	SURFACE VEHICLE RECOMMENDED PRACTICE	**J2284™-3**	**OCT2022**
		Issued 2001-05 Revised 2022-10	
		Superseding J2284-3 NOV2016	
	High-Speed CAN (HSC) for Vehicle Applications at 500 kbps		

RATIONALE

Addition of stub length requirements for HS-CAN based on the presentation on 21st March and 25th April 2022.

FOREWORD

The objective of SAE J2284-3 is to define a level of standardization in the implementation of a 500 kbps 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 high-speed CAN (HSC) protocol implementation. Both electronic control unit (ECU) and media design requirements for networks will be specified. Requirements will primarily address the controller area network (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. The minimum performance level shall be specified by system level performance requirements or characteristics described in detail in Section 5 of this document.

This document is designed such that if the 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

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 J2962-2   Communication Transceivers Qualification Requirements - CAN

2.1.2 ISO Publications

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

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 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

2.2   Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

2.2.1   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 J1930   Electrical/Electronic Systems Diagnostic Terms, Definitions, Abbreviations, and Acronyms - Equivalent to ISO/TR 15031-2

SAE J1962   Diagnostic Connector

SAE J2190   Enhanced E/E Diagnostic Test Modes

SAE J2284-4   High-Speed CAN for Vehicle Applications at 500 kbps with CAN FD Data at 2 Mbps

Dietmayer, K. and Overberg, K., "CAN Bit Timing Requirements," SAE Technical Paper 970295, 1997, https://doi.org/10.4271/970295.

2.2.2   ISO Publications

Copies of these documents are available online at https://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 14229   Road Vehicles - Diagnostic Systems - Specification of Diagnostic Services

2.2.3   Other Publications

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 (3.22).

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 CAN 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 bit sample captures the logical state of the bus. The programmable bit sample point is located between t_{SEG1} and t_{SEG2}. Equation 1 shows the relationship of t_{SAMPLE} to t_{SEG2}:

$$t_{SAMPLE} = t_{BIT} - t_{SEG2}$$ (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 J2284-3 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).

$$t_{ECU} = (t_{TX} + t_{RX} + t_{LOGIC} + t_{CHK}) \hspace{4cm} \text{(Eq. 2)}$$

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 Tables 1, 2, 3, and 8.

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, refer to 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 Equations 3 or 4.

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

or

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

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 bit 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. Figure 1 is for informative reference only. See 6.4 for passive component values.
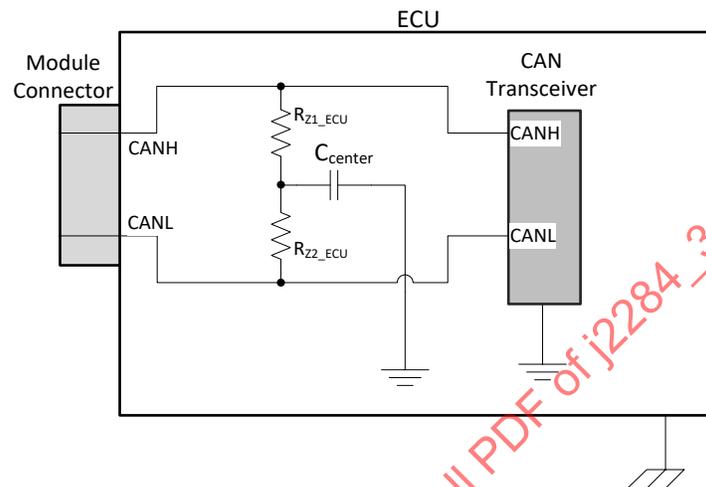
Figure 1 - Split bus termination

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, refer to 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).

$$t_{SEG1} = t_{BIT} - 1 (t_Q) - t_{SEG2} \qquad\qquad\text{(Eq. 5)}$$

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)

Vbatt   Power supply for the ECUs present in a communication network (12 V 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 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 and ISO 11898-2, releases as stated in 2.1.2, with the exception that requirements that only apply to CAN FD format messages are not applicable to this standard (SAE J2284-3). For details, see Sections 6 and 7 in this document.

All ECUs that utilize the 11-bit base frame identifier (ID-28 to ID-18) shall be, at a minimum, passive to the 29-bit extended frame identifier (ID-28 to ID-0). All SAE J2284-3-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 (refer to CAN 2.0 protocol specification and superseded ISO 11898-1 CAN documents) specifying that the seven most significant CAN ID bits (ID-28 through ID-22) must not be all recessive shall not be enforced in hardware by SAE J2284-3. CAN protocol implementations shall be capable to transmit and receive all identifier bit combinations without any restrictions.

Classical CAN messages (also known as CAN 2.0) shall consist of the CAN identifier (CAN ID) plus up to 8 data bytes. Classical CAN messages with 11-bit identifiers are called Classical CAN base format messages. Classical CAN messages with 29-bit identifiers are called classical CAN extended frame format messages.

Optionally, ECU CAN interfaces may be passive to CAN FD format frames, meaning they shall not send error frames upon presence of syntactically correct CAN FD format frames with 500 kbps arbitration bit rate and 2 Mbps CAN FD data bit rate (SAE J2284-4); further, they would not increase ECU-internal error counters.

5.2   Communication Rate

The network shall operate at a single communication rate of 500 kbps.

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	Ω	(3)
(Wiring) Resistance between any two bus transceiver CAN_H to CAN_H (CAN_L to CAN_L) pins	R_w		9	Ω	(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 6.4. Note that the presence of bus termination is needed; otherwise, the network will not work.

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 2 and Table 2.
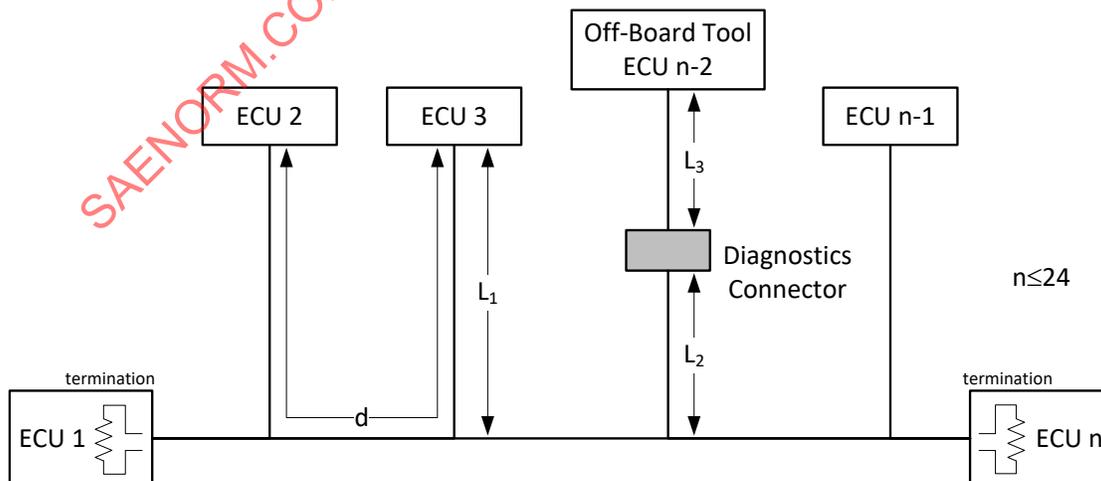
Figure 2 - Multiple on-board ECU configuration

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. [1]
In-vehicle diagnostic connector cable stub length	L_2	0		1	Meter	Stub length between on-board bus line and diagnostic connector for multiple on-board ECU configuration.
Off-board tool cable length	L_3	0		5	Meter	Cable length between diagnostic connector and off-board tools.
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.

[1] Any/all stub lengths more than 1.0 m shall have a variance of at least 5% between each other. For example, if stub length to ECU1 is 1.7 m, the stub length to the other ECUs shall be less than 1.7 m - 5%; i.e., less than 1.61 m in length. As an example, if a CAN topology has four stubs, and if the final wire routing strategy requires the maximum possible stub length, the following restrictions on the length shall apply:
Stub 1 = 1.7 m
Stub 2 = 1.7 - 5% ≤ 1.61 m
Stub 3 = 1.61 - 5% ≤ 1.53 m
Stub 4 = 1.53 - 5% ≤ 1.45 m

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.

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.

5.4.2   Single On-Board ECU Configuration

The topology requirements for a network containing a single ECU on-board the vehicle and a single ECU off-board the vehicle (e.g., an OBD scan tool) are shown in Figure 3 and Table 3.
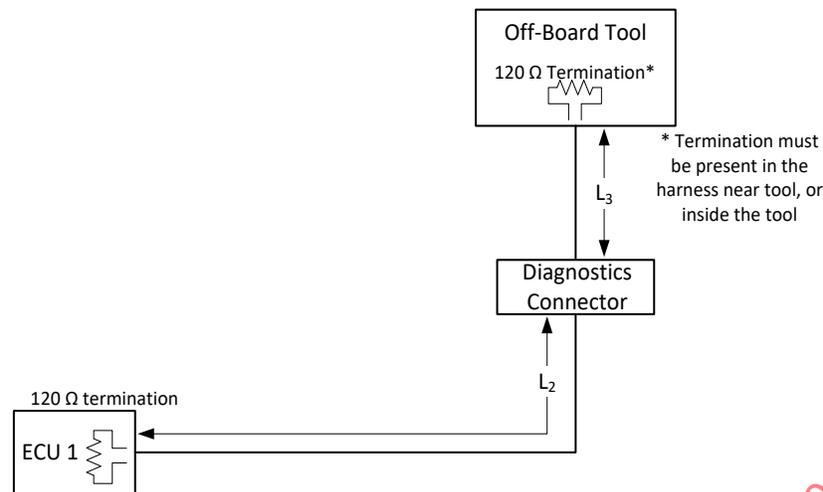
Figure 3 - Single on-board ECU configuration

Table 3 - Single on-board ECU topology requirements

Parameter	Symbol	Minimum	Nominal	Maximum	Unit	Remark
In-vehicle diagnostic connector cable length	L_2	0		5	Meter	Length between on-board terminating ECU and diagnostic connector for single on-board ECU configuration.
Off-board tool cable length	L_3	See Table 2		See Table 2	Meter	--

For topology and termination requirements for tools, see 5.8.

5.5   Unshielded Media

The network shall operate using a shielded or unshielded twisted wire pair. The bus cable details are specified in Table 4.

Table 4 - 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 4 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 5.

Table 5 - 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 5 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 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 Tables 2 and 3), including the bus cable requirements (for in-vehicle) stated in Table 4.

If the SAE J2284-3 bus is to be wired to the diagnostic connector, the following requirements must be met:

a. For multiple ECU configurations (5.4.1), the off-board tool shall be counted as one of the 24 allowable system ECUs.

b. For multiple ECU configurations (5.4.1), the off-board tool shall always be an unterminated node on the CAN network.

c. For single On-Board ECU configurations (5.4.2), the off-board tool shall be a terminated node on the CAN network.

This section specifies the required electrical parameters (capacitance, propagation delay) to be fulfilled by the off-board tool.

NOTE: This does not include the cable between the off-board tool and the diagnostic connector. Cable requirements are specified in 5.9.

5.8.1   Off-Board Tool Capacitive Load

See Figure 4 and Table 6.
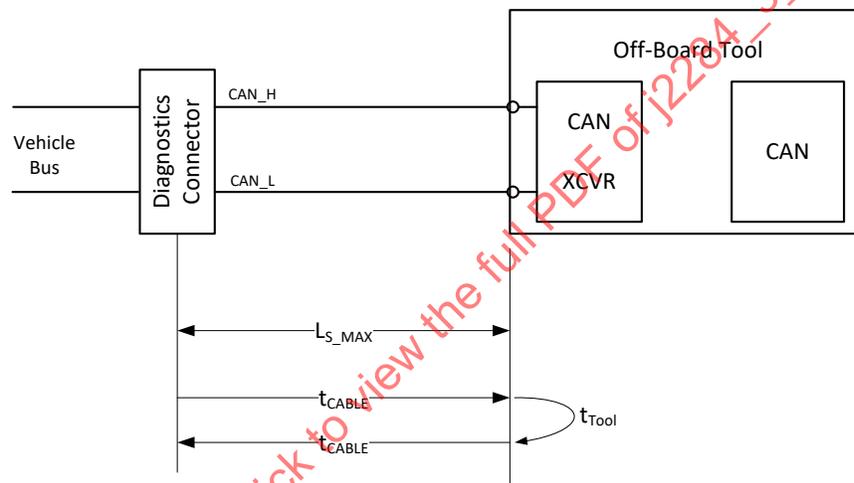
Figure 4 - Off-board tool parameters

The specified values for the off-board tool capacitive load do not include the capacitive load of the off-board tool cable.

Table 6 - Off-board tool capacitive load (without cable load)

Symbol	Minimum	Nominal	Maximum	Units	Remark
C_{diff}	—	—	50	pF	CAN_H to CAN_L
C_{Can_H}, C_{CAN_L}	—	—	100	pF	CAN_H/CAN_L to ground potential

5.8.2   Off-Board Tool Propagation Delay

The below given value for the off-board tool propagation delay does not include the cable propagation delay. This requirement is based upon the most critical timing when operating at the bit rate of 500 kbps. The off-board tool propagation delay (loop delay) includes the following four delays (see Table 7):

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).

$$t_{TOOL} = (t_{TX} + t_{RX} + t_{LOGIC} + t_{CHK}) \tag{Eq. 6}$$

Table 7 - Off-board tool propagation delay
(loop delay without cable delay)

Symbol	Minimum	Nominal	Maximum	Units	Remark
t_{TOOL}	—	—	340	ns	Loop delay of off-board tool

5.9   Off-Board Tool Cable Requirements

The off-board tool cable provides interconnection between the vehicle diagnostic connector and the CAN interface of the off-board tool (see 5.4). The off-board tool cable shall meet the (CAN) bus cable requirements stated in Table 4.

5.9.1   Cable Length

The off-board tool cable length (L_3) is defined to be the length of the cable between the diagnostic connector and the off-board tool CAN interface. See Tables 2 and 3.

5.9.2   Cable Propagation Delay

The cable propagation delay is defined as a one-way delay. See Table 8.

Table 8 - Off-board tool cable propagation delay
(one-way delay without off-board tool delay)

Symbol	Minimum	Nominal	Maximum	Units	Remark
t_{CABLE}	—	—	30	ns	Off-board tool cable delay

5.9.3   Cable Configuration

The following requirements apply to the off-board tool cable:

a.   No other wires shall be twisted with either CAN conductor CAN_H or CAN_L.

b.   The CAN_H and CAN_L conductors shall be of the same length and traverse the same path for the entire distance.

c.   CAN_H and CAN_L conductors shall not be included in any wire bundle containing radiating wires which induce more than 0.5 V differential signal between the CAN_H and CAN_L conductors.

d.   The off-board cable may be shielded. If it is shielded, the shield shall not be grounded at both ends.

e.   The off-board tool cable shall have no requirement for twisting or characteristic impedance value.

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. 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 12 V nominal. Abbreviation NOP stands for non-operating (survival). See Table 9.

Table 9 - 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 seconds
$V_{CAN\_L\_ECU-NOP}$	-13.0	27.0	Volts	All ECUs, t = 120 seconds
$V_{Diff\_ECU-NOP1}$	-5.0	7.0	Volts	All ECUs, t = 120 seconds
$V_{Diff\_ECU-NOP2}$	n/a	10.0	Volts	All ECUs: t = 10 ms Non-terminating ECUs: t = 120 seconds

Table 9 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 = 0 V) 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 25) 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 26, line item TxD dominant duty cycle).

6.1.2   Unpowered Storage Temperature

The SAE J2284-3 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-OP} in Table 1. Compliance shall be maintained over the following ECU operating ranges:

ECU operating ambient temperature:

a.   High temperature -40 to +125 °C

b.   Low temperature -40 to +85 °C

ECU operating parameters: See Table 10.

Table 10 - 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)
$V_{CAN\_H\_ECU-OP}$, $V_{CAN\_L\_ECU-OP}$	-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 ms.
(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 11.

Table 11 - 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 6.4. CAN transmit data input (TxD) not asserted. -2 V < V_{CAN_H} < +7 V, -2 V < V_{CAN_L} < +7 V. Applies to powered state only.
(3) Applies to ECUs with built in termination according to 6.4. CAN transmit data input (TxD) not asserted. -2 V < V_{CAN_H} < +7 V, -2 V < V_{CAN_L} < +7 V. Split termination implementations are allowed with equal value 1% resistors. Minimum value 116.8 Ω 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 12.

Table 12 - 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 Ω 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 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). -3 V < V_{CAN_H} < +18 V. 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 26) down to V_{CAN_H} = -5 V or -13 V.

(7) Absolute output current value. CAN_L connected to a fixed voltage (short-circuit). -13 V < V_{CAN_L} < +18 V. ECU attempts to transmit messages (e.g., TxD dominant duty cycle according to Table 26).

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 13.

Table 13 - 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 0 V. CAN_H and CAN_L connected to +5 V. 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 14.

Table 14 - 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 14 apply over operating bus voltage ranges (V_{CAN_H-OP}, V_{CAN_L-OP}) specified in Table 10.

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 15.

Table 15 - 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 16.

Table 16 - 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 17.

Table 17 - 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 Ω < R_L < 70 Ω

6.3 ECU Internal Capacitance

Capacitance of a single CAN bus interface in the absence of other bus nodes. See Table 18.

Table 18 - 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 19. For location of terminations within a network, see 5.4.

Table 19 - ECU termination characteristics

Symbol	Minimum	Nominal	Maximum	Units	Conditions
R_{Z_ECU}	see Table 11, $R_{Diff\_ECU-REC-RZ}$		see Table 11, $R_{Diff\_ECU-REC-RZ}$	Ω	Each bus termination [1]
R_{Z1_ECU} 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 Ω 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 9 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.

C_{Center} is vehicle manufacturer specific. Proposed nominal capacitor value for C_{Center} is 4.7 nF or 100 nF.

6.5 Connector Parameters

Requirements for all connectors conveying the CAN signals are specified in Table 20.

Table 20 - 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 21 and 22 specify timing requirements and briefly indicate the conditions which determine the minimum and maximum values required for SAE J2284-3 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 CAN controller 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 CAN controller clock periods. When the programmable nominal bit period is set to exactly 500 kbps, accuracy is only affected by the CAN controller clock tolerance. Otherwise, the accuracy is dependent upon both the deviation of the programmed bit period from nominal and the CAN controller clock tolerance. The contributions from drift or aging of the CAN controller 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. For equations applying to bit timing for classical CAN frames, refer to ISO 11898-1:2015(E).

6.6.2	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 1, line item maximum propagation time between any two ECUs, and Table 2, line item ECU Distance eliminate the option of 2 out of 3 majority sampling.

6.6.3	CAN Bit Timing and Register Settings

Table 21 defines the CAN bit timing requirements. Coordinated bit timing settings are required to maintain synchronization between ECUs during both normal and error conditions.

Table 21 - ECU CAN bit timing - min/max

Term	Min	Nominal	Max
t_{BIT} [1]	1992 ns	2000 ns	2008 ns
t_{BUS} [2]	—	—	[2]
t_{LOGIC_TX} + t_{LOGIC_RX}	10 ns		95 ns
t_{TX} + t_{RX}	40 ns		255 ns
t_{ECU} [3]	50 ns	—	350 ns
t_{Q} [4]	—	—	125 ns
t_{SEG1}	[5]	[5]	[5]

[1]	Bit time output from the CAN controller for entire message when classical CAN format used. The nominal bit time must be a programmable, integer multiple of the CAN controller clock periods. Minimum and maximum values correspond to a clock tolerance of ±0.4%.

[2]	t_{BUS} one trip through bus wiring longest distance. Value specified in Table 1.

[3]	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).

[4]	Time quantum length shall be identical in the message arbitration field and in the message data field.

[5]	t_{SEG1} = t_{BIT} - 1 (t_{Q}) - t_{SEG2}.

Table 22 defines compliant bit timing settings for the quanta which meet network assumptions outlined in Section 5.

Table 22 - ECU CAN register settings for standard time quanta

N_Q	t_Q	#t_Q $t_{SJW\ min}$	#t_Q $t_{SEG2\ min}$	#t_Q $t_{SEG2\ max}$
40	50 ns	6	6	8
20	100 ns	3	3	4
16	125 ns	3	3	3

N_Q reflects the number of time quanta per bit. N_Q = 40 may not be supported by all CAN controllers. Bit settings for time quanta in Table 22 were calculated using Equations 7 to 9:

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

NOTE: t_{BIT} is always set to 2000 ns. If the ECU is unable to be programmed to allow t_{BIT} nominal to be equal to 2000 ns, the offset should be taken into account in the Δf term not the t_{BIT} term.

$$t_{SJW} \geq \text{maximum of } \frac{20t_{BIT}\Delta f}{1-\Delta f} \text{ or } \frac{\Delta f(20t_{BIT}-t_Q)+t_Q-t_{PROPmin}}{1+\Delta f} \tag{Eq. 7}$$

$$t_{SEG2min} \geq \text{maximum of } t_{SJW} \text{ or } 2t_Q \tag{Eq. 8}$$

$$t_{SEG2max} \leq \text{minimum of } \frac{t_{BIT}(1-25\Delta f)-t_{PROPmax}}{1-\Delta f} \text{ or } \frac{t_{BIT}-t_{PROP\ max}-t_Q-\Delta f(25t_{BIT}-t_Q)+t_{PROP\ min/2}}{1-\Delta f} \tag{Eq. 9}$$

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 Table 22 for specified values.

6.6.4   Transmitter Delay Compensation

Not required for this standard.

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:

- 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 5.6.

6.8   ECU Configuration Requirements

This section reflects configuration requirements for ECUs. ECUs shall comply with the content of Table 23, unless otherwise indicated for a particular ECU or CAN interface.

Table 23 - ECU - basic CAN interface functional requirements

Functionality	Functional Block	Active / Enabled	Inactive / Disabled
Protocol exception event on res bit detected recessive[1]	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	

[1] Controllers shall not stop syntax or CRC checking for a message depending on bit values in that message.

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 ECUs 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).