SAE INTERNATIONAL

SURFACE VEHICLE RECOMMENDED PRACTICE

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High-Speed CAN (HSC) for Vehicle Applications at 500 kbps with CAN FD Data at 2 Mbps

RATIONALE

Facilitate usage of the CAN with Flexible Data Rate (CAN FD) message format for in-vehicle data communication use cases.

FOREWORD

The objective of SAE J2284-4 is to define a level of standardization in the implementation of a 500 kbps arbitration bus with CAN FD Data at 2 Mbps vehicle communication network using the Controller Area Network (CAN) protocol. The goal is to achieve a standard Electronic Control Unit (ECU) Physical Layer, Data Link Layer, and Media Design Criteria which will allow ECU and tool manufacturers to satisfy the needs of multiple end users with minimum modification to a basic design. Likewise, end users will benefit in lower ECU cost achieved from the high volumes of the basic design.

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1. SCOPE

This SAE Recommended Practice will define the Physical Layer and portions of the Data Link Layer of the Open Systems Interconnection model (ISO 7498) for a 500 kbps arbitration bus with CAN FD Data at 2 Mbps High-Speed CAN (HSC) protocol implementation. Both ECU and media design requirements for networks will be specified. Requirements will primarily address the CAN physical layer implementation.

Requirements will focus on a minimum standard level of performance from the HSC implementation. All ECUs and media shall be designed to meet certain component level requirements in order to ensure the HSC implementation system level performance at 500 kbps arbitration bus with CAN FD Data at 2 Mbps. The minimum performance level shall be specified by system level performance requirements or characteristics described in detail in Section 6 of this document.

This document is designed such that if the Electronic Control Unit (ECU) requirements defined in Section 6 are met, then the system level attributes should be obtainable.

This document will address only requirements which may be tested at the ECU and media level. No requirements which apply to the testing of the HSC implementation as integrated into a vehicle are contained in this document. However, compliance with all ECU and media requirements will increase the possibility of communication compatibility between separately procured components and will greatly simplify the task of successfully integrating a HSC communication system in a vehicle.

2. REFERENCES

This specification takes precedence over all conflicts in the documents cited in this section.

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J551-15 Vehicle Electromagnetic Immunity – Electrostatic Discharge (ESD)

SAE J1213-1 Glossary of Vehicle Networks for Multiplexing and Data Communications

SAE J1930 Electrical/Electronic Systems Diagnostic Terms, Definitions, Abbreviations, and Acronyms

SAE J1962 Diagnostic Connector

SAE J2190 Enhanced E/E Diagnostic Test Modes

SAE J2962-2 Communication Transceivers Qualification Requirements – CAN

SAE 970295 CAN Bit Timing Requirements

2.1.2 ISO Publications

Copies of these documents are available online at http://webstore.ansi.org/

ISO 7498	Data processing systems - Open systems interconnection standard reference model
ISO 7637-1	Road vehicles - Electrical disturbance by conduction and coupling
ISO 10605	Road vehicles - Test methods for electrical disturbances from electrostatic discharge
ISO 11451-2	Road vehicles - Vehicle test methods for electrical disturbances from narrowband radiated electromagnetic energy - Part 2: Off-vehicle radiation sources
ISO 11452-4	Road vehicles - Component test methods for electrical disturbances from narrowband radiated electromagnetic energy - Part 4: Harness excitation methods
ISO 11898-1:2015(E)	Road vehicles - Interchange of digital information - Controller area network (CAN), Part 1: Data link layer and physical signalling
ISO 11898-2 :2016(E)	Road vehicles - Interchange of digital information - Controller area network (CAN), Part 2: High-speed medium access unit
ISO 14229	Road vehicles - Diagnostic systems - Specification of diagnostic services
ISO 26262	Road vehicles - Functional safety

2.1.3 Other Publications

CISPR 25	Limits and Methods of Measurement of Radio Disturbance Characteristics for the Protection of Receivers Used On-Board Vehicles
AUTOSAR Release 4.2.2	www.autosar.org

3. DEFINITIONS

The definitions provided in SAE J1213-1 apply to this document. Additional or modified definitions, acronyms, and abbreviations included in this document or relevant to the communication of information in a vehicle are catalogued in this section.

3.1 ARBITRATION BIT TIME

See Nominal Bit Time.

3.2 CAN_H

The CAN_H bus wire is fixed to a mean voltage level during the recessive state and is driven in a positive voltage direction during the dominant bit state.

3.3 CAN_L

The CAN_L bus wire is fixed to a mean voltage level during the recessive state and is driven in a negative voltage direction during the dominant bit state.

3.4 CAN ACTIVITY FILTER TIME

Duration for which the bus needs to be continuously in the same state to enable the signal to pass the bus wake-up filter.

3.5 CAN BUS

Subnet where a number of ECUs communicate via a two-wire link (CAN_H, CAN_L) and where the Controller Area Network protocol is used as data link layer (DLL).

3.6 CAN IDENTIFIER

Bit pattern of 11 bits or 29 bits, located at the beginning of a message that denotes message content and also reflects message priority.

3.7 CLASSICAL CAN MESSAGE

Bus message according to ISO 11898:1993/Amd.1:1995(E). Bus message according to ISO 11898-1 :2015(E) where the FDF bit is dominant, also known as CAN 2.0.

3.8 CAN FD MESSAGE

Bus message according to ISO 11898-1:2015(E) where the FDF bit is recessive. A CAN FD message typically employs different bit rates in the data field and in the arbitration field.

3.9 DATA BIT TIME

Length of a single bit in those parts of CAN FD messages where a dedicated separately configurable data bit time is used. The data bit time is not used anywhere in Classical CAN messages and is not used in those CAN FD messages where the BRS bit is dominant.

3.10 DATA LINK LAYER

Provides the reliable transfer of information across the Physical Layer. This includes message qualification and error control.

3.11 DATA SAMPLE POINT (t_{SAMPLE})

The sample point is the time within the bit period at which the single data sample captures the state of the bus. The programmable sample point is located between t_{SEG1} and t_{SEG2}. Equation 1 shows the relationship of t_{SAMPLE} to t_{SEG2}:

$$t_{SAMPLE} = t_{BIT} - t_{SEG2} \quad \text{(Eq. 1)}$$

3.12 DIAGNOSTIC CONNECTOR

Provides the electrical connection between Off-Board and On-Board ECUs. For some vehicles, the diagnostic connector is the SAE J1962 connector.

3.13 DISABLING OF DLC MATCHING

When this functionality is supported and active, then the bus transceiver will not compare message data length code (DLC) values as to whether or not they match to configured DLC values when scanning messages for presence of valid wake-up requests.

3.14 DOMINANT STATE

The dominant state is represented by a differential voltage greater than a minimum threshold between the CAN_L and CAN_H bus wires. The dominant state overwrites the recessive state and represents a logic “0” bit value.

3.15 ELECTRONIC CONTROL UNIT (ECU)

An On- or Off-vehicle electronic assembly from which CAN SAE J2284-4 messages may be sent and/or received.

3.16 ECU Delay (t_{ECU})

An ECU's loop delay includes the following four delays:

a. Transmitter Propagation Delay (t_{TX}, this includes device delay and slew)

b. Receiver Propagation Delay (t_{RX})

c. Receiver Logic Delay (t_{LOGIC})

d. Common Mode Choke (t_{CHK}, optional, Includes both Tx and Rx choke delays)

$$t_{ECU} = (t_{TX} + t_{RX} + t_{LOGIC} + t_{CHK}) \quad \text{(Eq. 2)}$$

3.17 FD_Receive / FD_Transmit

Status flags indicating whether the bus controller employs CAN FD data bit timing presently.

3.18 HANDLE

Hardware object label of one or multiple LLC frames (LPDU). Identifies hardware element used for transaction. Used to facilitate cancellation of pending message transmission requests.

3.19 MEDIA

The physical entity which conveys the electrical (or equivalent means of communication) transmission between ECUs on the network (e.g., unshielded twisted pair wires). Media is defined as all elements between the connector pins of the communicating ECUs through which the signals pass.

3.20 MEDIA DELAY (t_{BUS})

Media delay is defined as the time required for a signal to pass through the media at the longest specified distance (see Table 1 in 5.3, Table 2 in 5.4, and Table 3 in 5.5).

3.21 MUST

The word "**Must**" is used to indicate that a binding requirement exists on components or devices which are outside the scope of this specification.

3.22 NOMINAL BIT TIME

Length of a single bit in Classical CAN messages. Length of a single bit in CAN FD messages except where data bit timing applies. Also known as arbitration bit time.

3.23 PCS STATUS

Indicates what logical level is presently being received or transmitted and whether or not CAN FD data bit timing applies presently. For details see ISO 11898-1 :2015(E).

3.24 PHYSICAL LAYER

Concerns the transmission of an unstructured bit stream over physical media: deals with the mechanical, electrical, functional, and procedural characteristics to access the physical media.

3.25 PROTOCOL

Formal set of conventions or rules for the exchange of information between ECUs. This includes the specification of frame administration, frame transfer, and physical layer.

3.26 RADIATED EMISSIONS

Radiated Emissions consists of energy that emanate from the CAN bus wires. Electric field strength in dbμV/m is the typical measure of radiated emissions.

3.27 RADIATED IMMUNITY

A property that ensures that the CAN bus wires will not suffer degraded functional operation within its intended electromagnetic environment.

3.28 RECESSIVE STATE

The recessive state is represented by an inactive state differential voltage that is approximately 0. The recessive state represents a logic “1” bit value.

3.29 PROPAGATION DELAY (t_{PROP})

Part of bit cell that serves compensation of data signal delay times in a network. Because CAN is an arbitrating protocol, the propagation delay must take into account the time required for a signal to make a complete round trip from one CAN controller to another and back. This translates to Equation 3 or 4.

$$t_{PROP} = 2(t_{TX} + t_{RX} + t_{LOGIC} + t_{CHK} + t_{BUS}) \quad \text{(Eq. 3)}$$

or

$$t_{PROP} = 2(t_{ECU} + t_{BUS}) \quad \text{(Eq. 4)}$$

3.30 SECONDARY SAMPLE POINT (SSP)

Sample point that applies to data bit timing in CAN FD (BRS = recessive) messages when the transmitter delay compensation functionality is configured to be enabled/active. The transmitting bus controller automatically determines/adapts/delays the location of the sample point based on observed data signal delay of the particular transmitter implementation, unless transmitter delay compensation disabled.

3.31 SELECTIVE WAKE-UP BUS TRANSCEIVER

Bus transceiver capable to monitor bus messages while in low power mode and capable to generate a wake-up interrupt when valid messages present on the bus match configured message content (identifier, data field).

3.32 SHALL

The word "**Shall**" is to be used in the following ways:

a. To state a binding requirement on the CAN interfaces which comprise the ECU, which is verifiable by external manipulation and/or observation of an input or output.

b. To state a binding requirement upon an ECU that is verifiable through a review of the document.

3.33 SHOULD

The word "**Should**" is used to denote a preference or desired conformance.

3.34 SPLIT BUS TERMINATION

Bus termination where the resistance between CAN_H and CAN_L is split into two parts of equal value. Resistance center tap connected to ground via a capacitor unless otherwise specified.

3.35 SYNCHRONIZATION JUMP WIDTH (t_{SJW})

This time interval is the maximum amount of time by which t_{SEG1} may be lengthened or t_{SEG2} shortened to compensate for synchronization differences between ECUs on the CAN network. This is accomplished automatically in the CAN controller as a basic part of the protocol. However, the amount of skew tolerated is adjustable by software programming.

3.36 SYNCHRONIZATION SEGMENT (t_{SYNC_SEG})

This time interval is used to synchronize all ECUs on the bus. If all ECUs are fully synchronized, then all bit edges occur in this interval, which has a fixed period of one Time Quantum.

3.37 TIME QUANTUM (t_Q)

This is the basic unit of time for bit timing. This time is derived from the microcontroller's oscillator clock and is programmable based on the CAN controller's divide register values.

3.38 TRANSMITTER DELAY COMPENSATION (TDC)

For data bit timing in CAN FD messages the transmitting CAN controller automatically will compensate the signal delay caused by the ECU-internal transmitter implementation, unless TDC functionality disabled. Functionality inactive for arbitration bit timing in CAN FD messages and generally inactive in classical CAN messages. For details see ISO 11898-1 :2015(E).

3.39 TSEG1 (t_{SEG1})

This time interval is used to compensate for positive phase errors in synchronization between ECUs on the network. If an edge occurs during this interval, t_{SEG1} is lengthened to compensate for synchronization differences with other ECUs on the CAN network. T_{SEG1} is equivalent to the combination of the Prop_Seg and Phase_Seg1 parts of the bit period defined in ISO 11898-1 :2015(E).

3.40 TSEG2 (t_{SEG2})

This time interval is used to compensate for negative phase errors in synchronization between ECUs on the network. If an edge occurs during this interval, t_{SEG2} is shortened to compensate for synchronization differences with other ECUs on the CAN network. T_{SEG2} is equivalent to the Phase_Seg2 part of the bit period defined in ISO 11898-1 :2015(E).

3.41 WILL

The word "**Will**" is used to state an immutable law of physics.

4. ACRONYMS

ASIL	Automotive Safety Integrity Level
BRS	Bit Rate Switch
CAN	Controller Area Network
CAN FD	CAN with Flexible Data Rate
CAN ID	CAN Identifier
DLC	Data Length Code
ECU	Electronic Control Unit
EMC	ElectroMagnetic Compatibility
ESD	Electrostatic Discharge
ESI	Error Status Indicator
FD	Flexible Data Rate (message format)
FDF	Flexible Data Rate Format
HSC	High-Speed CAN
ISO	International Standardization Organization
kbps	KiloBits Per Second
LLC	Logical Link Control (layer)
LPDU	LLC Protocol Data Unit (frame)
MAC	Media Access Control (layer)
Mbps	MegaBits Per Second
NOP	Non-operating (only survival is demanded)
OBD II	On Board Diagnostics (level 2)
PCS	Physical Coding Sub-layer
R_L	Resistive Load between CAN_H and CAN_L
R_Z	Bus Termination Resistance (125 Ω nominal)
SAE	SAE International
Vbatt	Power supply for the ECUs present in a communication network (12V nominal)
V_{Diff}	Differential bus voltage ($V_{Diff} = V_{CAN\_H} – V_{CAN\_L}$)

5. SYSTEM LEVEL ATTRIBUTES OF THE NETWORK

This section describes System Level performance attributes of a 500 kbps HSC network for automotive vehicle applications. It is up to the particular system owner to ensure that network level limits in this chapter are met. This HSC network is based on ISO 11898-1 and ISO 11898-2 releases stated in section 2.1.2 with the modifications and additions described as follows:

5.1 Message Format

All ECU CAN interfaces shall, at a minimum, conform to the ISO 11898-1 (Road vehicles — Controller area network (CAN) — Part 1: Data link layer and physical signalling) and ISO 11898-2 (Road vehicles — Controller area network (CAN) — Part 2: High-speed medium access unit), releases as stated in section 2.1.2. For details, see sections 6 and 7 later in this document.

All ECUs intended for use in a subnet according to J2284-4 shall, at a minimum, be passive to CAN FD format frames, meaning shall not send error frames against and shall not increase ECU-internal error counters when syntactically correct CAN FD format frames with bit rates stated below in this document are present.

All ECUs that utilize the 11-bit base frame identifier shall be, at a minimum, passive to the 29-bit extended frame identifier. All SAE J2284-4 compliant ECUs that support OBD II requirements shall fully support a 29-bit extended frame identifier.

The encoding of the 11-bit identifier field shall be vehicle manufacturer specific. The CAN requirement (see CAN 2.0 protocol specification and superseded ISO 11898-1 CAN documents) specifying that the 7 most significant bits (ID-28 – ID-22) must not be all recessive shall not be enforced in hardware by SAE J2284-4. CAN protocol implementations shall be capable to transmit and receive all identifier bit combinations without any restrictions.

The maximum message frame shall consist of the CAN identifier (CAN ID) plus 64 data bytes.

5.2 Communication Rate

Classical CAN messages and CAN FD messages where the bit BRS is dominant shall utilize a single communication rate of 500 kbps. CAN FD messages where the bit BRS is recessive shall utilize a communication rate of 500 kbps for arbitration, end of frame fields, and syntax error notifications and shall utilize 2 Mbps for message data fields (i.e. from sample point of BRS bit to sample point of CRC Delimiter bit).

5.3 Basic Communication Network Parameters

The intent of this standard is to specify data communication for networks with these properties.

Table 1 - Basic communication network parameters

Parameter	Symbol	Minimum	Maximum	Units	Conditions
Number of nodes (bus interfaces)	N_{nd}	2	24	--	(1)
Data communication operating ground offset voltage	V_{GND-OP}		2	Volts	(2)
Network level overall differential resistive load	R_L	45	70	Ohms	(3)
(Wiring) Resistance between any two bus transceiver CAN_H to CAN_H (CAN_L to CAN_L) pins	R_w		9	Ohms	(4)
Maximum propagation time between any two ECUs	t_{BUS}		300	ns	(5)

1. Directly connected within a particular subnet.
2. Between any two ECUs in a subnet.
3. Between CAN_H and CAN_L.
4. Intends to reflect the bus wiring resistive behavior.
5. Includes one way wiring delay and node loading delay.

5.4 Topology and Termination

The wiring topology of this network supports a linear structure, including daisy-chain configurations, and including bus cable stubs. The bus shall be terminated in a way so that the network level overall resistive load between the CAN_H and CAN_L wires will be consistent to line item R_L in Table 1. Termination shall be located at each end of the bus. Termination units shall establish a defined resistance between the CAN_H and CAN_L wires. Two bus termination units shall be present in a subnet. Each of two termination units shall meet the requirements stated in section 6.4.

5.4.1 Multiple On-Board ECU Configuration

The topology requirements for a network containing more than one ECU On-Board the vehicle are specified in Figure 1 and Table 2. Note, presence of bus termination is needed, otherwise the network will not work.

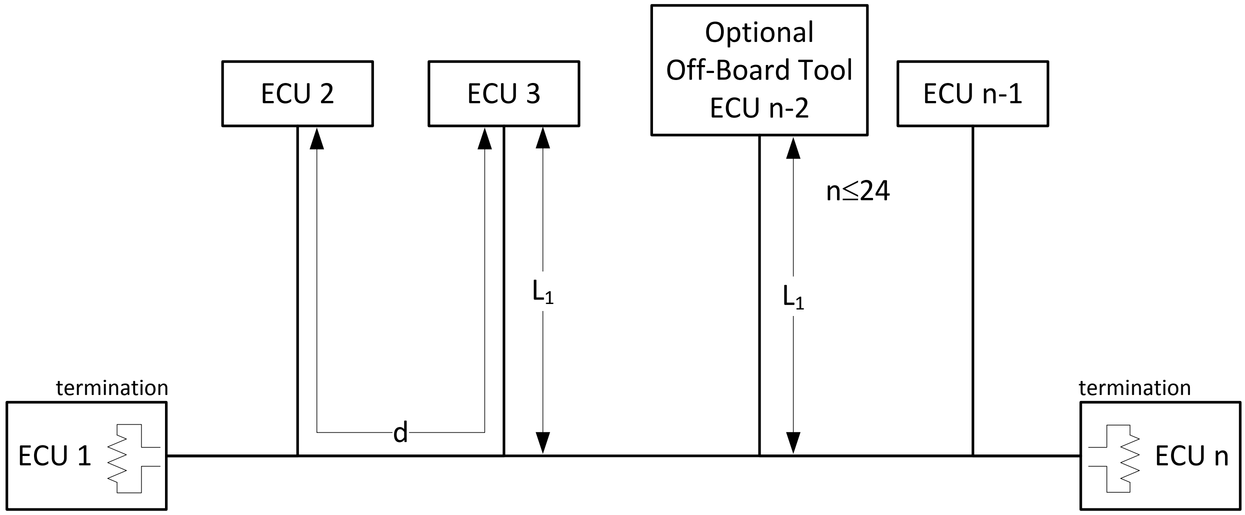

Figure 1 - Multiple on-board ECU configuration

Table 2 - Multiple on-board ECU topology requirements

Parameter	Symbol	Minimum	Nominal	Maximum	Unit	Comments
ECU Cable Stub Length	L_1	0		1.7	meter	Minimum of 0 allows for daisy chain configurations. Applies to ECUs and to tools connected to On-Board networks.
ECU Distance	d	0.1	33		meter	Cable length between any two ECUs on the bus, including cable stubs, and including any On- or Off-Board Tools. Maximum distance varies depending on number of ECUs, wiring propagation delay, and bit timing settings.

The purpose of the ECU minimum distance requirement is to ensure that wires are twisted in-between ECUs and/or splices. This does not apply to multiple nodes in the same ECU.

For topology and termination requirements for tools see section 5.8.

5.4.2 Additional Requirements

a. The terminations may be placed within ECUs. Terminations shall be placed adjacent to, or within, the two On-Board ECUs which are located at the greatest bus distance from each other.

b. Non-terminating ECUs can be optional connections.

5.5 Unshielded Media

The network shall operate using a shielded or unshielded twisted wire pair. The bus cable details are specified in Table 3.

(See Table 3.)

Table 3 - Physical media parameters for unshielded twisted pair

Symbol	Minimum	Nominal	Maximum	Units	Conditions
Z	90	115	140	Ω	f = 1 MHz
R_{LENGTH}			120	mΩ/meter	Single conductor
t_{DELAY}			5.3	ns/meter	Wire only
$RATE_{TWIST}$	33	40		Twists/meter	360 degrees

Parameter values in Table 3 apply over operating conditions and product lifetime, unless otherwise indicated.

5.6 Communication/Survivability Under Faulted Conditions

No damage to ECUs when one, and only one at a time, of the below listed failures becomes present. (See Table 4.)

Table 4 - Fault Behavior

Description of Failure	Communication Behavior
One non-terminating ECU becomes disconnected from the bus	Remaining ECUs continue to communicate with no degradation. (Exception = daisy chained network)
ECU loss of power or ground (includes low battery condition)	Remaining ECUs continue to communicate with no degradation.
CPU goes into reset, while its physical layer and IC is still powered	Remaining ECUs continue to communicate with no degradation.
CAN_H wire open	Data communication between ECUs on opposite sides of an interruption is not required. Data communication between ECUs on the same side of an interruption may be possible with reduced signal to noise ratio.
CAN_L wire open	Data communication between ECUs on opposite sides of an interruption is not required. Data communication between ECUs on the same side of an interruption may be possible with reduced signal to noise ratio.
CAN_H shorted to battery	Data communication may be possible with reduced signal to noise ratio. Data communication is not required when Vbatt is greater than the maximum allowed common mode voltage.
CAN_L shorted to battery	Data communication is not possible.
CAN_H shorted to ground	Data communication is not possible.
CAN_L shorted to ground	Data communication may be possible with reduced signal to noise ratio.
CAN_H shorted to CAN_L	Data communication is not possible.
Bus is stuck in a dominant state	Data communication is not possible.
CAN_H and CAN_L concurrently shorted to ground	Data communication is not possible.
CAN_H and CAN_L concurrently shorted to battery	Data communication is not possible.
CAN_H ECU terminal connected to CAN_L wire and CAN_L ECU terminal connected to CAN_H wire	Data communication is not required with the ECU incorrectly connected to the bus.
Loss of one termination	Depending on bus wire length, number of ECUs, and bit timing margin, data communication may be possible with reduced signal to noise ratio.
Transceiver's transmit control input (TxD) continuously asserted	ECUs terminate transmission of dominant condition within specified time, see later in this document.

Where Table 4 suggests "data communication is not required" and the application allows, then the ECU may enter low-power mode until there is a valid wake-up condition.

5.7 EMC Criteria

The ECU EMC requirements as specified in section 6.9 are intended to satisfy vehicle level EMC compliance when tested in accordance with CISPR 25, ISO 11451-2, and ISO 10605.

5.8 Tools

Any (On-Board and/or Off-Board) tools that connect to the (On-Board) bus (e.g., for monitoring or development purposes) need to follow the same topology rules as ECUs (see Table 2), including the bus cable requirements (for in-vehicle) stated in Table 3.

6. ECU REQUIREMENTS

This section describes the electrical requirements for an ECU on an HSC network. The requirements described are designed to support the design goals described in Section 5, System Level Attributes. Parameter values in this specification apply over operating conditions and product lifetime, unless otherwise indicated. Parameter values in this section are measured at the connector pins of the particular ECU, unless otherwise indicated.

6.1 Absolute Maximum Ratings

Network related electrical components within the ECU shall not suffer permanent damage. Ability to perform network communications under these conditions is out of scope (not required).

6.1.1 Direct Voltage Connection

The table below states requirements on ECUs intended for use in networks powered with a voltage of 12V nominal. Abbreviation NOP stands for non-operating (survival). (See Table 5.)

Table 5 - ECU maximum bus wire voltage - no damage to ECU (12 V system)

Symbol	Minimum	Maximum	Units	Conditions
$V_{CAN\_H\_ECU-NOP}$	–13.0	27.0	Volts	All ECUs, t = 120 s
$V_{CAN\_L\_ECU-NOP}$	–13.0	27.0	Volts	All ECUs, t = 120 s
$V_{Diff\_ECU-NOP1}$	–5.0	7.0	Volts	All ECUs, t = 120 s
$V_{Diff\_ECU-NOP2}$	n/a	10.0	Volts	All ECUs: t = 10 ms Non-terminating ECUs: t = 120 s

Table 5 reflects maximum and minimum voltages which shall not cause damage when connected to CAN bus outputs of an ECU. These limits apply for when an ECU is attempting to transmit message, receive messages, and for bus idle. These limits also apply to all operating modes of an ECU including regular communication, sleep, scanning messages for presence of valid wake-up request, and unpowered (Vbatt disconnected, Vbatt = 0V) conditions. Successful transfer of messages between bus nodes is not expected when stated minimum or maximum voltages are present ($V_{Diff} = V_{CAN\_H} – V_{CAN\_L}$). Maximum value for $V_{Diff-NOP1}$ selected so that bus termination power dissipation will be below 500 mW.

ECUs shall survive when a suppressed load dump pulse (ISO 7637-2, pulse 5b, positive voltage, maximum voltage modified see column “Maximum”, line item “$V_{CAN\_H-NOP1-IC}$, $V_{CAN\_L-NOP1-IC}$” in Table 22) becomes coupled to CAN_H and CAN_L through a coupling capacitance of 1 nF each, at presence of transmit data input (TxD) patterns as will be generated by a regular CAN controller attempting to transmit messages (Table 23, line item TxD dominant duty cycle).

6.1.2 Unpowered Storage Temperature

The SAE J2284-4 electrical components within the ECU shall not suffer permanent damage if subjected to storage temperatures between –40 °C and +150 °C.

6.2 DC Operating Parameters

DC parameters shall be within the defined ranges for four unique conditions:

a. Recessive Bus State, ECU disconnected from CAN Bus

b. Dominant Bus State, ECU disconnected from CAN Bus

c. Recessive Bus State, ECU connected to maximum CAN Bus

d. Dominant Bus State, ECU connected to maximum CAN Bus

Compliance with the defined voltage ranges shall insure that ECUs will operate in a vehicle network application where a maximum DC offset between any two ECUs is present as stated in line item $V_{GND\text{-}OP}$ in Table 1. Compliance shall be maintained over the following ECU operating ranges:

ECU Operating Ambient Temperature

a. High Temperature –40 °C to +125 °C

b. Low Temperature –40 °C to +85 °C

ECU Operating Parameters

Table 6 – ECU operating parameters – CAN data communication

Symbol	Minimum	Nominal	Maximum	Units	Conditions
V_{SUP1_ECU}	7	12	16	Volts	(1)
V_{SUP2_ECU}	6	12		Volts	(2)
V_{SUP3_ECU}		12	18	Volts	(3)
V_{SUP4_ECU}		12	26.5	Volts	(4)
V_{SUP5_ECU}		12	34	Volts	(5)
$V_{CAN\_H\_ECU\text{-}OP}$, $V_{CAN\_L\_ECU\text{-}OP}$	–12		12	Volts	(6)
Δt_{BIT_ECU}	–0.4		0.4	%	(7)
t_{RSM_ECU}			300	ms	(8)
ASIL rating	QM		B	--	(9)

1. Compliance (data communication) shall be maintained over said operating static ECU supply voltage range as measured at the ECU connector power/ground pins unless otherwise specified for a particular ECU or bus interface.
2. Selected ECUs shall support data communication functionality down to said voltage continuously.
3. Selected ECUs shall support data communication functionality up to said voltage for t = 60 minutes.
4. Selected ECUs shall support data communication functionality up to said voltage for t = 60 seconds.
5. Selected ECUs shall support data communication functionality up to said voltage for t = 400 milliseconds.
6. Data communication operating common-mode bus input voltage range. Applies to recessive state and to dominant state.
7. Tolerance of length of a CAN bit time. Internal to the CAN controller. Including PLL effects. Tolerance value is applicable over operating conditions and aging, e.g., temperature, supply voltage and age drift, over specified ECU operating temperature, including ECU lifetime.
8. Maximum time after power disconnect for resuming regular data communication operation (capability to receive and transmit CAN messages) unless otherwise specified for a particular ECU. Time counts from the point in time when supply voltage enters operating supply voltage range specified for the particular ECU/particular bus interface. Upon return of power, the ECU shall resume regular data communication (ability to successfully receive messages and ability to attempt to transmit syntactically correct messages) without any operator intervention within said time.
9. Selected ECUs shall be capable to support an ASIL rating of up to B (ISO 26262) at one or more selected CAN bus interfaces.

6.2.1 DC Parameters – Output Behavior - Recessive Bus State - Bus Disconnected

DC bus output behavior of a single ECU (in the absence of other bus nodes) when transmitting a recessive bus state. Transmit data input (TxD) not asserted. (See Table 7.)

Table 7 - ECU DC parameters - output behavior recessive - bus disconnected

Symbol	Minimum	Nominal	Maximum	Units	Conditions
$V_{CAN\_H\_ECU-REC}$	2.0	2.5	3.0	Volts	no load (1)
$V_{CAN\_L\_ECU-REC}$	2.0	2.5	3.0	Volts	no load (1)
$V_{DIFF\_ECU\_OUT-REC}$	–500	0	50	Millivolts	no load (1)
$R_{DIFF\_ECU-REC-NZ}$	3.9		100	KΩ	no load (2)
$R_{DIFF\_ECU-REC-RZ}$	118	125	132	Ω	no load (3)
$R_{IN\_ECU-REC}$	5		50	KΩ	no load (2)

1. Bus bias functionality is on (active).
2. Applies to ECUs that do not contain a termination according to section 6.4. CAN transmit data input (TxD) not asserted. Applies over specified bus voltage ranges (V_{CAN_H-OP}, V_{CAN_L-OP}) stated in Table 6. Applies to powered state only.
3. Applies to ECUs with built in termination according to section 6.4. CAN transmit data input (TxD) not asserted. Applies over specified bus voltage ranges (V_{CAN_H-OP}, V_{CAN_L-OP}) stated in Table 6. Split termination implementations are allowed with equal value 1% resistors. Minimum value 116.8 Ohms when indicated so in a particular sourcing document.

6.2.2 DC Parameters – Output Behavior - Dominant Bus State - Bus Disconnected

DC bus output behavior of a single ECU (in the absence of other bus nodes) when transmitting a dominant bus state. Transmit data input (TxD) asserted. (See Table 8.)

Table 8 - ECU DC parameters - output behavior dominant - bus disconnected

Symbol	Minimum	Nominal	Maximum	Units	Conditions
$V_{CAN\_H\_ECU-DOM}$	2.75	3.5	4.5	Volts	(1)
$V_{CAN\_L\_ECU-DOM}$	0.5	1.5	2.25	Volts	(1)
V_{SYM_ECU}	0.9	1.0	1.1	--	(2)
$V_{DIFF\_ECU\_OUT-DOM1}$	1.5	2.0	3.0	Volts	(1)
$V_{DIFF\_ECU\_OUT-DOM2}$	1.4			Volts	(3)
$V_{OUT\_ECU\_OUT-DOM3}$			3.3	Volts	(4)
$V_{DIFF\_ECU\_OUT-DOM4}$			5.0	Volts	(5)
$I_{CAN\_H\_ECU-DOM-SC}$			115	mA	(6)
$I_{CAN\_L\_ECU-DOM-SC}$			115	mA	(7)

1. Resistive load of 50 Ω < R_L < 65 Ω connected between CAN_H and CAN_L. When termination present in an ECU then load 120 Ω connected between CAN_H and CAN_L.
2. $V_{SYM} = (V_{CAN\_H} + V_{CAN\_L}) / V_{CC}$, with V_{CC} being the supply voltage of the transmitter. Applies to dominant state and to recessive state and to transitions between the two states. Two times 30 Ohms between CAN_H and CAN_L. Split termination concept with 4.7 nF center capacitance to ground. ECU attempts to transmit a message.
3. Load 45 Ω between CAN_H and CAN_L including ECU-internal termination. When termination present in an ECU according to section 6.4, then load 72 Ω between CAN_H and CAN_L.
4. Load 70 Ω between CAN_H and CAN_L. When termination present in an ECU, then load 153 Ω between CAN_H and CAN_L.
5. Load 2240 Ω between CAN_H and CAN_L. Does not apply when termination present in an ECU.
6. Absolute output current value. CAN_H connected to a fixed voltage (short-circuit). -3V < V_{CAN_H} < +18V. ECU attempts to transmit messages. Selected ECUs may have to exhibit specified bus output currents at presence of a CAN_H short-circuit (e.g., TxD dominant duty cycle according to Table 23) down to V_{CAN_H} = - 5V or -13V.
7. Absolute output current value. CAN_L connected to a fixed voltage (short-circuit). -13V < V_{CAN_L} < +18V. ECU attempts to transmit messages (e.g., TxD dominant duty cycle according to Table 23).

6.2.3 DC Parameters – Output Behavior – ECU unpowered/Bus Bias Off - Bus Disconnected

DC bus output behavior of a single ECU (in the absence of other bus nodes) when ECU unpowered and/or when bus bias functionality is off (inactive). (See Table 9.)

Table 9 - ECU DC parameters - input behavior - ECU unpowered/bus bias off - bus disconnected

Symbol	Minimum	Nominal	Maximum	Units	Conditions
$I_{CAN\_H\_ECU\_LK}$, $I_{CAN\_L\_ECU\_LK}$	–10		20	μA	(1)
1. All power supply inputs connected to 0V. CAN_H and CAN_L connected to +5V. Positive currents flow into the ECU.					

6.2.4 DC Parameters – Input Behavior – Bus Disconnected

DC bus input behavior of a single ECU in the absence of other bus nodes. (See Table 10.)

Table 10 - ECU DC parameters - input behavior - bus disconnected

Symbol	Minimum	Nominal	Maximum	Units	Conditions
$V_{DIFF\_ECU\_IN-REC-RG}$	–3		0.5	Volts	(1)
$V_{DIFF\_ECU\_IN-REC-LP}$	–3		0.4	Volts	(2)
$V_{DIFF\_ECU\_IN-DOM-RG}$	0.9		8	Volts	(3)
$V_{DIFF\_ECU\_IN-DOM-LP}$	1.15		8	Volts	(4)

1. Bus interface not in sleep mode. Differential bus input voltage, bus disconnected. No time limit. ECU shall detect this as a recessive bus condition.
2. Bus interface in sleep mode. Differential bus input voltage, bus disconnected. No time limit. ECU shall detect this as a recessive bus condition.
3. Bus interface not in sleep mode. Bus bias is on and data receiver not in a low-power mode. Differential bus input voltage, bus disconnected. No time limit. ECU shall detect this as a dominant bus condition.
4. Bus interface in sleep mode. Differential bus input voltage, bus disconnected. No time limit. ECU shall detect this as a dominant bus condition.

All line items in the Table 10 apply over operating bus voltage ranges (V_{CAN_H-OP}, V_{CAN_L-OP}) specified in Table 6.

6.2.5 AC Parameters – Output Behavior – Bus Disconnected

AC bus output behavior of a single ECU in the absence of other bus nodes. (See Table 11.)

Table 11 - ECU AC parameters - output behavior - bus disconnected

Symbol	Minimum	Nominal	Maximum	Units	Conditions
t_{DOM_ECU}	0.8		10	ms	(1)
1. Transmit data input (TxD) continuously asserted.					

6.2.6 DC Parameters - Recessive Bus State – Normal Operating Mode - Bus Connected

(See Table 12.)

Table 12 - ECU DC parameters - recessive bus state - bus connected

Symbol	Minimum	Nominal	Maximum	Units	Conditions
$V_{CAN\_H\_ECU-REC}$		2.5	12.0	Volts	Reference ECU ground
$V_{CAN\_L\_ECU-REC}$	–12.0	2.5		Volts	Reference ECU ground
$V_{DIFF\_ECU\_OUT-REC}$	–120	0	12	Millivolts	45 Ω < R_L < 70 Ω

6.2.7 DC Parameters - Dominant Bus State – Normal Operating Mode - Bus Connected

(See Table 13.)

Table 13 - ECU DC parameters - dominant bus state - bus connected

Symbol	Minimum	Nominal	Maximum	Units	Conditions
$V_{CAN\_H\_ECU-DOM}$		3.5	12.0	Volts	Reference ECU ground
$V_{CAN\_L\_ECU-REC}$	–12.0	1.5		Volts	Reference ECU ground
$V_{DIFF\_ECU\_OUT-DOM}$	1.4	2.0	3.3	Volts	$45\ \Omega < R_L < 70\ \Omega$

6.3 ECU Internal Capacitance

Capacitance of a single CAN bus interface in the absence of other bus nodes. (See Table 14.)

Table 14 - ECU internal capacitance - ECU disconnected

Symbol	Minimum	Nominal	Maximum	Units	Conditions
$C_{CAN\_H\_ECU}$			130	pF	f = 1 MHz
$C_{CAN\_L\_ECU}$			130	pF	f = 1 MHz
C_{DIFF_ECU}			65	pF	f = 1 MHz

6.4 Termination

Bus terminations may be placed within ECUs. Terminations shall establish a defined resistance between the CAN_H and CAN_L wires. Each of two terminations in a network shall meet the requirements stated in Table 15. For location of terminations within a network, see section 5.4.

Table 15 - ECU termination characteristics

Symbol	Minimum	Nominal	Maximum	Units	Conditions
R_{Z_ECU}	see Table 7, $R_{DIFF\_ECU-REC-RZ}$		see Table 7, $R_{DIFF\_ECU-REC-RZ}$	Ω	Each bus termination (1)
R_{Z2_ECU}	59		66	Ω	Split termination resistors (1)
PWR_{RZ_ECU}	500			mW	For single resistor bus termination implementations (2)

1. Split termination implementations are allowed with equal value 1% resistors. Minimum value 58.4 Ohms when indicated so in a particular sourcing document.
2. Over the entire operating ambient temperature range applicable to the position where the termination is located. Resistor power ratings need to be such that resistors will not be damaged when differential voltages stated in the two V_{Diff} line items in Table 5 are applied to CAN_H and CAN_L. Note, when termination is implemented with split termination resistors, then the necessary resistor power rating will be less (e.g., half) than indicated above in line item PWR_{Rz_ECU}.

Unless otherwise indicated in a particular sourcing document, ECUs shall package protect for implementation of split bus termination consisting of two equal value 1%, 400 mW resistors and one capacitor connecting from the termination center tap to ground. For terminating nodes, resistance R_{Z_ECU} as measured between CAN_H and CAN_L shall always be present, including low power and loss of power modes.

6.5 Connector Parameters

Requirements for all connectors conveying the CAN signals are specified in Table 16.

Table 16 - ECU connector characteristics

Parameter	Symbol	Minimum	Nominal	Maximum	Units	Conditions
Current	I_t		40	300	mA	(1)
Contact Resistance	R_t		70	100	mΩ	
1. Maximum value accommodates short-circuit current of two bus transceivers.						

Connectors should have minimum length differences between CAN_H and CAN_L. Best practices for board layout should be followed to minimize differences in CAN_H and CAN_L trace lengths.

6.6 Bit Timing Requirements

Timing synchronization between ECUs shall be controlled by specification of the nominal (arbitration) bit time (inverse of bit rate), synchronization jump width, data sample point in the bit period, and the data sample mode. The bit period corresponds to the amount of time that a single NRZ data bit is logically driven onto the CAN bus. The data sample mode refers to the number of data samples taken within the bit period which are used to determine the NRZ data value on the CAN bus. The data sample point refers to the time period as measured from the start of the bit period to the point in the bit period where the NRZ data value is sampled. The synchronization jump width refers to the maximum amount of time by which a bit period may be shortened or lengthened to compensate for differences in bit periods and propagation delays between different ECUs on the network.

Tables 17, 18, and 19 specify timing requirements and briefly indicate the conditions which determine the minimum and maximum values required for SAE J2284-4 HSC implementation compliance.

6.6.1 Nominal Bit Time (t_{BIT})

Compliance with the nominal (arbitration) bit time tolerance requirement is directly dependent on the system clock tolerance of the ECU and the programmed nominal bit time. In the typical CAN controller, the nominal bit time must be an integer multiple of the system clock periods. When the programmable nominal bit period is set to exactly 500 kbps, accuracy is only affected by the system clock tolerance. Otherwise, the accuracy is dependent upon both the deviation of the programmed bit period from nominal and the system clock tolerance. The contributions from drift or aging of the system clock source and contributions from inability to achieve the desired nominal bit time value are additive; the tolerance specification must be met after consideration of both.

6.6.2 Data Bit Time

Time quantum length shall be identical for nominal bit timing (arbitration bit rate) and for data bit timing (data bit rate used in CAN FD messages). For equations applying to data bit timing in CAN FD (BRS = recessive) messages see ISO 11898-1 :2015(E).

6.6.3 Data Sample Mode

The data sampling shall always be set to single sample mode. Timing constraints to support 500 kbps communication over length of cable indicated in Table 2, line item ECU Distance eliminate the option of 2 out of 3 majority sampling.

6.6.4 CAN Bit Timing and Register Settings

Table 17 defines the CAN bit timing requirements. Coordinated bit timing settings are required to maintain synchronization between ECUs during both normal and error conditions.

Table 17 - ECU CAN bit timing - min/max

Term	Min	Nominal	Max
$t_{BIT(N)}$ (1)	1992 ns	2000 ns	2008 ns
$t_{BIT(D)}$ (2)	498 ns	500 ns	502 ns
t_{BUS} (3)	—	—	(3)
$t_{LOGIC\_TX} + t_{LOGIC\_RX}$	10 ns		95 ns
$t_{TX} + t_{RX}$	40 ns		255 ns
t_{ECU} (4)	50 ns	—	350 ns
t_Q (5)	—	—	50 ns
t_{SEG1}	(6)	(6)	(6)

1. Bit time output from the CAN controller for message arbitration field when CAN FD format and for entire message when Classical CAN format used. The nominal bit time and the data bit time must be a programmable, integer multiple of the system clock periods. Minimum and maximum values correspond to a clock tolerance of ±0.4%.
2. Bit time output from the CAN controller for message data field when CAN FD format used and BRS=R.
3. t_{BUS} one trip through bus wiring longest distance. Value specified in Table 1.
4. $t_{ECU} = t_{LOGIC\_TX} + t_{LOGIC\_RX} + t_{TX} + t_{RX} + t_{CHK}$. t_{LOGIC} reflects an interface delay between transceiver and microcontroller (includes microcontroller internal delay and PCB delay).
5. Time quantum length shall be identical in the message arbitration field and in the message data field.
6. $t_{SEG1} = t_{BIT} - 1\ (t_Q) - t_{SEG2}$

Tables 18 and 19 define compliant bit timing settings for the quanta which meet network assumptions outlined in Section 5.

Table 18 - ECU CAN register settings for first standard time quanta

Bit type	N_Q	t_Q	$\#t_Q\ t_{SJW}$	$\#t_Q\ t_{SEG2}$
(N)	40	50 ns	8	8
(D)	10	50 ns	2	2

Table 19 - ECU CAN register settings for second standard time quanta

Bit type	N_Q	t_Q	$\#t_Q\ t_{SJW}$	$\#t_Q\ t_{SEG2}$
(N)	80	25 ns	16	16
(D)	20	25 ns	4	4

(N) denominates nominal (arbitration) bit timing settings. (D) denominates data (field) bit timing settings. Bit settings for time quanta in Tables 18 and 19 were calculated using Equations 5 to 7:

NOTE: All ECUs in a particular subnet need to use the same sample point positions in terms of percentage into the bit cell.

NOTE: $t_{BIT(N)}$ is always set to 2000 ns. If the ECU is unable to be programmed to allow $t_{BIT(N)}$ nominal to be equal to 2000 ns, the offset should be taken into account in the $\underline{\Delta f}$ term not the $t_{BIT(N)}$ term.

$$t_{SJW} \geq \text{maximum of } \frac{20 t_{BIT} \Delta f}{1 - \Delta f} \text{ or } \frac{\Delta f (20 t_{BIT} - t_Q) + t_Q - t_{PROPmin}}{1 + \Delta f} \quad \text{(Eq. 5)}$$

$$t_{SEG2min} \geq \text{maximum of } t_{SJW} \text{ or } 2t_Q \quad \text{(Eq. 6)}$$

$$t_{SEG2max} \leq \text{minimum of } \frac{t_{BIT}(1 - 25\Delta f) - t_{PROPmax}}{1 - \Delta f} \text{ or } \frac{t_{BIT} - t_{PROP\,max} - t_Q - \Delta f(25 t_{BIT} - t_Q) + t_{PROP\,min/2}}{1 - \Delta f} \quad \text{(Eq. 7)}$$

DEFINITION: Δf equals the maximum allowable deviation (either maximum or minimum) from the specified nominal bit rate divided by the specified nominal bit rate. See Tables 18 and 19 for specified values.

6.6.5 Transmitter Delay Compensation

Bus interfaces connecting to a subnet according to this standard shall perform (meaning shall support and enable) transmitter delay compensation functionality according to ISO 11898-1 :2015(E), unless otherwise indicated in a particular sourcing document.

6.7 Message Transmission and Reception

Unless otherwise indicated in a particular sourcing document, bus interfaces connecting to a subnet according to this standard shall be capable of receiving without losing messages and transmitting any of these message formats at any time in any sequence, interleaved in an arbitrary fashion:

- CAN FD format with 11 bit identifier length and with message data length of up to 64 bytes
- CAN FD format with 29 bit identifier length with message data length of up to 64 bytes
- Classical CAN format with 11 bit identifier length with message data length of up to 8 bytes
- Classical CAN format with 29 bit identifier length with message data length of up to 8 bytes

ECU becomes disconnected from power: ECU shall not disturb data communication between other ECUs, however if that ECU is in the process of transmitting, that single message may be truncated.

ECU experiences a reset: ECU shall not disturb data communication between other ECUs.

ECU becomes re-connected to power: ECU shall not disturb data communication between other ECUs, e.g., shall not cause error frames due to power re-apply. ECU shall resume data communication without any operator intervention.

When an ECU attempts to enter a low power mode, then the ECU shall enter the low power mode and shall remain in the low power mode until there is a valid wake-up condition. In other words, the ECU shall be capable to successfully enter the low power mode even when the bus is stuck in a dominant state.

ECUs that are in a low power condition shall not disturb data communication between other bus nodes.

ECUs shall behave consistent to the requirements stated in section 5.6 (Communication/Survivability Under Faulted Conditions).

6.8 ECU Configuration Requirements

This section reflects configuration requirements for ECUs. ECUs shall comply with the content of Table 20, unless otherwise indicated for a particular ECU or CAN interface.

Table 20 - ECU - Basic CAN interface functional requirements

Functionality	Functional Block	Active / Enabled	Inactive / Disabled
Protocol exception event on res bit detected recessive (Controllers shall not stop syntax or CRC checking for a message depending on bit values in that message)	Controller		X
Transmission of frames including bytes padded by the bus controller	Controller		X
Transmitter delay compensation for data bit timing	Controller	X	
Transmit (TxD) dominant timeout	Transceiver	X	
Auto Bias	Transceiver	X	
CAN activity filter time, long	Transceiver	X	
Wake-up timeout	Transceiver	X	

6.9 ElectroMagnetic Compatibility (EMC)

The CAN physical layer, when incorporated into an ECU design, shall function as specified in the ECU's intended electromagnetic environment [CISPR 25, ISO 11451-2, and ISO 10605]. Additionally, the electromagnetic emissions produced during CAN related operation shall not interfere with the normal operation of other ECU's or subsystems.

Recommended testing includes:

a. Radiated Immunity [ISO 11452-4 using the substitution method]

b. Radiated Emissions [CISPR 25]

c. Electrostatic Discharge (handling unpowered disconnected, powered connected) [ISO 10605]

Testing, using the SAE J2962-2 method, can be used to assess and/or compare the EMC performance of a CAN physical layer design(s).

Formal validation of the CAN physical layer design, however, shall occur during EMC testing of the actual ECU, using test procedures and acceptance criteria specified by the vehicle manufacturer.

7. CAN COMPONENT REQUIREMENTS

This section reflects selected recommended characteristics for integrated circuits (CAN semiconductor products) intended to support this standard. Unless otherwise indicated, parameter values in this section are measured at the pins of the particular integrated product (and not at the connector pins of an ECU).

7.1 BUS TRANSCEIVER REQUIREMENTS

This section reflects selected recommended characteristics for CAN bus transceiver functionality intended to support this standard. Unless otherwise indicated, parameter values in this section are measured at the pins of the particular integrated product (and not at the connector pins of an ECU). Some parts of this section are labeled non-normative. Said content are present for reference only, because its source is ISO 11898-2 :2016(E).

The transceiver/SBC product data sheet shall state the following:

- CAN_H (CAN_L) output current maximum [mA] in regular operating mode (low power modes absent) when CAN_H (CAN_L) shorted to - 3V < $V_{CAN\_H/L}$ < +18V (reflects a network fault condition) when CAN transmit data input asserted (alternatively: A wider range than stated above).
- IC product supply current maximum [mA] in regular operating mode (low power modes absent) when both CAN outputs concurrently shorted to - 3V < $V_{CAN\_H/L}$ < +18V (reflects a network fault condition) when CAN transmit data input asserted (alternatively: A wider range than stated above). Note, it would be sufficient to state what the physical layer functionality will consume excluding other outputs, such as supply voltage outputs, logic control outputs.

The transceiver shall meet the following requirements qualified as optional in ISO 11898-2, edition 2016.

Table 21 - Bus transceiver - basic requirements

Feature / Characteristic	Mandatory	Optional	Not recommended
Consistent to ISO 11898-2, edition 2016	X		
Support of extended bus load range (45 Ohms < R_L < 70 Ohms)	X		
Transmit dominant timeout	X		
Bit timing requirements for data bit rates above 1 and up to 2 Mbit/s	X		
Bit timing requirements for data bit rates above 2 and up to 5 Mbit/s		X	
Tolerance to CAN FD frames with bit rate ratio of up to 1:4 or maximum 2 Mbit/s in data field for FD-capable PN parts	X		
Tolerance to CAN FD frames with bit rate ratio of up to 1:10 or maximum 5 Mbit/s in data field for FD-capable PN parts		X	
CAN activity filter time, long	X		
CAN activity filter time, short		X	
Wake-up timeout	X		
Disabling of DLC matching for FD-capable PN parts		X	
Extended maximum rating for CAN_H and CAN_L (+/-58V)		X	

Note: When the short times in Table 21 are used it may be more difficult to pass required immunity testing when the transceiver is in low power mode and monitoring the bus for valid wake-ups.

The transceiver/SBC product shall not suffer damage when its CAN bus inputs are subjected to the voltages and durations stated in the Table 22. Successful transfer of messages between bus nodes is not expected (out of scope) when stated minimum or maximum voltages are present. (See Table 22.)

Table 22 - Bus transceiver - maximum bus pin voltage - no damage to transceiver (12 V system)

Symbol	Minimum	Nominal	Maximum	Units	Conditions
$V_{CAN\_H\text{-}NOP1\text{-}IC}$, $V_{CAN\_L\text{-}NOP1\text{-}IC}$	–27		40	Volts	(1)
$V_{CAN\_H\text{-}NOP2\text{-}IC}$, $V_{CAN\_L\text{-}NOP2\text{-}IC}$	–15		+27	Volts	(2)
$V_{Diff\text{-}NOP\text{-}IC}$	–5		10	Volts	(3)
$V_{CAN\_H\text{-}ESDU\text{-}IC}$, $V_{CAN\_L\text{-}ESDU\text{-}IC}$	See SAE J2962-2		See SAE J2962-2	Volts	(4)

1. t = 120 s. Maximum and minimum static voltages without damage to the transceiver. Applies to transceiver powered and transceiver unpowered.
2. t = 120 s. Transmit data pattern representative for CAN controller attempts to transmit messages (e.g., TxD dominant duty cycle according to Table 23, note 4). Termination resistance 60 Ohms.
3. t = 120 s. $V_{Diff} = V_{CAN\_H} – V_{CAN\_L}$. Preferred: No damage when V_{Diff} = +17V for 0.1 ms at V_{CAN_H} = +18V, for 1000 pulses over IC product lifetime.
4. See SAE J2962-2 for details.

Minimum and maximum values in Table 22, line items $V_{CAN\_H/L\text{-}NOP1\text{-}IC}$ and $V_{Diff\text{-}NOP\text{-}IC}$ are non-normative.

The CAN physical layer (bus transceiver) shall comply with the EMC requirements as specified in SAE J2962-2.

The table below states general operating conditions for CAN transceiver/SBC products. (See Table 23.)

Table 23 - Bus transceiver - general operating conditions

Symbol	Minimum	Nominal	Maximum	Units	Conditions
V_{SUP}	see Table 6		see Table 6	Volts	(1)
$V_{CAN\_H\text{-}OP}$, $V_{CAN\_L\text{-}OP}$	see Table 6		see Table 6	Volts	(2)
V_{SYM_IC}	0.9	1.0	1.1	--	(3)
TxD dominant duty cycle	75			%	(4)

1. Table 6 contains information relevant for the specification of transceiver operating supply voltage ranges.
2. Transceiver operating common-mode bus input voltage range. Applies to recessive state and to dominant state.
3. Two times 30 Ohms between CAN_H and CAN_L. Split termination concept with 4.7 nF center capacitance to ground. $V_{SYM} = (V_{CAN\_H} + V_{CAN\_L}) / V_{CC}$, with V_{CC} being the supply voltage of the transmitter. Applies to dominant state and to recessive state and to transitions between the two states. 1 MHz square wave signal on TxD (2 Mbps).
4. Transmit (TxD) dominant duty cycle without thermal shutdown for –40 °C < T_{amb_IC} < +105 °C (ambient to the bus transceiver IC placed on a defined PCB). Repetitive TxD signal pattern of 2 µs recessive followed by 6 µs dominant.

Minimum/nominal/maximum values in line item V_{SYM_IC} in Table 23 are non-normative.

For selected use cases the bus transceiver may need to be capable to support data communication during presence of a suppressed load dump pulse (ISO 7637-1, pulse 5b, positive voltage, maximum voltage modified), coupled symmetrically to CAN_H and CAN_L through a coupling capacitance of 1 nF each. Data communication not required to work during pulse rising slope (10ms).

Table 24 - Bus transceiver - DC parameters - output behavior - recessive/off state

Symbol	Minimum	Nominal	Maximum	Units	Conditions
$V_{Diff\text{-}REC}$	–0.5		0.05	Volts	(1)
$V_{CAN\_H\text{-}REC}$	2.0	2.5	3.0	Volts	(1)
$V_{CAN\_L\text{-}REC}$	2.0	2.5	3.0	Volts	(1)
R_{DIFF_REC}	12		100	kΩ	(2)
R_{CAN_H}, R_{CAN_L}	6		50	kΩ	(2)
m_R	-0.03		+0.03	--	(3)
$V_{Diff\text{-}OFF}$	–0.2	0	0.2	Volts	(4)
$V_{CAN\_H\text{-}OFF}$	–0.1	0	0.1	Volts	(4)
$V_{CAN\_L\text{-}OFF}$	–0.1	0	0.1	Volts	(4)
$I_{CAN\_H\_LK}$, $I_{CAN\_L\_LK}$	–10		10	µA	(5)

1. No resistive load present (R_L > 10 MOhms). Bus bias functionality is active (on).
2. Over specified common-mode bus voltage ranges, see Table 6 ($V_{CAN\_H\text{-}OP}$, $V_{CAN\_L\text{-}OP}$). R_{DIFF_REC} line item corresponds to a recessive state input current range of 9 µA to 75 µA at a test voltage of V_{Diff} = 0.9V. Applies to powered state only.
3. Matching of the internal resistance.
   $m_R = 2 * (R_{CAN\_H} - R_{CAN\_L}) / (R_{CAN\_H} + R_{CAN\_L})$. 0V < V_{CAN_H} < +5V, 0V< V_{CAN_L} < +5V.
4. No resistive load present (R_L > 10 MOhms). Bus bias functionality is inactive (off).
5. Leakage current when unpowered. All supply inputs connected to ground. Both CAN inputs at 5V. Positive currents flow into the transceiver.

Minimum/nominal/maximum values in Table 24 are non-normative.

Table 25 - Bus transceiver - DC parameters - output behavior - dominant state

Symbol	Minimum	Nominal	Maximum	Units	Conditions
V_{Diff_DOM1}	1.5	2	3.0	Volts	(1)
V_{Diff_DOM2}	1.4	2	3.3	Volts	(2)
V_{Diff_DOM3}	1.5	3	5.0	Volts	(3)
$V_{CAN\_H\text{-}DOM}$	2.75	3.5	4.5	Volts	(4)
$V_{CAN\_L\text{-}DOM}$	0.5	1.5	2.25	Volts	(4)
$I_{CAN\_H\_SC1}$		60	115	mA	(5)
$I_{CAN\_H\_SC2}$			150	mA	(6)
$I_{CAN\_L\_SC1}$		60	115	mA	(7)
$I_{CAN\_L\_SC2}$			150	mA	(8)

1. 50 Ohms < R_L < 65 Ohms between CAN_H and CAN_L. Production test at R_L = 60 Ohms is sufficient.
2. 45 Ohms < R_L < 70 Ohms. Characterization with R_L = 45 Ohms and R_L = 70 Ohms is sufficient. This line item establishes a minimum bus output current drive capability of 31.111 mA.
3. R_L = 2240 Ohms. Calculation: 32 * 70 = 2240. Maximum output voltage at weak loading condition.
4. R_L = 60 Ohms between CAN_H and CAN_L.
5. Absolute output current value. - 3V < V_{CAN_H} < +27V. TxD dominant duty cycle as indicated in Table 23. Reflects a fault condition.
6. Optional functionality. Absolute output current value. - 15V < V_{CAN_H} < - 3V. TxD dominant duty cycle as indicated in Table 23. Reflects a fault condition. Preferred: 115 mA maximum.
7. Absolute output current value. - 15V < V_{CAN_L} < +18V. TxD dominant duty cycle as indicated in Table 23. Reflects a fault condition.
8. Optional functionality . Absolute output current value. +18V < V_{CAN_L} < +27V. TxD dominant duty cycle as indicated in Table 23. Reflects a fault condition. Preferred: 115 mA maximum.

Minimum/nominal/maximum values in Table 25 are non-normative, except of $I_{CAN\_H\_SC2}$ and $I_{CAN\_L\_SC2}$. Table 25 applies over operating common-mode bus voltage ranges specified in Table 6 ($V_{CAN\_H\text{-}OP}$, $V_{CAN\_L\text{-}OP}$).

The bus transceiver shall be thermally self-protected and shall exhibit well-defined dominant state bus output current levels (maximum stated in the IC data sheet) at presence of bus short-circuit conditions or bad ground contact in a 12V-powered system where the combination of the transceiver and bus controller is capable of transmitting syntactically correct CAN messages.

Table 26 - Bus transceiver - DC parameters - input behavior/threshold - sleep mode absent

Symbol	Minimum	Nominal	Maximum	Units	Conditions
$V_{Diff\_RG\_TH}$	0.5	0.7	0.9	Volts	(1)
$V_{Diff\_RG\_HI}$			8	Volts	(2)
$V_{Diff\_RG\_LO}$	–3			Volts	(3)

1. Transceiver not in sleep mode. Bus bias functionality is on (active).
2. Transceiver not in sleep mode. Bus bias functionality is on (active). No time limit. Preferred (proposed for new designs): +9V maximum.
3. Transceiver not in sleep mode. Bus bias functionality is on (active). No time limit. Preferred (proposed for new designs): -4V minimum.

Minimum/nominal/maximum values in Table 26 are non-normative. Table 26 applies over operating common-mode bus voltage ranges specified in Table 6 ($V_{CAN\_H\text{-}OP}$, $V_{CAN\_L\text{-}OP}$).

Table 27 - Bus transceiver - DC parameters - input behavior/threshold - sleep mode present

Symbol	Minimum	Nominal	Maximum	Units	Conditions
$V_{Diff\_LP\_TH}$	0.4	0.7	1.15	Volts	(1)
$V_{Diff\_LP\_HI}$			8	Volts	(2)
$V_{Diff\_LP\_LO}$	–3			Volts	(3)

1. Transceiver in sleep mode. Bus bias functionality is off (inactive). Ideally, 1.1V maximum.
2. Transceiver in sleep mode. Bus bias functionality is off (inactive). No time limit. Ideally, +9V maximum.
3. Transceiver in sleep mode. Bus bias functionality is off (inactive). No time limit. Ideally, -4V minimum.

Minimum/nominal/maximum values in Table 27 are non-normative. Table 27 applies over operating common-mode bus voltage ranges specified in Table 6 (V_{CAN_H-OP}, V_{CAN_L-OP}).

The transceiver/SBC product shall support the AC parameters stated in Table 28 below. Note, the two line items $t_{Silence}$ and t_{FD_TOL} are applicable only to transceivers supporting selective wake-up functionality (does not apply to transceivers not supporting selective wakeup functionality).

Table 28 - Bus transceiver - AC parameters

Symbol	Minimum	Nominal	Maximum	Units	Conditions
$t_{LOOP-RG}$	0		255	ns	(1)
$t_{Bit(Bus)}$	435		530	ns	(2)
$t_{Bit(RXD)}$	400		550	ns	(3)
Δt_{REC}	–65		40	ns	(4)
t_{DOM}	0.8	4	10	ms	(5)
$t_{Silence}$	0.6		1.2	s	(6)
t_{Filter}	0.5		5	µs	(7)
t_{Wake}	0.8		10	ms	(8)
t_{Bias}	0		250	µs	(9)
t_{FD_TOL}	5		17.5	%	(10)

1. Defined behavior is needed for 45 Ohms < R_L < 70 Ohms, C_L = 100 pF. Production test at R_L = 60 Ohms, C_L = 100 pF, C_{RxD} = 15 pF is sufficient. Specification item does not apply when transceiver in (some kind of) low power mode.
2. Transmitted recessive bit width at 2 Mbit/s when there are five dominant bits followed by one recessive bit. R_L , C_L , and C_{RxD} see note 1 above.
3. Received recessive bit width at 2 Mbit/s when there are five dominant bits followed by one recessive bit. R_L , C_L , and C_{RxD} see note 1 above.
4. Receiver timing symmetry at 2 Mbit/s. R_L , C_L , and C_{RxD} see note 1 above.
5. Transmit data input (TxD) continuously asserted for stated length in time. Preferred (proposed for new designs): t_{DOM} < 9 ms.
6. Applies to selective wake-up functionality. Transceiver-internal timer shall be reset and restarted, when bus changes from dominant to recessive or vice versa.
7. CAN activity filter time (long) for bus wake-up behavior. Bus dominant to receive output asserted when transceiver in lowest power mode and no bus messages present (CAN activity filter time, long).
8. When there are dominant states on the bus and a bus wake-up could not be completed successfully, then transceiver shall reduce its power consumption after t_{Wake} has expired.
9. Time from bus bias activation criterion present to bus bias functionality on (active).
10. Applies to selective wake-up functionality (interframe space detection). Dominant signals less than 5% of the arbitration bit time in duration shall not be considered to be a valid bit and shall not restart the recessive bit counter. Dominant signals longer than 17.5 % of the arbitration bit time in duration shall restart the recessive bit counter.

Minimum/nominal/maximum values in Table 28 are non-normative.

Bus transceivers should be capable to transmit and receive dominant and recessive states at differential loads between 45 Ohms and 150 Ohms.

Bus transceivers with a serial configuration interface (e.g., SPI) should enable the host to know when a TxD dominant timeout condition was present. A flag that can be polled is sufficient.

(Selective wake-up) bus transceivers shall not increase their internal bit/format error counters as a result of presence of syntactically correct CAN FD format frames.

Selective wake-up bus transceivers shall be capable to treat the following bit combination as a bit/format error: Both the FDF bit and the bit that comes subsequent to FDF were detected as a recessive state.

Selective wake-up bus transceivers shall be capable to perform automatic voltage biasing.

7.2 BUS CONTROLLER REQUIREMENTS

This section reflects selected recommended characteristics for CAN controllers intended to support this standard.

Bus controllers shall meet the following requirements qualified as optional in ISO 11898-1, edition 2015. Entries in column "Not recommended" mean functionality should not be used in a controller/ECU designed to meet the specification.

Table 29 - CAN controller - basic requirements

Feature / Characteristic	Mandatory	Optional	Not recommended
Consistent to ISO 11898-1, edition 2015	X		
Ability to transmit and receive CAN FD frame format with data length of up to 64 bytes	X		
Ability to disable selected frame formats		X	
Disabling of protocol exception event on res bit detected recessive	X		
Ability to limit transmission to frames not containing bytes padded by the bus controller	X		
Limited LLC frames			X
MAC data consistency		X	
LLC Abort interface	X		
ESI and BRS bit values		X	
Handle		X	
PCS Status			X
FD_Transmit / FD_Receive message indication			X
Message time stamping	ECU-dependent		
Time base (subnet-wide common notion of time)	ECU-dependent		
Time base triggered message transmission			X
Disabling of automated retransmission attempts		X	
Limiting number of retransmission retries		X	
Bus monitoring mode	For tools	For ECUs	
Restricted operation mode		X	
Transmitter delay compensation for data bit timing	X		
Separate prescalers for nominal bits and for CAN FD data bits			X
Edge filtering during the bus integration state		X	
Time resolution for secondary sample point placement		X	

For a definition of terms used in Table 29, see chapters 3 and 4 in this document and see ISO 11898-1 :2015(E).

Bus controllers shall not stop syntax or CRC checking for a message depending on bit values in that message (in other words: The bus controller shall disable CAN protocol exception event handling).

Bus controllers shall perform bit resynchronization only on recessive to dominant signal edges.

Bus controllers shall support a bit timing parameter setting of Sync Jump Width (SJW) = 2 time quanta = PHASE_SEG2.

Bus controllers shall support that both the arbitration bit time and the data bit time be integer multiples of the oscillator period that drives the CAN protocol controller (no change of time quanta length shall be needed within a CAN FD message).

Bus controllers shall support the entire range of base frame format message identifiers from 0 thru 2047 decimal without any exceptions.

Bus controllers shall support all numbers of data bytes in a message as specified in ISO 11898-1 :2015(E).

Bus controllers shall provide at least 2 (preferred: 3) transmit message buffers and 2 receive message buffers. Transmit buffers shall be able to be independently loaded.

Bus controllers shall support a minimum of one 64 byte transmit register and one 64 byte receive register.

Bus controllers shall be capable to automatically (e.g., without any CPU-support) transmit the message with the lowest CAN identifier first any time when more than one transmit buffer is armed for transmission.

If the bus controller supports multiple messages with the same CAN identifier then when two or more messages with the same CAN identifier are queued for transmission, bus controllers should transmit these messages in a first in, first out (FIFO) fashion, i.e., in the sequence in which they were queued.

Bus controllers shall support cancellation of a pending transmission (message awaiting access to bus) and should support notification to the host whether or not a transmit cancellation request was successful.

7.3 MICROCONTROLLER REQUIREMENTS AND PREFERENCES

This section reflects selected recommended characteristics for microcontrollers with embedded CAN controllers intended to support this standard.

Unless otherwise indicated in a particular sourcing document, microcontrollers connecting to a subnet according to this standard shall be capable of receiving without losing messages and transmitting any of these message formats at any time in any sequence, interleaved in an arbitrary fashion:

- CAN FD format with 11 bit identifier length and with message data length of up to 64 bytes
- CAN FD format with 29 bit identifier length with message data length of up to 64 bytes
- Classical CAN format with 11 bit identifier length with message data length of up to 8 bytes
- Classical CAN format with 29 bit identifier length with message data length of up to 8 bytes

Some ECUs will have to be capable to support communication-network-wide accurate common notion of time. Consequently, unless otherwise indicated, microcontrollers intended to be used for this standard shall be capable of performing message time stamping and shall foresee hardware as needed to implement global time synchronization according to AUTOSAR release R4.2.2 or greater. Unless otherwise indicated, microcontrollers shall be capable to support a subnet-wide common notion of time where notion of time deviations between any two nodes are less than or equal to 1 ms.

Microcontrollers shall be designed such that they do not need to send Overload Frames on the bus.

Microcontrollers should have the ability to receive messages with any CAN identifier sent by other nodes even if the microcontroller transmits messages with that identical CAN identifier.

Microcontrollers shall provide dedicated indication flags for these wake-up event sources: Bus wake-up event, Microcontroller-local wake-up event, reset event.

Microcontrollers shall be capable to enter low power modes when the receive data input is stuck dominant.

8. NOTES

8.1 Revision Indicator

A change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

PREPARED BY THE SAE VEHICLE ARCHITECTURE FOR DATA COMMUNICATIONS STANDARDS COMMITTEE