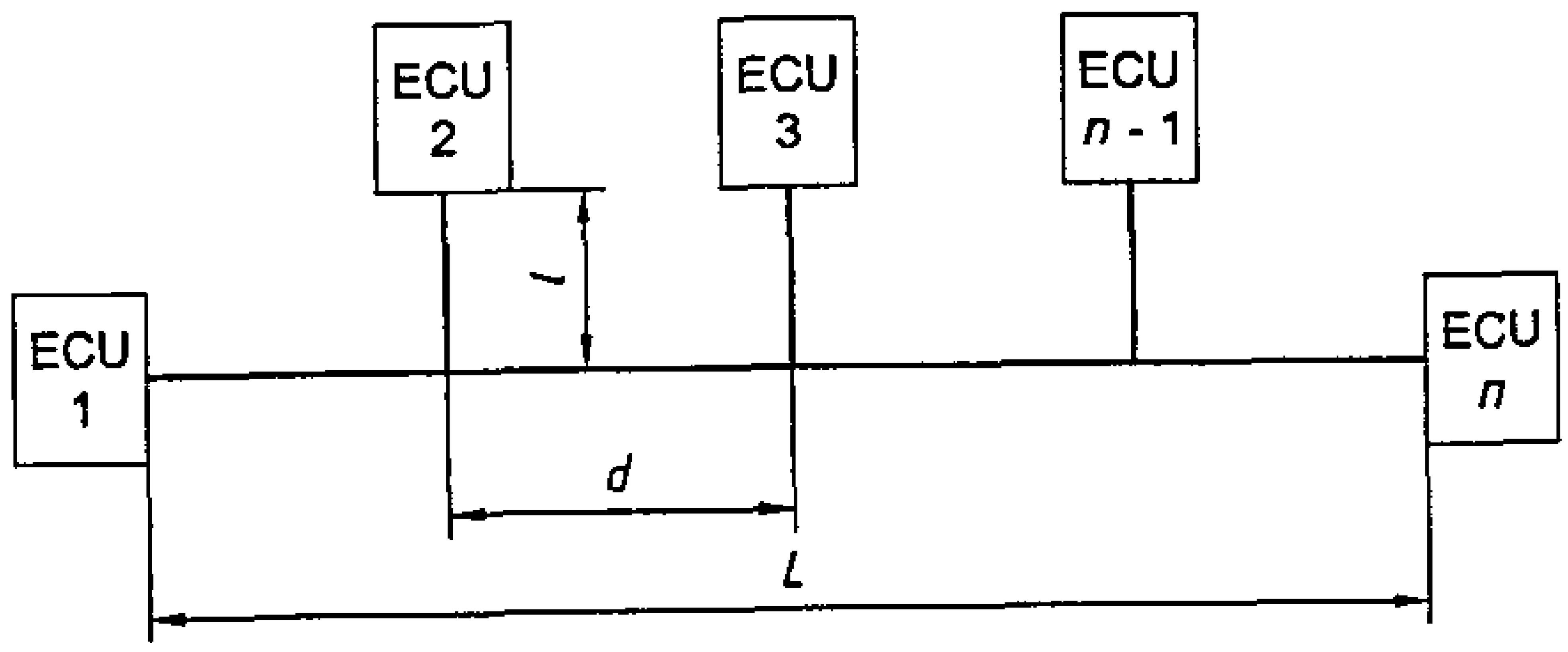


Key

L bus length

l cable stub length

d node distance

Figure 3 — Wiring network topology

6 Conformance tests

6.1 General

The conformance of the MAU shall be tested in accordance with ISO 16845.

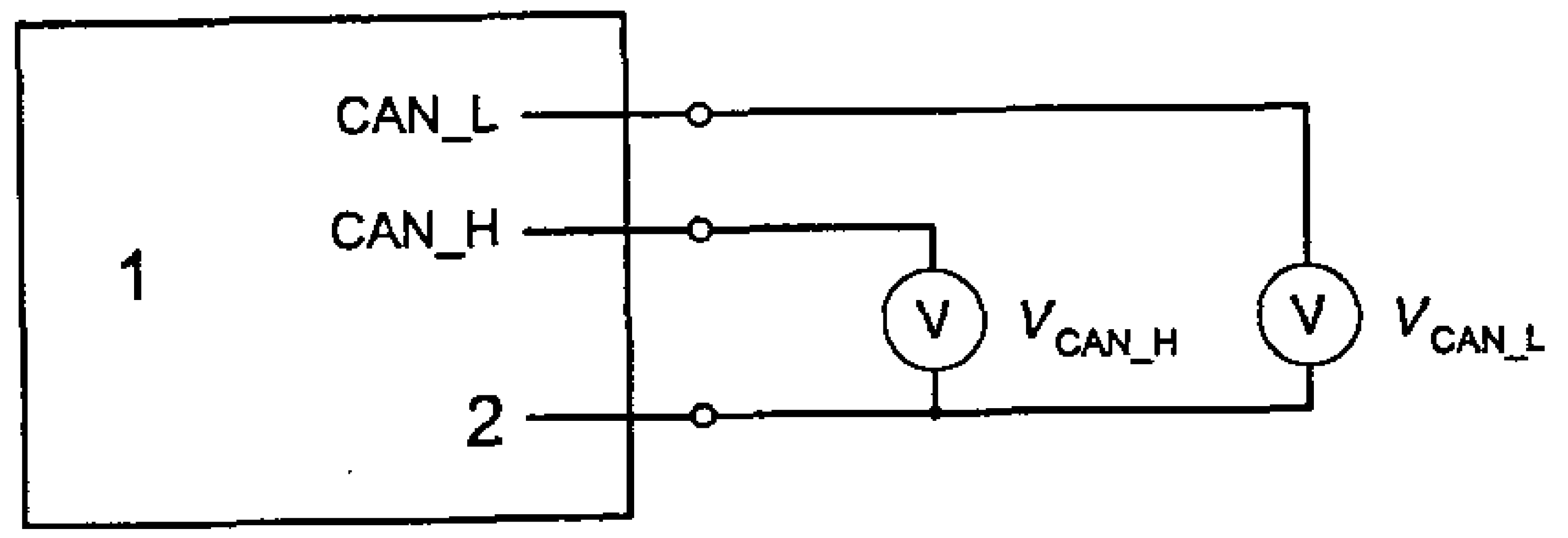
Figures 4 to 12 and the formulae indicate the principles by which the electrical parameters specified in Clause 7 are verified.

6.2 Recessive output of CAN nodes

The recessive output voltages V_{CAN_H} and V_{CAN_L} shall be taken as shown in Figure 4; they are measured unloaded while the bus is idle.

The corresponding value of V_{diff} is given by

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



Key

1 CAN node with termination network

2 Ground

Figure 4 — Measurements of V_{CAN_L} and V_{CAN_H} during bus idle state

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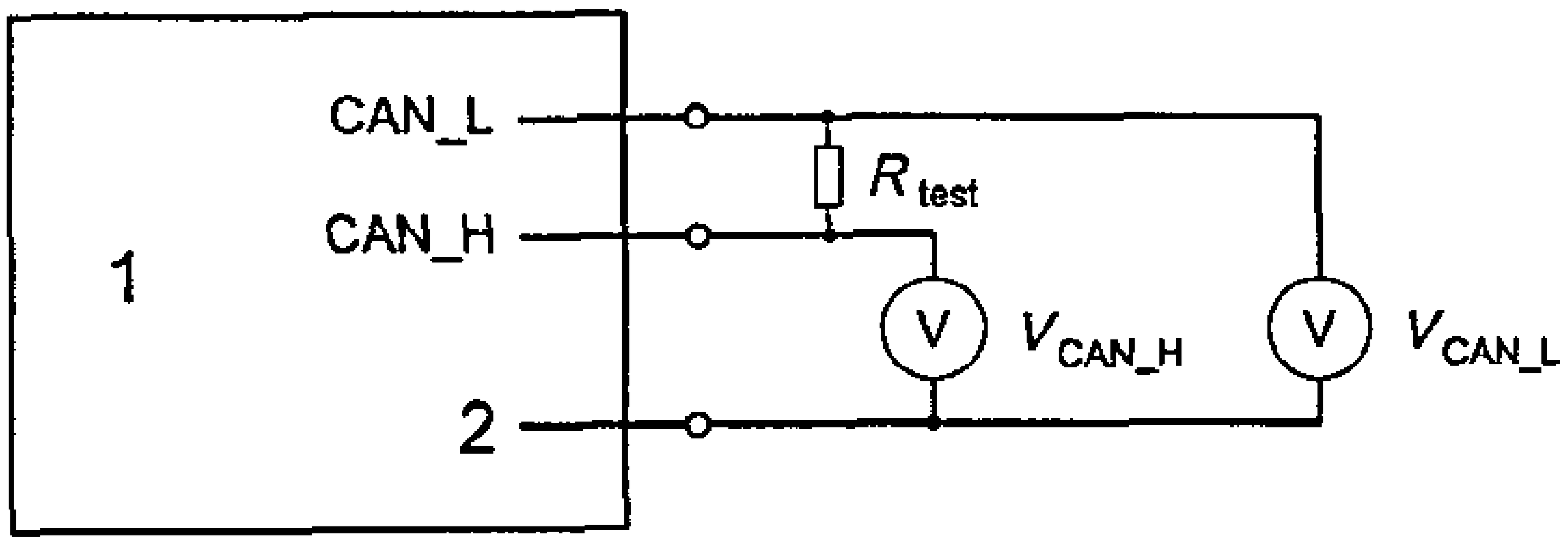
6.3 Dominant output of CAN node

6.3.1 General

The dominant output voltages V_{CAN_H} and V_{CAN_L} shall be taken as shown in Figure 5; they are measured while the CAN node is transmitting a dominant bit.



Key

1 CAN node with termination network

2 Ground

Figure 5 — Measurement of V_{CAN_L} and V_{CAN_H} while CAN node transmits dominant bit

The corresponding value of V_{diff} is given by

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

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.

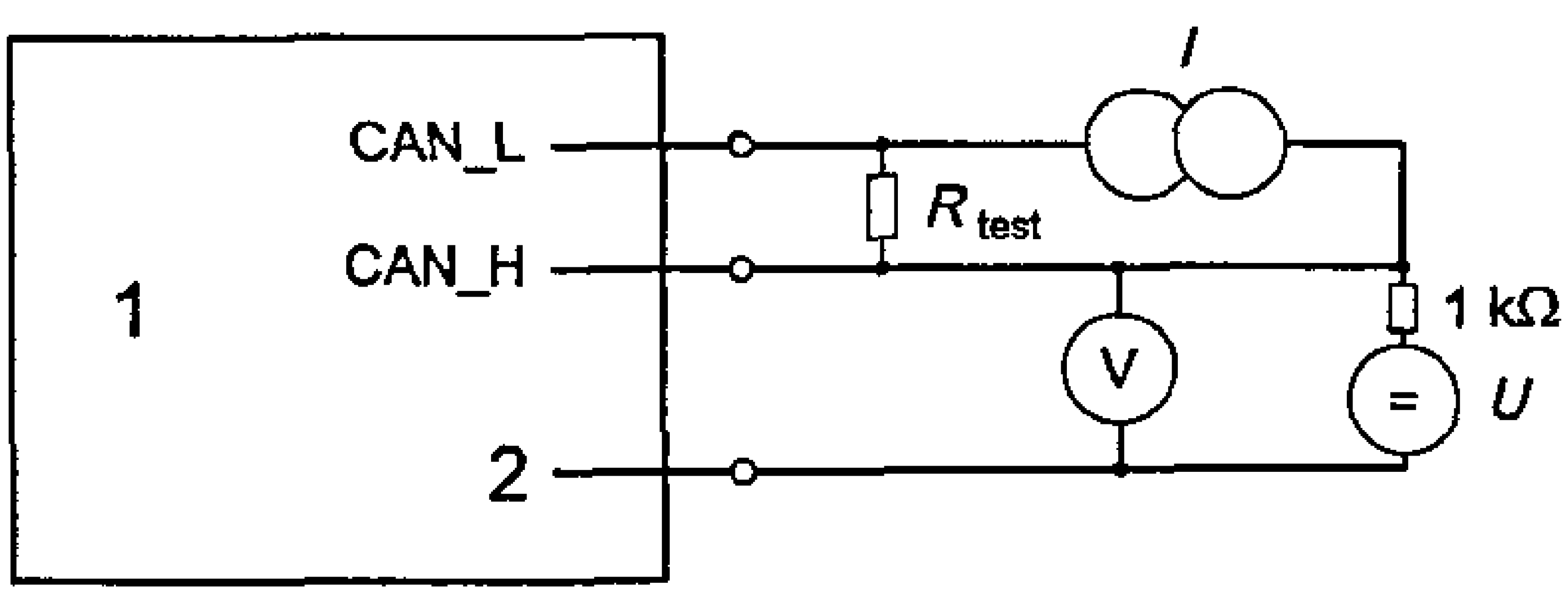
The current, I, is adjusted to a value which induces the upper threshold of the differential input voltage for detecting a recessive bit during the recessive state. Alternatively, U (mean voltage level) is set to two values that produce

— V = (minimum common mode voltage of V_{CAN_H} in recessive state), and

— V = (maximum common mode voltage of V_{CAN_H} – maximum V_{diff} in recessive state),

during bus idle.

Under these conditions the CAN node shall leave the bus in 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 V_{diff} is nearly independent of U.



Key

1 CAN node with termination network

2 Ground

Figure 6 — Testing of input threshold for recessive bit detection

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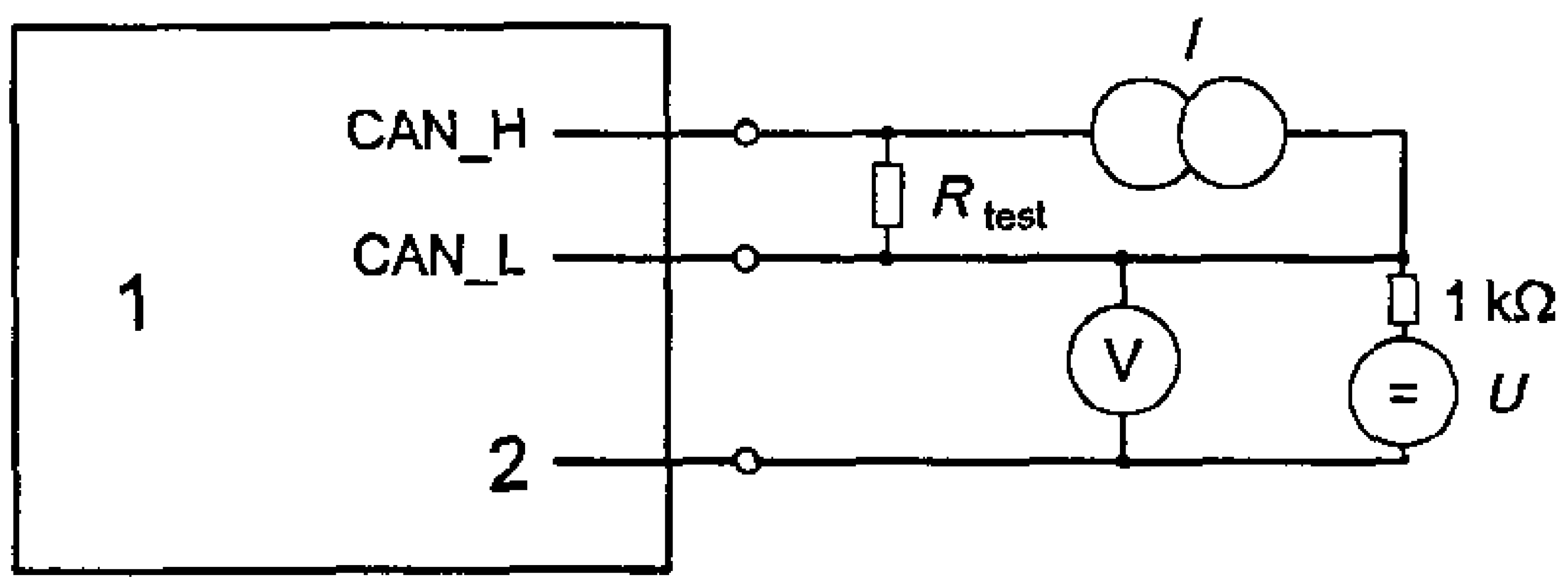
6.4 Dominant input threshold of CAN node

The testing of the input threshold of a CAN node to detect a dominant bit shall be undertaken as shown in Figure 7 with the node set to cyclic transmitting frames.



Key

1 CAN node with termination network

2 Ground

Figure 7 — Testing input threshold for dominant bit detection

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. Alternatively, U is set to two values that produce

— V = (minimum common mode voltage of V_{CAN_L} in dominant state), and

— V = (maximum common mode voltage of V_{CAN_L} – maximum V_{diff} in dominant state),

during bus idle.

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 V_{diff} is nearly independent of 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 (R_{in_L} and R_{in_H}) is measured as shown in Figure 8, with the CAN node protocol IC set to bus idle.

R_{in_L} and R_{in_H} are determined for R_{test}, and calculated by

$$R_{in\_L,H} = \frac{R_{test}\left(V_{CAN\_L,H} - V\right)}{V - U}$$

where V_{CAN_L} and V_{CAN_H} are the open circuit voltages according to Figure 4.

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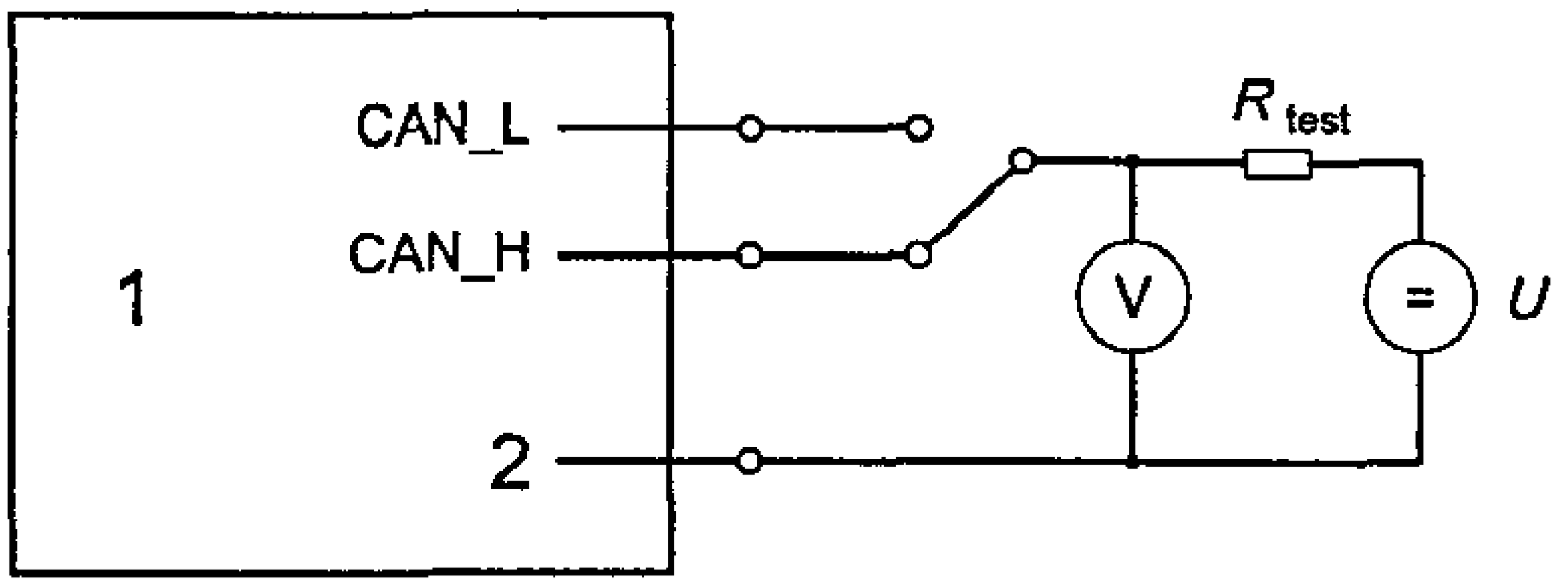


Key

1 CAN node with termination network

2 Ground

Figure 8 — Measurement of R_{in} while CAN node protocol IC is set to bus idle

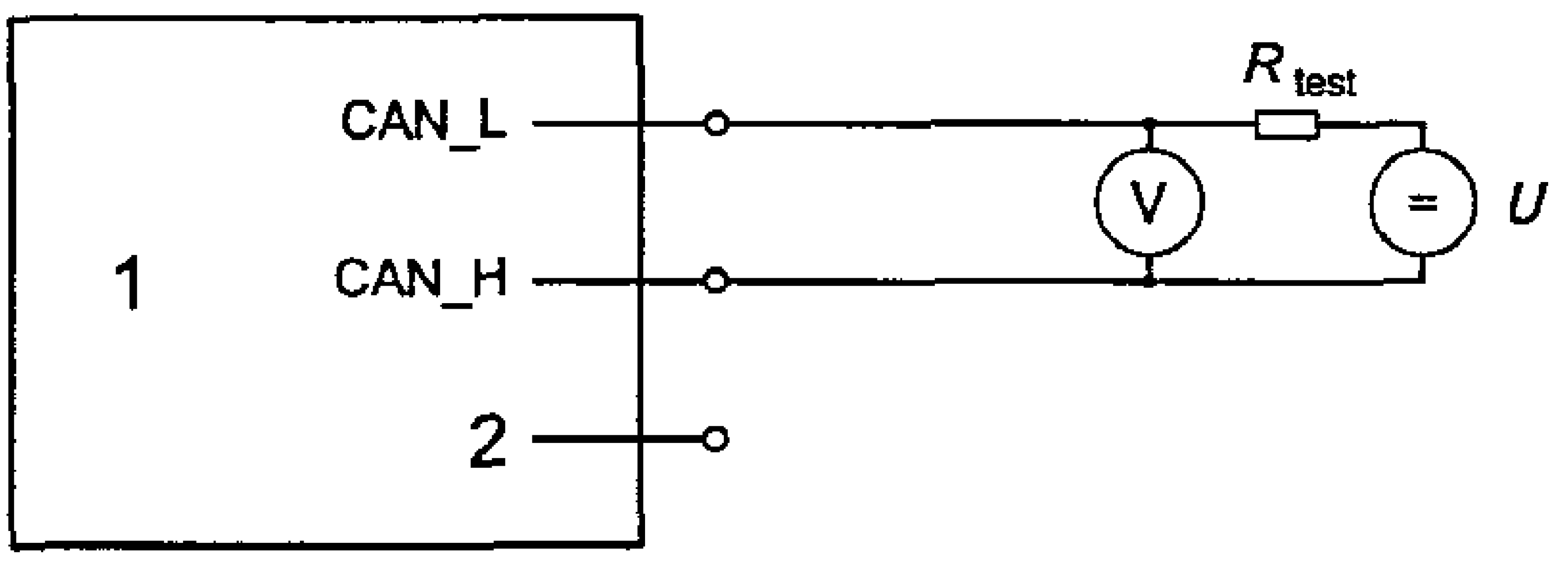
6.5.2 Internal differential resistor

The measurements of R_{diff} while the CAN node protocol IC is set to idle shall be taken as shown in Figure 9.

R_{diff} is determined for R_{test} during bus idle as:

$$R_{\text{diff}} = \frac{R_{\text{test}}\left(V_{\text{diff}} - V\right)}{V - U}$$

where V_{diff} is the differential open circuit voltage, calculated in accordance with 6.3.1.



Key

1 CAN node with termination network

2 Ground

Figure 9 — Measurement of R_{diff} while CAN node protocol IC is set to bus idle

6.6 Input capacitances

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

— C_{busin} (see Figure 10);

— C_{in} (see Figure 11);

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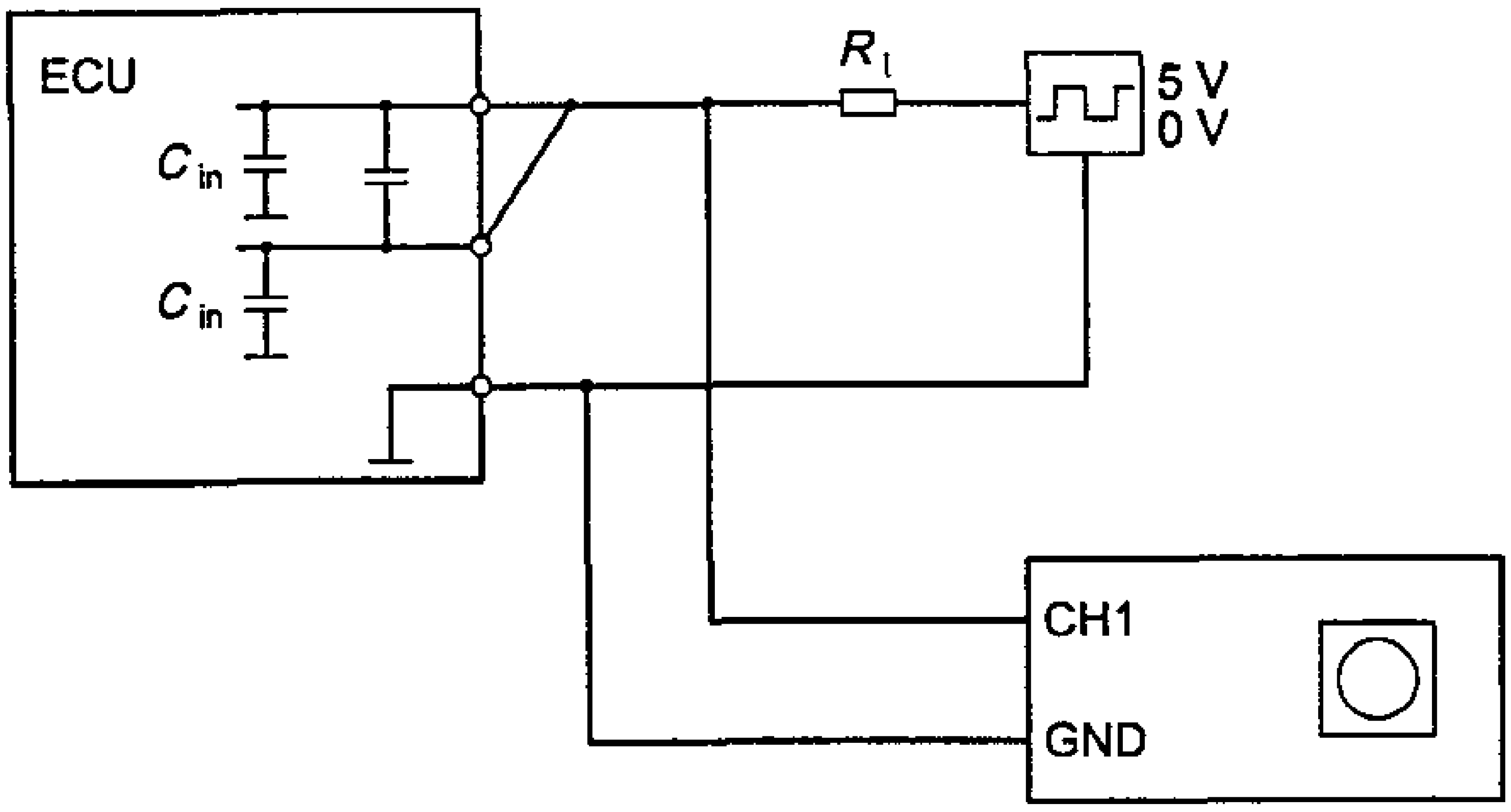

Figure 10 — Measurement of input capacitance, C_{busin}, during the recessive state

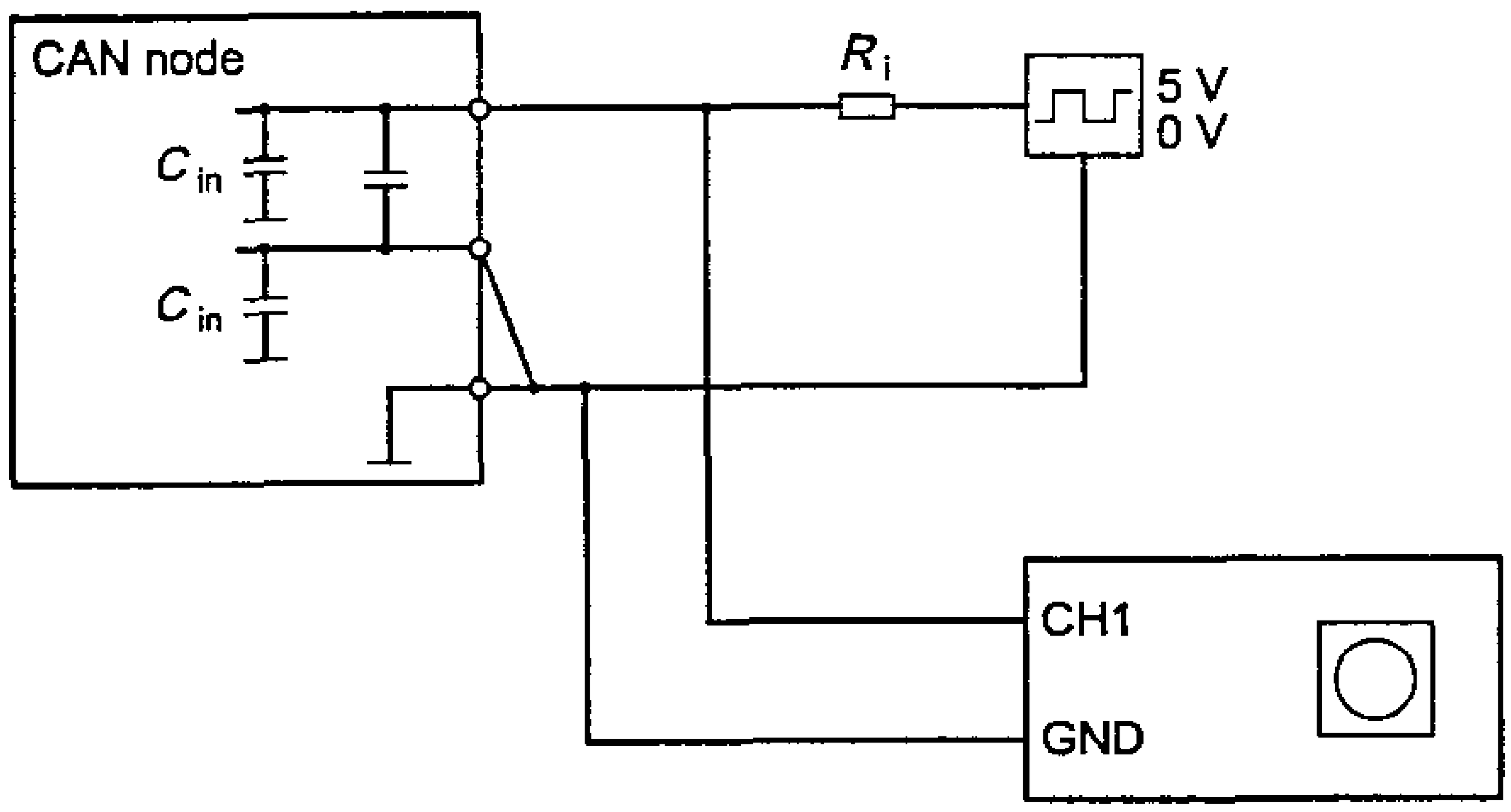

Figure 11 — Measurement of input capacitance, C_{in}, of a CAN node at the recessive state

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 picofarads. Therefore, the measurement equipment itself shall have a negligible capacitance or its capacitance shall be compensated for by an exact measurement.

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

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

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

Then C_{diff} can be determined:

$$C_{diff} = \frac{C_{busin} - C_{in}}{2}$$

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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 in idle state. The CAN node shall regard the dominant bit as a start of frame (SOF) and perform a hard resynchronization. The CAN controller shall detect a stuff error at the sixth recessive bit after the dominant bit and respond with an active error flag. The time measured between the externally applied dominant bit and the beginning of the error flag is $t_{edge\_to\_edge}$.

$$t_{\Delta edge} = 6 \cdot \text{NBT} - (t_{outputRD} - t_{outputDR})$$

$$t_{inputRD} + t_{outputRD} = t_{edge\_to\_edge} - 7 \cdot \text{NBT} + \text{sync}$$

The sync term can be eliminated by adjusting the phasing to get the maximum value for $t_{edge\_to\_edge}$ (maximization of the CAN cell sampling error: 1 tq).

The measurement of the ECU internal delay time is illustrated in Figure 12.

Values in volts

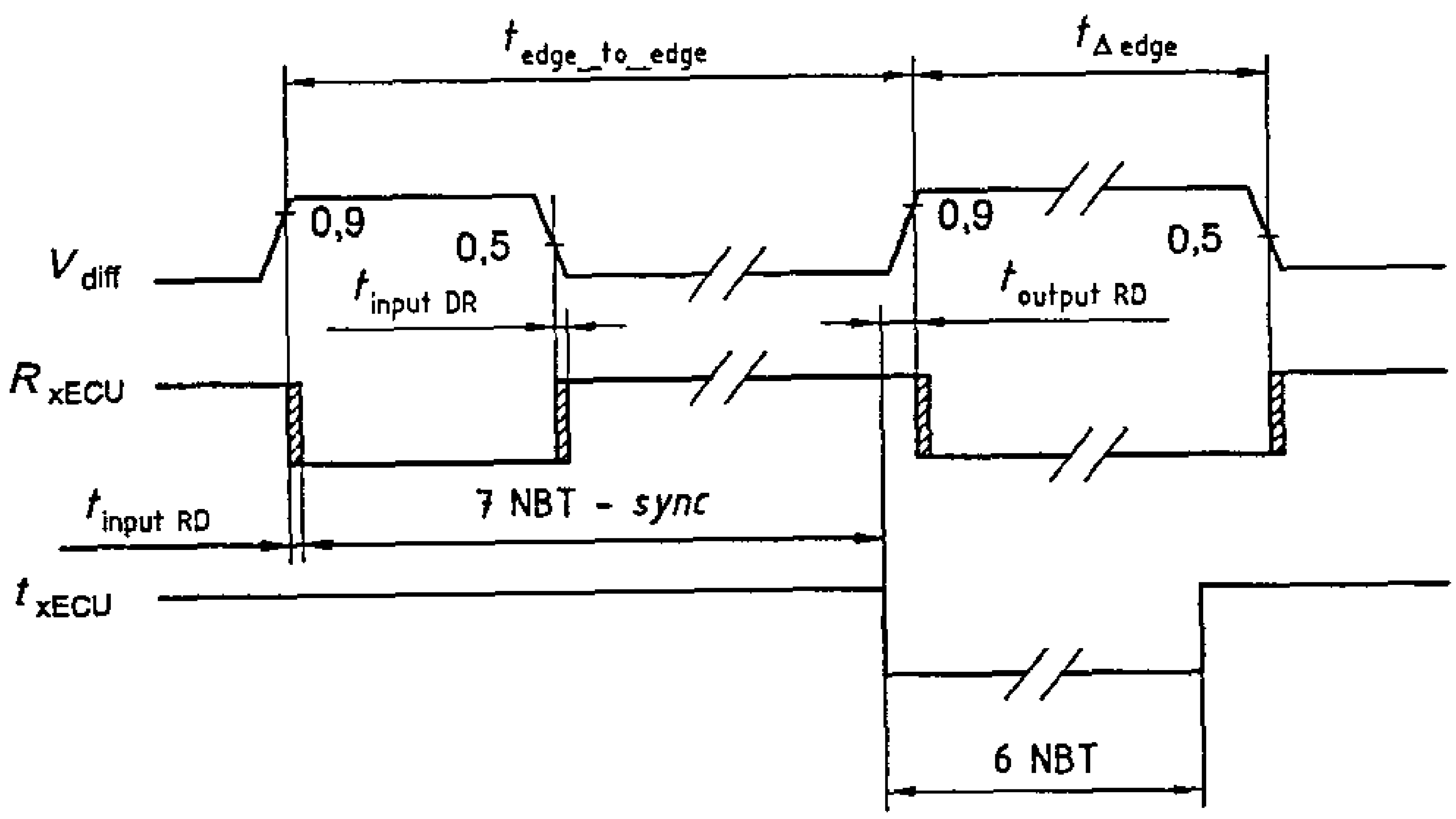

Figure 12 — Measurement of the ECU internal delay time

Using a test method derived from the above to assess $t_{inputRD}$ the test unit synchronizes itself to the SOF sent by the CAN node. Upon detection of the first recessive bit, the test unit shall partly overwrite the duration of this recessive bit by a dominant level, starting backwards from the expected end of the bit (see hatched area). The overwriting is started earlier and earlier until the node eventually loses arbitration and stops transmitting. Figure 13 illustrates this overwriting.

$$t_{inputRD} + t_{outputDR} = t_{sample} - \text{NBT} - t_x$$

This equation may be used to assess the terms $t_{inputRD}$ and $t_{outputRD}$ for the network synchronization.

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Values in volts

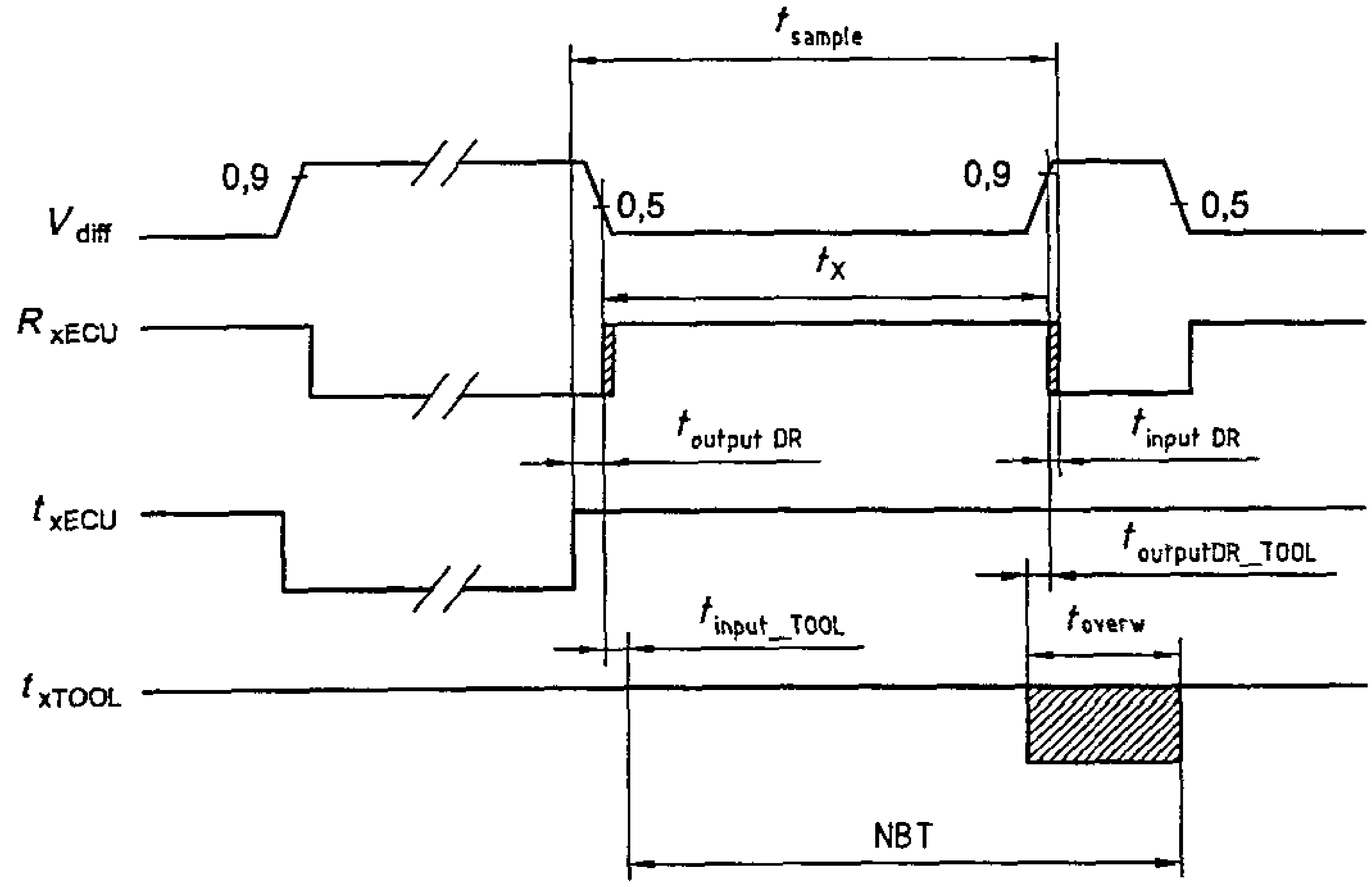

Figure 13 — Synchronization by overwriting recessive bits by dominant bit of test unit

7 Electrical specification of 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 14 is specified in Table 10. It is not recommended to integrate the termination into a CAN node.

a) **Termination A** b) **Termination B**

Figure 14 — Bus termination of the high-speed bus implementation

7.2 Physical medium attachment sublayer specification

7.2.1 General

The parameters specified in Tables 1 to 5 shall be adhered to throughout the operating condition range of every CAN node. The parameters are chosen such that a maximum number of CAN nodes may be connected to the common bus.

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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 [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 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			Condition
			min.	nom.	max.	
Common mode bus voltage [a]	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 [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 — Maximum ratings of V_{CAN_L} and V_{CAN_H} of CAN node

Nominal battery voltage V	Notation	Voltage [a] V	
		min.	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

[a] Undisturbed operation does not have to be guaranteed, but no destruction of bus driver circuit and no time limit.

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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 [a]
Internal resistor [b]	R_{in}	kΩ	5		50	
Differential input voltage [c]	V_{diff}	V	– 1,0		0,5	[d, e]

[a] 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).

[b] 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.

[c] 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).

[d] Threshold for receiving a recessive bit.

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

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 $R_L/2$ [a]
	V_{CAN_L}	V	0,5	1,5	2,25	
Differential output voltage	V_{diff}	V	1,5	2,0	3,0	load $R_L/2$ [a]
Differential input voltage [b]	V_{diff}	V	0,9		5,0	load $R_L/2$ [a, c, d]

[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] Threshold for receiving a dominant bit.

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

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.

7.2.2.2 Disturbance by coupling

The tolerated disturbances of CAN_H and CAN_L by coupling are defined in accordance with ISO 7637-3:1995, test pulses 3a and 3b.

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7.3 CAN node

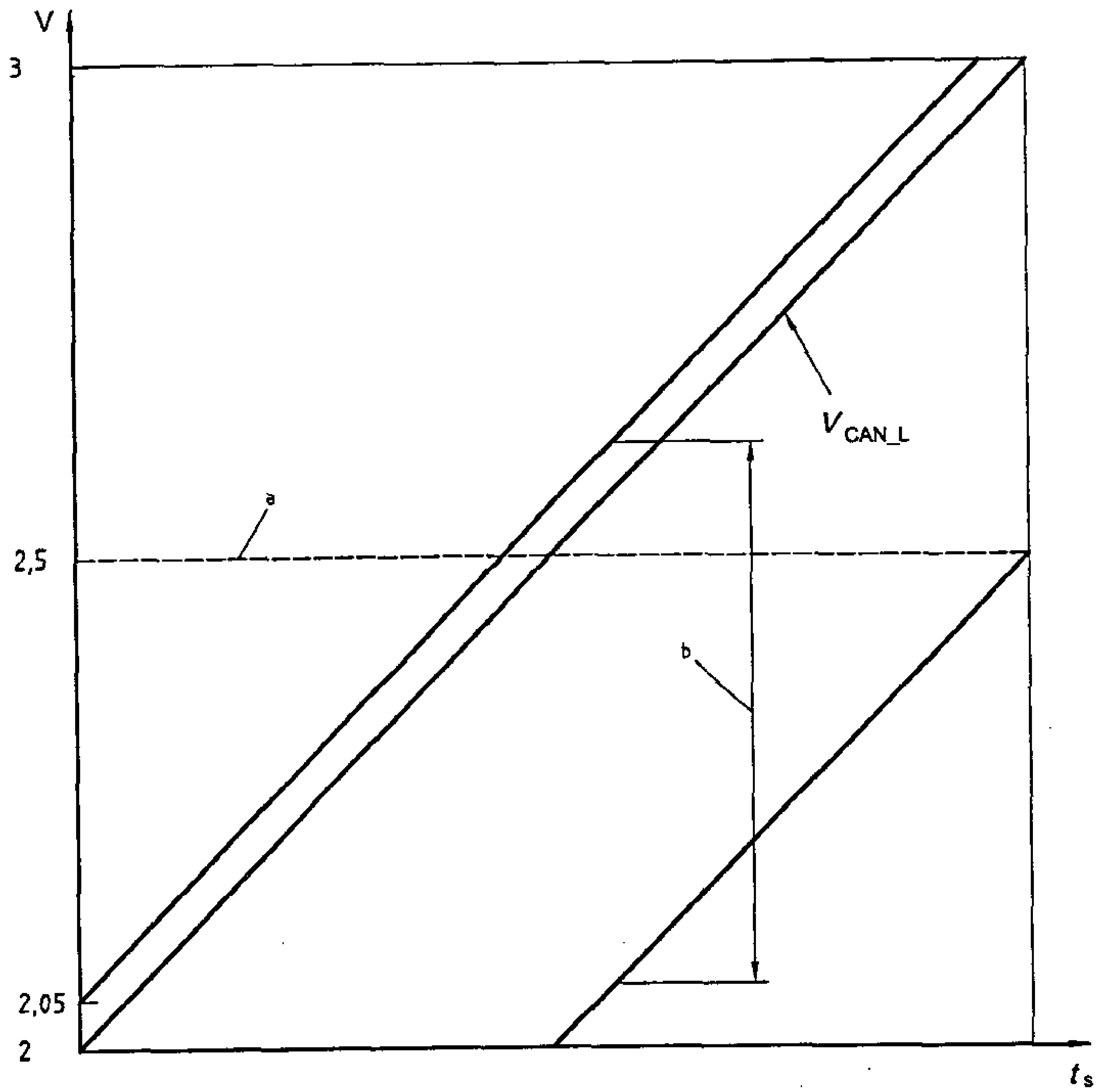
7.3.1 General

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).

The parameters given in Tables 4 and 5 shall be tested at the CAN_L and CAN_H pins of each CAN node, according to conformance tests 6.2 to 6.7 of ISO 16845.

7.3.2 Illustration of voltage range

Load conditions are specified in Tables 1 to 5. Figures 15 to 18 illustrate the valid voltage ranges of V_{CAN_H} and V_{CAN_L}.



Key

t_s Random time.

a Nominal.

b Range of V_{CAN_H}.

Figure 15 — 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

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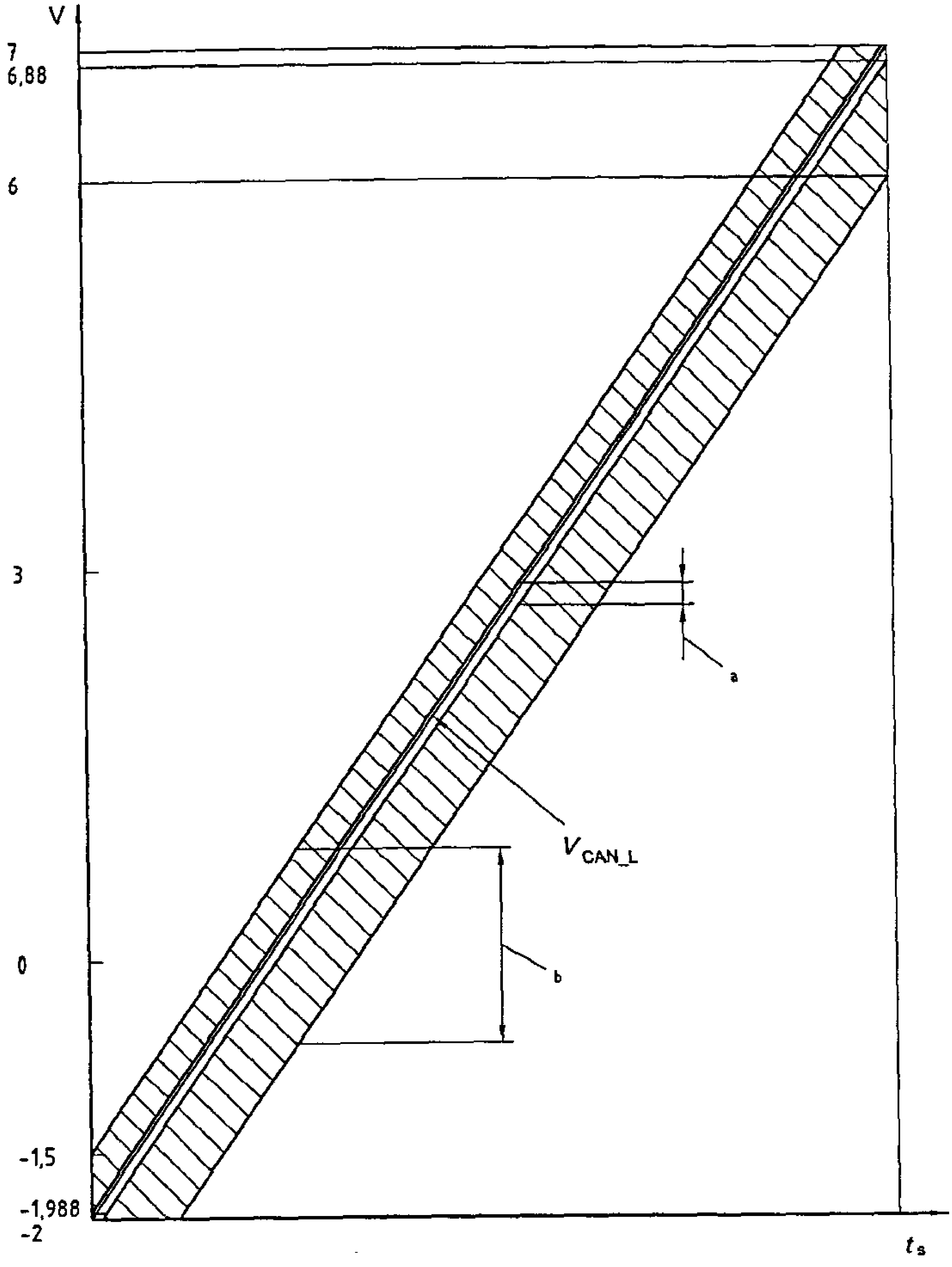

Key

t_s Random time.

a Actual range of V_{CAN_H} of the bus line.

b Range of V_{CAN_H} for reception.

Figure 16 — 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

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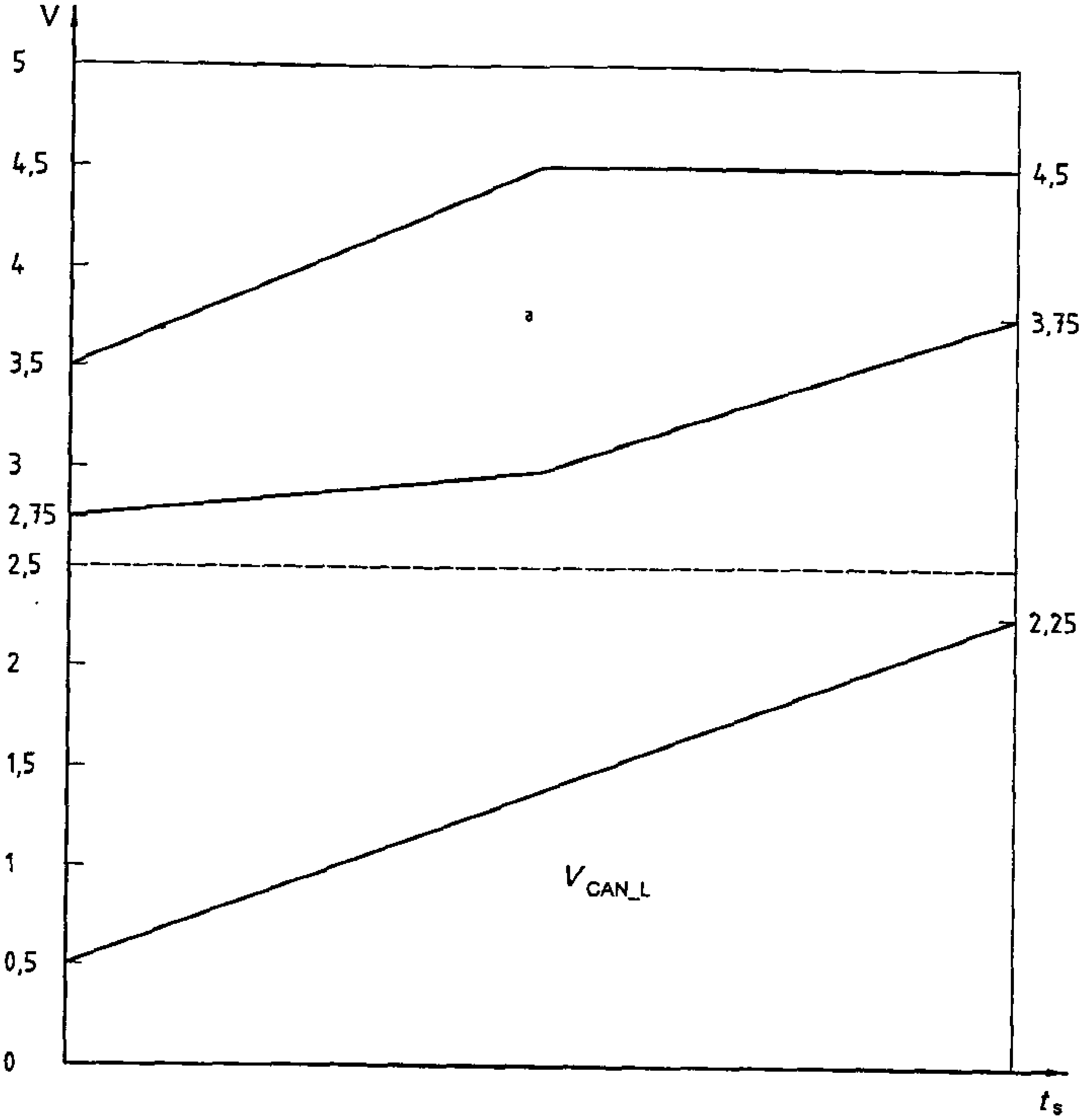

Key

t_s Random time.

a Range of V_{CAN_H}.

Figure 17 — Valid voltage range of V_{CAN_H} during dominant state of CAN node disconnected from bus if V_{CAN_L} varies from min. to max. voltage level

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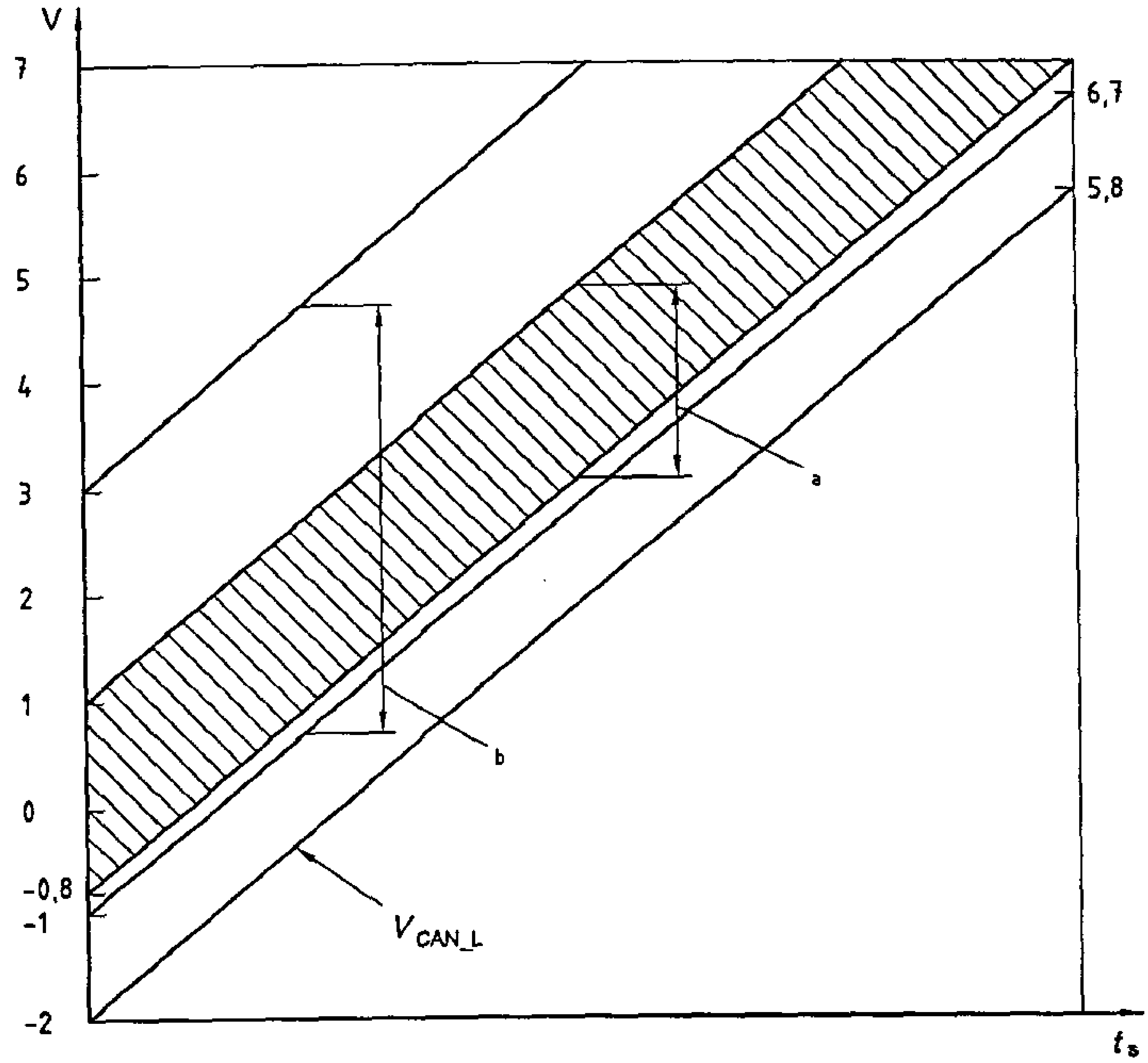

Key

t_s Random time.

a Actual range of V_{CAN_H} of the bus line.

b Range of V_{CAN_H} for reception.

Figure 18 — 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 the conformance tests specified in Clause 6 of ISO 16845.

Table 6 — AC parameters of CAN node disconnected from bus

Parameter	Notation	Unit	Value			Condition
			min.	nom.	max.	
Bit time	t_B	µs	1			a
Internal capacitance	C_{in}	pF		20		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.

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 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 the footnote to Table 11). 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).

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

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The test voltages U_{ST} are specified in Table 7.

Table 7 — Test voltages

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

7.4 MDI specification, connector parameters

A connector used to plug CAN nodes to the bus shall be in accordance with 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 [a]		I_P	mA			500
Transmission frequency		f	MHz	25		
Transmission resistance [b]		R_T	mΩ		70	

[a] Time restriction: 101 t_B.

[b] 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

The specifications given below shall be fulfilled by the cables chosen for the CAN bus. The aim of these specifications is to standardize the electrical characteristics and not to specify mechanical and material parameters of the cable.

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

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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		[a]
Specific line delay		ns/m		5		[b]

[a] 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.

[b] 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 [a]	Ω	100	120	130	Min. power dissipation: 220 mW

[a] Dependent on the topology, the bit rate, and the slew rate, deviations from 120 Ω are possible. It is, however, necessary to check the applicability of other resistor values in each case.

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

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. Network topology parameters shall be in accordance with Table 11.

Table 11 — Network topology parameters

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

[a] 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, Footnote c).

7.6 Bus failure management

During normal operation, several bus failures can occur that influence the bus operation. The resulting behaviour of the network shall be as given in Table 12. The possible open circuit and short circuit failures are shown in Figure 19.

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Table 12 — Bus failure detection

Description of bus failure	Behaviour of network [a]	Quality of specification [b]
One node becomes disconnected from the bus	The remaining nodes continue communicating.	Recommended
One node loses power	The remaining nodes continue communicating with reduced signal-to-noise ratio.	Recommended
One node loses ground	The remaining nodes continue communicating with reduced signal-to-noise ratio.	Recommended
Loss of the shield connection at any node [c]	All nodes continue communicating.	Recommended
Open and short failures [d]	All nodes continue communicating with reduced signal-to-noise ratio.	Recommended
1 CAN_H interrupted		
2 CAN_L interrupted		
3 CAN_H shorted to battery voltage		
4 CAN_L shorted to ground		
5 CAN_H shorted to ground		
6 CAN_L shorted to battery voltage		
7 CAN_L wire shorted to CAN_H wire		Optional
8 CAN_H and CAN_L wires interrupted at the same location		Recommended
9 Loss of one connection to termination network		Recommended

[a] The example in Figure 19 excludes all fault tolerant modes.

[b] The quality of specification is as follows.

— If the respective failure occurs the network shall behave as described in the second column of the table.

— If the respective failure occurs, the network behaviour should be as described in the second column of the table. Exclusion of this specified functionality is at the manufacturer's discretion.

— If the respective failure occurs the network behaviour may be as described in the second column of the table. Inclusion of this fuller specified functionality is at the manufacturer's discretion.

[c] This failure should be considered only if a shielded cable is used. In this case the loss of shield connection at one node may cause common mode voltage induced between the shield and the two signal wires.

[d] The numbers 1 to 9 refer to Cases 1 to 9 in Figure 19.

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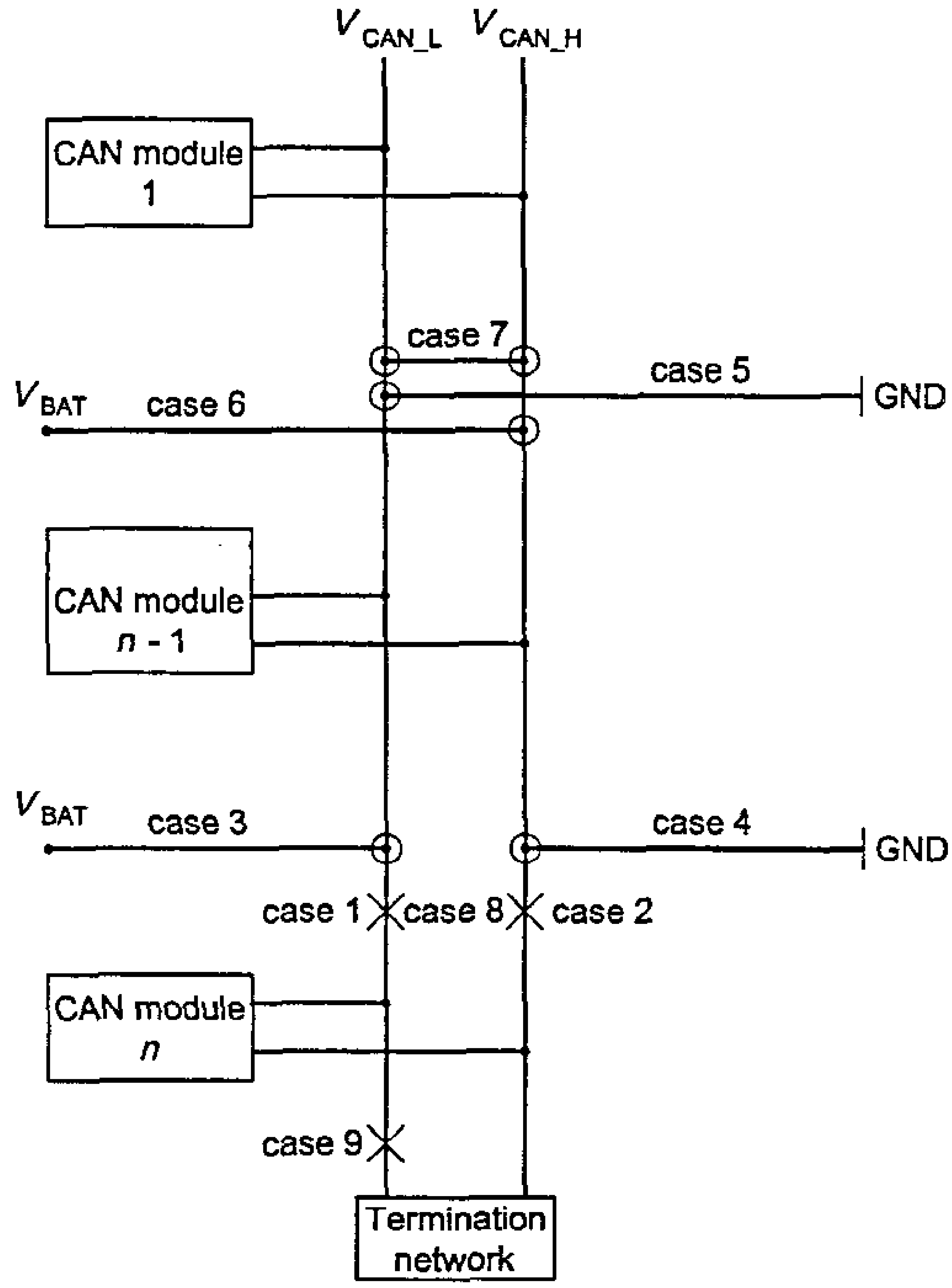

Figure 19 — Possible failures of bus lines

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