SURFACE VEHICLE STANDARD	J1939™-17	DEC2020
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CAN FD Physical Layer, 500 kbps/2 Mbps

RATIONALE

This document is developed to support the use of SAE J1939 networks utilizing CAN FD with a base baud rate of 500 kbps and a flexible data rate of 2 Mbps. This is done to increase bandwidth and the data transfer rate.

FOREWORD

The set of SAE J1939 Recommended Practice documents define a high speed ISO 11898 CAN protocol based communications network that can support real-time closed loop control functions, simple information exchanges, and diagnostic data exchanges between Electronic Control Units (ECUs) physically distributed throughout the vehicle.

The SAE J1939 communications network is developed for use in heavy-duty environments and suitable for use in horizontally integrated vehicle industries. The physical layer aspects of SAE J1939 reflect its design goal for use in heavy-duty environments. Horizontally integrated vehicles involve the integration of different combinations of loose package components, such as engines and transmissions, which are sourced from many different component suppliers. The SAE J1939 common communication architecture strives to offer an open interconnect system that allows the ECUs associated with different component manufacturers to communicate with each other.

This set of SAE Recommended Practices has been developed by the SAE Truck and Bus Control and Communications Network Committee of the SAE Truck and Bus Electrical and Electronics Steering Committee. The SAE J1939 communications network is defined using a collection of individual SAE J1939 documents based upon the layers of the Open System Interconnect (OSI) model for computer communications architecture. These SAE J1939 documents are intended as a guide toward standard practice and are subject to change to keep pace with experience and technical advances.

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1. SCOPE

This document defines a physical layer having a high bandwidth capacity utilizing the Flexible Data Rate Frame Format as defined in ISO 11898-1:2015. CAN controllers which support this format and compatible high speed transceivers are required for use on SAE J1939-17 networks.

This SAE Recommended Practice is intended for light- and heavy-duty vehicles on- or off-road as well as appropriate stationary applications which use vehicle derived components (e.g., generator sets). Vehicles of interest include but are not limited to: on- and off-highway trucks and their trailers; construction equipment; and agricultural equipment and implements.

1.1 Purpose

Implementing a robust CAN network involves many tradeoffs affecting both the network layout and ECU design. This document presents a standard by which ECUs, tools, and vehicle networks from different sources may be compatible. The document is intended to stand alone, yet borrows from the many existing standards and papers for its methodology.

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.

2.2 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 J1128 Low Voltage Primary Cable

SAE J1939-11 Physical Layer, 250 Kbps, Twisted Shielded Pair

SAE J1939-15 Physical Layer, 250 Kbps, Un-Shielded Twisted Pair (UTP)

SAE J2030 Heavy-Duty Electrical Connector Performance Standard

2.3 ISO Publications

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

ISO 11898-1:2015 Road vehicles - Controller area network (CAN) - Part 1: Data link layer and physical signalling

ISO 11898-2:2016 Road vehicles - Controller area network (CAN) - Part 2: High-speed medium access unit

2.4 CAN in Automation (CiA) Publications

Copies of these documents are available online at https://www.can-cia.org.

CiA 601-4 (version 2.0.0) CAN FD Node and system design – Part 4: Signal Improvement Capability

CiA 601-6 (version 1.0.0) CAN FD Node and system design – Part 6: CAN FD Cable

3. DEFINITIONS

Many of the definitions in this document can also be found in SAE J1939-11, and are given here for convenience. The normative references are ISO 11898-2 and ISO 11898-1.

3.1 ARBITRATION PHASE

Parts of the frame where the nominal bit time is used. This includes the identifier at the beginning of the frame and the CRC and subsequent bits at the end of the frame. See Figure 1.

3.2 DATA PHASE

Part of the frame where data bit time is used. This includes the data byte payload. See Figure 1.

3.3 TIME QUANTA

The interval of the CAN system clock.

3.4 NOMINAL BIT TIME

The duration of one bit in the arbitration phase.

3.5 DATA BIT TIME

The duration of one bit in the data phase.

3.6 BIT RATE PRESCALER

A parameter of the CAN controller that determines a divisor by which the system clock frequency is reduced to produce the CAN clock frequency.

3.7 SYNCHRONIZATION JUMP WIDTH

For synchronization purposes, the maximum adjustment allowed for PHASE_SEG1 or PHASE_SEG2.

3.8 PROP_SEG

A part of the nominal bit time used to compensate for the physical delay times or signal instability within the network.

3.9 PHASE_SEG1

The first segment of the nominal bit time used to compensate for phase errors. PHASE_SEG1 may be lengthened by an amount less than or equal to the synchronization jump width.

3.10 PHASE_SEG2

The second segment of the nominal bit time used to compensate for phase errors. May be shortened by an amount less than or equal to the synchronization jump width.

3.11 SAMPLE POINT

The point of time at which the bus level is read and interpreted as the value of that respective bit. Its location is at the end of PHASE_SEG1.

3.12 TRANSMITTER DELAY COMPENSATION

This feature allows the CAN controller to compensate for loop delays of the hardware circuit. This applies only to the data phase.

3.13 SECONDARY SAMPLE POINT

Sample point used by the transmitter delay compensation mechanism.

3.14 DIFFERENTIAL VOLTAGE

The voltages of CAN_H and CAN_L relative to ground of each individual ECU are denoted by V_{CAN_H} and V_{CAN_L}. The differential voltage between V_{CAN_H} and V_{CAN_L} is defined by Equation 1:

$$V_{diff} = V_{CAN\_H} - V_{CAN\_L} \qquad \text{(Eq. 1)}$$

3.15 COMMON-MODE BUS VOLTAGE RANGE

The common-mode bus voltage is defined as the boundary voltage levels of CAN_H and CAN_L, measured with respect to the individual ground of each ECU, for which proper operation is guaranteed when all ECUs are connected to the bus line.

3.16 INTERNAL RESISTANCE

The internal resistance, R_{IN}, of an ECU is defined as the resistance between CAN_H (or CAN_L) and ground during the recessive state, with the ECU disconnected from the bus line.

3.17 DIFFERENTIAL INTERNAL RESISTANCE

The differential internal resistance, R_{DIFF}, is defined as the resistance between CAN_H and CAN_L during the recessive state, with the ECU disconnected from the bus line.

3.18 INTERNAL CAPACITANCE

The internal capacitance, C_{IN}, of an ECU is defined as the capacitance between CAN_H (or CAN_L) and ground during the recessive state, with the ECU disconnected from the bus line

3.19 DIFFERENTIAL INTERNAL CAPACITANCE

The differential internal capacitance, C_{DIFF}, of an ECU is defined as the capacitance between CAN_H and CAN_L during the recessive state, with the ECU disconnected from the bus line.

3.20 TYPE I ECU

An ECU that does not contain bus line termination.

3.21 TYPE II ECU

An ECU that includes a bus line termination resistor or split termination. Such an ECU, if used, shall be located at one or both ends of a network.

4. NETWORK

Physical wiring specifications for harness designers and wiring system manufacturers.

4.1 Wire

Cables meeting SAE J1939-11 or SAE J1939-15 are acceptable.

4.1.1 Type

Shielded or unshielded twisted pair wire may be used. Maintaining the twist to the greatest extent possible is critical to meeting impedance, radiated emissions and susceptibility requirements. The twist requirements are specified in Table 1 and are controlled by the lay length specification. Jacketed cable is recommended to maintain consistent twisting and impedance. When using shielded cable, it is especially important to observe the minimum bend radius requirement to avoid internal damage to the shield.

When shielded cable is used, shield should be terminated as described in SAE J1939-11. For mixed shielded/unshielded configurations, follow recommendations in SAE J1939-15.

4.1.2 Environmental Requirements

Cable should meet the environmental requirements of the application. Typically, cables for heavy truck applications will need to meet SAE J1128 requirements for SXL or GXL type wire.

4.1.3 Cable Properties

Table 1 - Cable properties

Parameter	Symbol	Min	Nom	Max	Unit
Impedance[1, 2]	Z	108	120	132	Ω
Specific Resistance	r_b	0	25	50	mΩ/m
Specific Line Delay	t_p		5.0	5.5	ns/m
Lay Length		20	25	38	mm
Cable Bend Radius	r	4x dia. of cable			Mm
Capacitance	C		35		pF/m

[1] Impedance requirement shall be met over the specified operating temperature. Dielectric materials such as PVC will not meet this requirement over temperature and lifetime.

[2] Impedance is measured according to CiA 601-6.

4.1.4 Color

The CAN_H conductor should be yellow and the CAN_L conductor should be green. Variations on this are acceptable for identifying other SAE J1939 networks or SAE J1939 network segments, as long as CAN_H has yellow and CAN_L has green. (For example, white with yellow stripe and solid green.)

4.2 Topology

The network shall have a linear topology consisting of a backbone and multiple stubs by which ECUs are connected. Stubs may have zero length. The backbone is terminated at the ends.

4.2.1 Stubs

The maximum length of a stub shall be 0.5 m. A stub may be left unconnected to an ECU, but this stub will count toward the maximum number of nodes on the network. The length of stubs should be minimized and should be varied to reduce the likelihood of coincident reflections.

4.2.2 Distance Between Nodes and Number of Nodes

The minimum distance between nodes should be 30 cm to minimize impedance mismatch on the backbone due to accumulated capacitive load.

The maximum distance between the farthest nodes (including stubs) on the network is allowed to vary according to the number of nodes on the network. Each node connected to the network adds capacitive load and effectively slows the rate of signal propagation on the network. The maximum number of nodes is 30.

Table 2 - Node count versus distance

Number of Nodes	Maximum Distance Between Nodes
2	56 m
3	56 m
4	55 m
5	54 m
6	53 m
7	53 m
8	52 m
9	51 m
10	51 m
11	50 m
12	49 m
13	49 m
14	48 m
15	47 m
16	47 m
17	46 m
18	46 m
19	45 m
20	45 m
21	44 m
22	44 m
23	43 m
24	43 m
25	42 m
26	42 m
27	41 m
28	41 m
29	40 m
30	40 m

4.3 Connection and Termination

Either splices or connectors may be used to connect stubs to the backbone. Splice methodologies and connectors should be chosen to minimize the untwisted length of wire.

4.3.1 Splices

Follow recommendations in SAE J1939-11 or SAE J1939-15 for splicing techniques.

4.3.2 Connectors

Connectors should meet performance specifications of SAE J2030 for "signal level circuits." Circuits of this type are defined in SAE J2030 as a circuit in which open circuit voltage is typically less than 5 V and current is typically less than 0.05 A. Connector impedance specifications are the same as given in Table 1.

4.3.3 Terminators

Each of the two endpoints of the backbone shall be terminated across the CAN_H and CAN_L conductors with a resistance equal to the characteristic impedance of the cable. These terminators suppress signal reflections. Also, without these resistors, the proper differential voltage is not produced between the conductors.

4.3.3.1 Termination Resistance

Termination resistance may be included within an ECU connected at the end of the network. If it is included, it shall be clearly identified in the device documentation or on the device itself.

Table 3 - Terminating resistor parameters

Parameter	Symbol	Min	Nom	Max	Unit
Resistance	R_L	110	120	130	Ω

4.3.3.2 Split Termination of Backbone

One or both ends of the backbone may be terminated with split termination in which R_L is divided into two well matching resistors. In order to achieve good electro-magnetic emission performance, it is recommended not to exceed ±1% tolerance between the two identical resistors of the split termination locally. Refer to ISO 11898-2:2016.

The center tap between the resistors should be connected to ground through a 1.0 nF capacitor, C_L.

4.3.3.3 Node Termination

Impedance characteristics of the CAN connections at the ECU specified within this document preclude the use of termination at the node. Providing termination at nodes (in addition to those that terminate the backbone) would reduce the number of nodes capable of being supported on the network, and are therefore not allowed.

4.4 Signal Improvement Circuitry (SIC) Transceivers

At the time of publication, two different types of active signal improvement transceivers are expected to become available. The two types are compatible, however best performance is achieved when all nodes use the same type of improvement transceiver. The type of SIC transceiver which uses suppression on the transmit signal is more widely supported and is recommened to be used on SAE J1939-17 networks.

Refer to CiA 601-4 for discussion of signal improvement circuitry.

4.5 ECU Circuit Board Layout

Best practices for board layout should be used. CAN_H and CAN_L PCB traces from connector to transceiver should be of equal distance and parallel, and should maintain 120 Ω impedence. Keep the TXD and RXD PCB traces between host controller and transceiver short.

4.6 ECU Type I and Type II Markings

An ECU that does not contain an internal Load Resistor (R_L) shall be designated as a Type I ECU and does not require a marking. An ECU that contains an internal R_L shall be designated as a Type II ECU. The Type II ECU may have a marking on the outside housing to easily determine the internal R_L feature.

4.7 Diagnostic Connection

A vehicle may use a diagnostic gateway to abstract the control architecture, provide network security, and maintain the topology, performance, and electrical integrity of the vehicle network. Implementation of access to a vehicle SAE J1939-17 network, whether through a gateway or direct connection is not described in this document.

5. ECU TRANSCEIVER REQUIREMENTS

This section details requirements to aid the designer in choosing an appropriate transceiver. It may also be used by chip makers when developing or marketing their devices.

5.1 Impedance

Impedance requirements are given in Table 4 and encompass the ECU as a whole, including the transceiver and additional filtering or protection circuitry.

Table 4 - ECU impedance

Parameter	Symbol	Unit	Min	Nom	Max
Input Resistance	R_{IN}	kΩ	5		50
Resistance Deviation CANH to CANL	$R_{IN(d)}$	%	-3		3
Differential Input Resistance	R_{DIFF}	kΩ	10		100
Input Capacitance	C_{IN}	pF		20	120
Differential Capacitance[1]	C_{DIFF}	pF		10	60

[1] Unusually challenging EMC environments such as some stationary generator applications may require additional capacitance which will affect node count or choice of transceiver.

5.2 Transmitter and Receiver Characteristics

Refer to ISO 11898-2 for voltage and current requirements.

5.3 Loop Delay

Loop delay is the sum of the transmitter and receiver delays. The transmitter delay consists of the propogation delay from the CAN controller to the transceiver TXD pin, the transmit propagation delay of the transceiver, and the transmit delay of other filter or isolation components if present. The receiver delay consists of the propogation delay from filter or isolation components if present, the receive propagation delay of the transceiver, and the propagation delay from the RXD pin to the CAN controller (and internal logic).

Table 5 - Time delay

Parameter	Unit	Min	Nom	Max
TX Propagation delay Recessive to Dominant	ns			70
TX Propagation delay Dominant to Recessive	ns			95
RX Propagation delay Recessive to Dominant	ns			75
RX Propagation delay Dominant to Recessive	ns			115

5.4 Protection

Bus terminals shall be protected against the following transients and fault conditions. Device shall meet short circuit requirements for the highest voltage associated with the system on which it may operate.

Table 6 - Protection

Parameter	Symbol	Unit	Min	Nom	Max
ESD Voltage (HBM)	V_{ESD}	kV	±8		
Short Circuit Voltage for 12/24 V Systems	$V_{SHORT24}$	V	±32		
Short Circuit Voltage for 48 V Systems	$V_{SHORT48}$	V	±58		

6. BIT TIMING

6.1 Oscillator Frequency and Bit Rate Prescaler

The CAN clock frequency shall be 40 MHz. ISO 11898-1 limits the Bit Rate Prescaler value to either 1 or 2 when Transmitter Delay Compensation (TDC) is enabled. Therefore, the frequency of the oscillator from which the CAN clock is derived shall be 40 MHz (with BRP = 1) or 80 MHz (with BRP = 2).

NOTE: To achieve bit time tolerance given in Table 7, oscillator tolerance is ±500 ppm.

6.2 Secondary Sample Point

The CAN controller shall be configured to perform automatic transmitter delay measurement for transmitter delay compensation. The TDC offset shall be configured to achieve the secondary sample point given in Table 7.

Table 7 - Bit timing parameters

	Arbitration Phase		Data Phase		
Parameter	Notation	Value	Notation	Value	Units
Nominal Bit Time	BT_A	2.000 ± 0.001			µs
Data Bit Time			BT_D	0.500 ± 0.00025	µs
Bit Rate Prescaler	BRP_A	See 6.1	BRP_D	See 6.1	
Number of Time Quanta per Nominal Bit Time	NQ_A	80	NQ_D	20	
Synchronization Jump Width	SJW_A	4	SJW_D	1	tq
SYNC_SEG	$SYNC_A$	1	$SYNC_D$	1	tq
TSEG1	$TSEG1_A$	63	$TSEG1_D$	15	tq
TSEG2	$TSEG2_A$	16	$TSEG2_D$	4	tq
Sample Point	SP_A	80	SP_D	80	%
Secondary Sample Point			SSP	75	%

NOTE: TSEG1 and TSEG2 are bit timing registers related to Propagation and Phase Segments as follows:
TSEG1 = PROP_SEG + PHASE_SEG1.
TSEG2 = PHASE_SEG2.

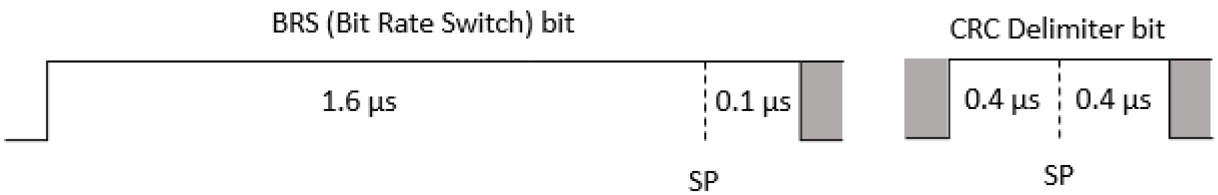

Figure 1 - Example bit lengths at phase transitions

7. NOTES

7.1 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.

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