



SURFACE VEHICLE RECOMMENDED PRACTICE

J1939™-11

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(R) Physical Layer, 250 kbit/s, Twisted Shielded Pair

RATIONALE

Document is updated for harmonization and compatibility with other SAE J1939 Physical Layer documents.

FOREWORD

The SAE J1939 common communication architecture is defined using a collection of individual SAE J1939 documents that are generally based upon the layers of the open system interconnect (OSI) model for computer communications architecture. This collection 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. These documents are subject to change to keep pace with experience and technical advances. They are intended as a guide toward a standard practice.

The SAE J1939 communications network is based on ISO 11898-1 and ISO 11898-2. SAE J1939 supports control functions, operating data, and diagnostic data exchanges between electronic control units (ECUs) from different manufacturers. The ECUs can be physically distributed throughout the vehicle as well as off-board, such as service tools.

The SAE J1939 communications network is suitable for both horizontally and vertically integrated vehicles such as light-duty, medium-duty, and heavy-duty vehicles used on-road or off-road, and for appropriate stationary applications which use vehicle derived components (e.g., generator sets). Applications include, but are not limited to, on-highway trucks with their trailers, off-highway trucks, construction equipment, marine, and agricultural or forestry equipment with their implements.

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1. SCOPE

This document defines a physical layer having a robust immunity to EMI and physical properties suitable for harsh environments. This document is suitable for CAN interfaces applying CAN HS (high-speed) transceivers as specified in ISO 11898-2.

These SAE Recommended Practices are 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.

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: 1-877-606-7323 (U.S. and Canada only) or 1-724-776-4970 (outside U.S. and Canada), www.sae.org.

AS85485D	Cable, Electric, Filter Line, Radio Frequency Absorptive
SAE J1113-13	Electromagnetic Compatibility Measurement Procedure for Vehicle Components - Part 13: Immunity to Electrostatic Discharge
SAE J1128	Low Voltage Primary Cable

2.1.2 ISO Publications

Copies of these documents are available online at www.iso.org/store.

ISO 11898-1:2024	Road vehicles — Controller area network (CAN) — Part 1: Data link layer and physical coding sublayer
ISO 11898-2:2026	Road vehicles — Controller area network (CAN) — Part 2: High-speed physical medium attachment (PMA) sublayer
ISO 19642-2:2019	Road vehicles — Automotive cables — Part 2: Test methods

2.2 Related Publications

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

2.2.1 SAE Publications

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

SAE J1939	Serial Control and Communications Heavy-Duty Vehicle Network - Top-Level Document
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3. DEFINITIONS

3.1 PHYSICAL LAYER

The physical layer is a realization of an electrical connection of a number of ECUs (electronic control units) to a network.

3.2 PHYSICAL MEDIA

Physical Media refers to the wiring and their materials used to transmit information. This document defines a physical media of shielded twisted pair wiring that is symmetrically driven with respect to the electrical currents.

The designations of the individual wires are CAN_H and CAN_L. The names of the corresponding pins of the ECUs are also denoted by CAN_H and CAN_L, respectively. The third connection for the termination of the shield is denoted by CAN_SHLD.

3.3 BUS LEVELS

The bus lines can have one of the two logical states: recessive or dominant (see Figure 1). In the recessive state, U_{CAN_H} and U_{CAN_L} are fixed to a mean voltage level. U_{diff} is approximately zero on a terminated bus. The recessive state is transmitted during bus idle or a recessive bit.

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

3.4 BUS LEVELS DURING ARBITRATION

A dominant and recessive bit imposed on the bus lines during a given bit time by two different ECUs results in a dominant bit.

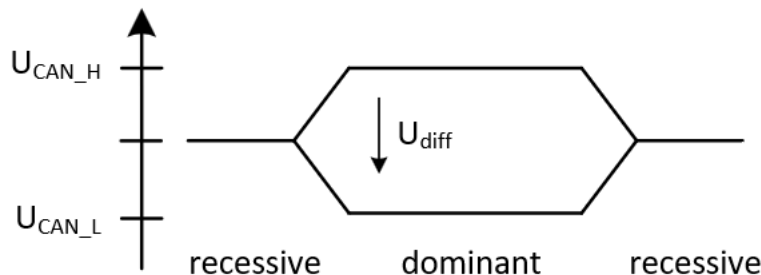


Figure 1 - Physical bit representation

3.5 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.

3.6 BUS TERMINATION

The bus line is electrically terminated at each end with a resistor denoted by R_L (see Figure 2) which has a resistance value matching the characteristic impedance of the physical media.

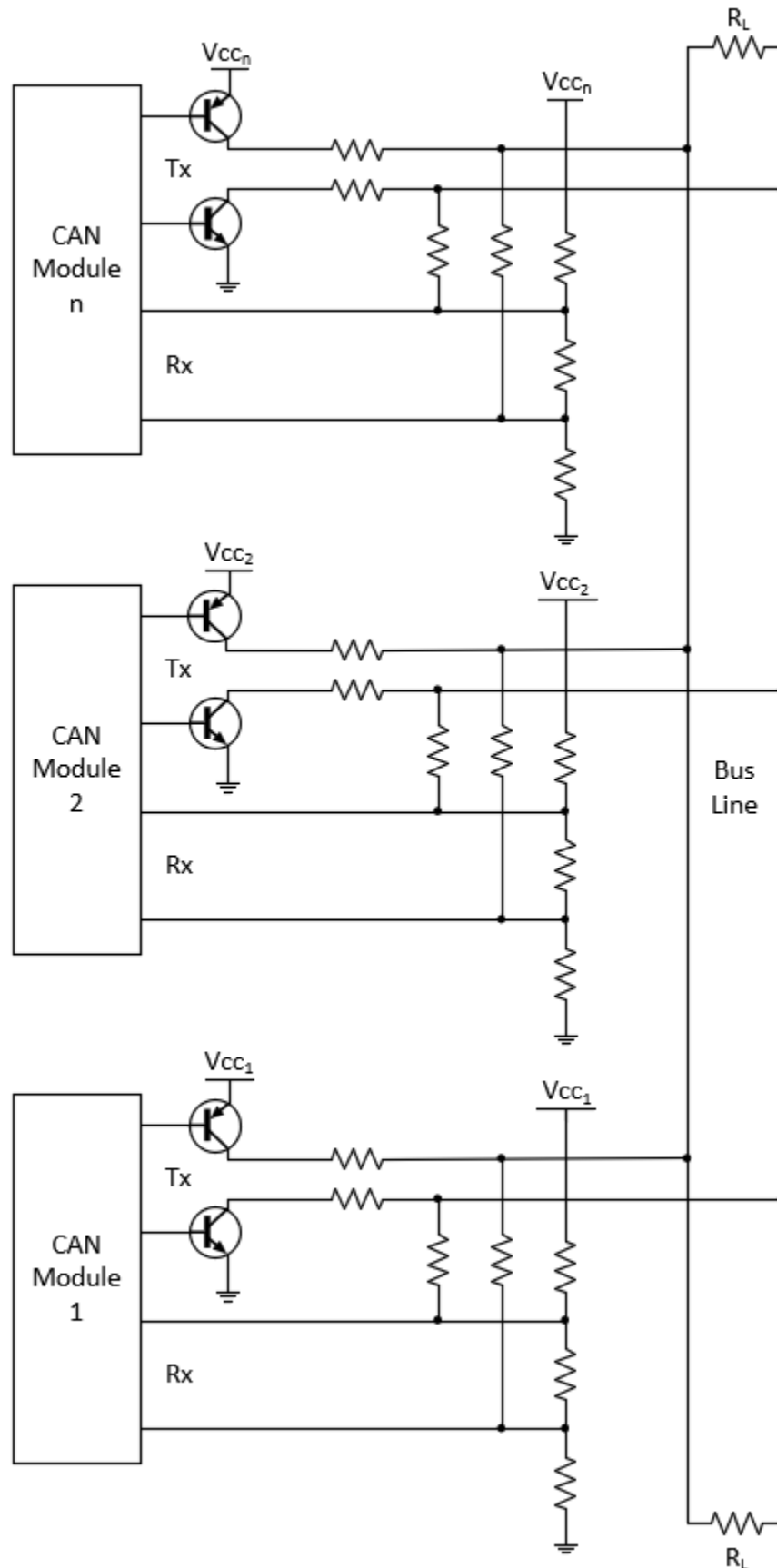


Figure 2 - Physical layer functional

3.7 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 (see Figure 3).

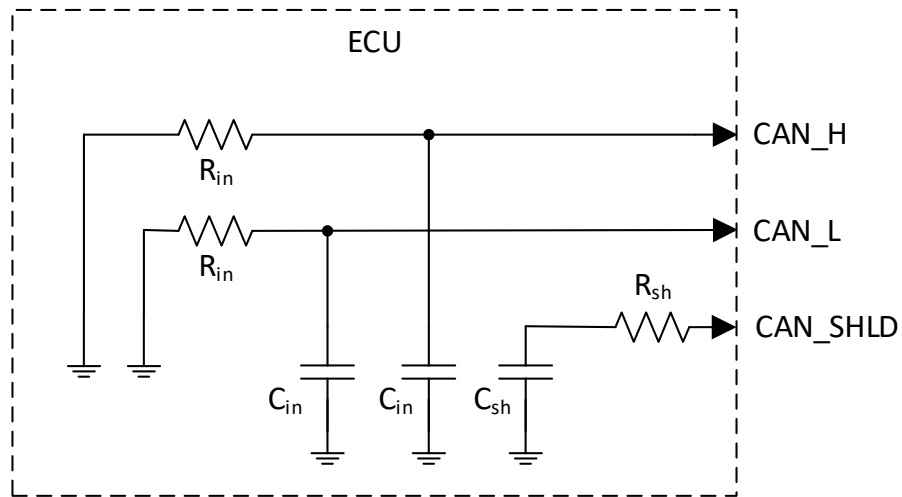


Figure 3 - Illustration of internal capacitance and resistance of an ECU in the recessive state

3.8 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 (see Figure 4).

3.9 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 (see Figure 3).

3.10 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 (see Figure 4).

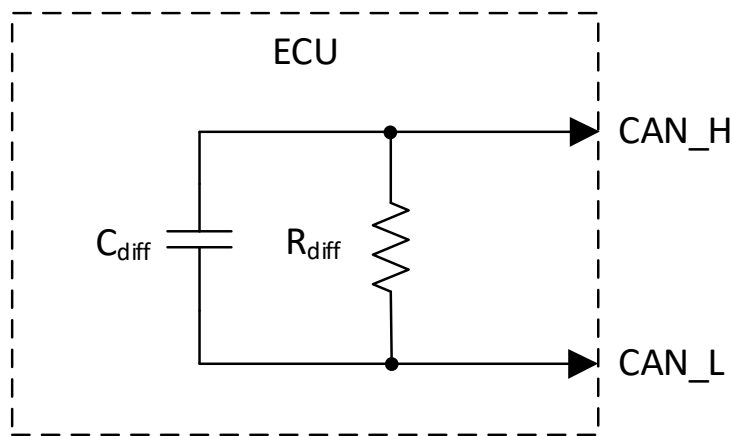


Figure 4 - Illustration of differential internal capacitance and resistance of an ECU in the recessive state

3.11 TIME QUANTA

The interval of the CAN system clock. An integer multiple of the system clock period, the smallest division of a bit time used by the CAN controller.

3.12 BIT TIME

The duration of one bit in either the arbitration or data phase. See Section 6 for timing requirements. Bus management functions executed within this bit time, such as ECU synchronization behavior, network transmission delay compensation, and sample point positioning, are defined by the programmable bit timing logic of the CAN controller.

3.13 BAUD RATE PRESCALER (BRP)

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

3.14 SYNCHRONIZATION JUMP WIDTH (SJW)

The maximum interval by which Phase_Seg1 and Phase_Seg2 can be adjusted.

3.15 SYNC_SEG

The first 1 t_q portion of a bit time. An edge is expected within this bit segment. (See Figure 5.)

3.16 PROP_SEG

A part of the bit time used to compensate for the physical delay times within the network. (See Figure 5.)

3.17 PHASE_SEG1

The first segment of the bit time used to compensate for phase errors. It can be lengthened by an amount less than or equal to SJW. (See Figure 5.)

3.18 PHASE_SEG2

The second segment of the bit time used to compensate for phase errors. It can be shortened by an amount less than or equal to SJW. (See Figure 5.)

3.19 TSEG1

Combination of the PROP_SEG and PHASE_SEG1.

3.20 TSEG2

Same as PHASE_SEG2.

3.21 SAMPLE POINT

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

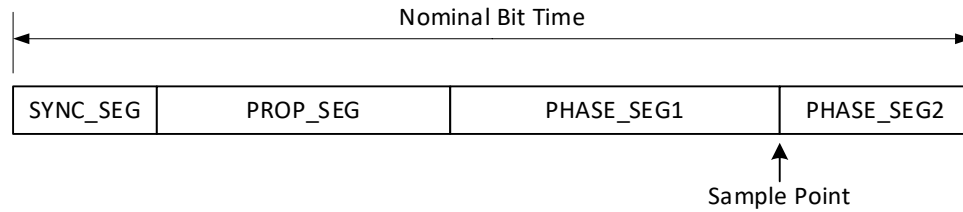


Figure 5 - Partition of the bit

3.22 INTERNAL DELAY TIME

The sum of all asynchronous delays that occur along the transmission and reception path of the individual ECUs, relative to the bit timing logic unit of the CAN controller.

3.23 DIFFERENTIAL VOTAGE

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

$$U_{diff} = U_{CAN_H} - U_{CAN_L} \quad (\text{Eq. 1})$$

3.24 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.

3.25 TYPE I ECU

An ECU that does not contain bus line termination.

3.26 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 and shall be marked as specified in 4.2.7.

4. NETWORK

Physical wiring specifications for harness designers and wiring system manufacturers.

4.1 Physical Media Parameters

The following sections describe the characteristics of the cable (see Table 1), termination (see Table 3), and topology of the network (see Table 2.).

4.1.1 Bus Line

The bus line consists of a CAN_H, CAN_L, and CAN_SHLD conductors.

Maintaining the twist to the greatest extent possible is critical to meeting radiated emissions and susceptibility requirements. The twist requirements are specified in Table 1 and are controlled by the lay length specification. It is especially important to observe the minimum bend radius requirement to avoid internal damage to the shield.

4.1.2 Cable Properties

Cable properties are specified in Table 1. See Figure 6.

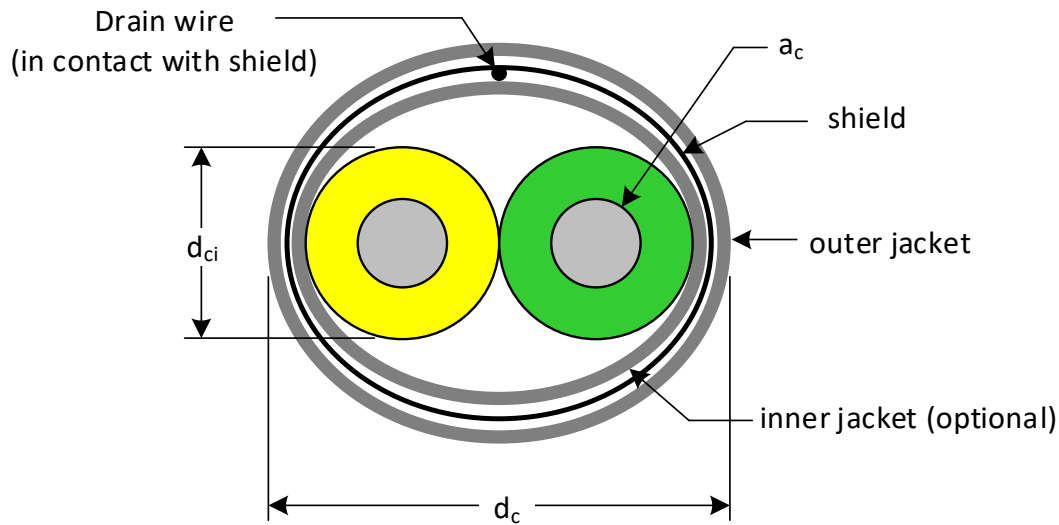


Figure 6 - Cable cross section

Table 1 - Physical media parameters for twisted shielded cable

Parameter	Symbol	Min	Nom	Max	Unit	Notes
Impedance	Z	108	120	132	Ω	
Specific Resistance	r_b	0	25	50	m Ω /m	
Specific Line Delay	t_p	n/a	5.0	n/a	ns/m	Equivalent to 67% Propagation Velocity (V_p)
Specific Capacitance	c_b	0	40	75	pF/m	Between conductors
	c_s	0	70	110	pF/m	Conductor to shield
0.5 mm ² Conductor Area	a_c	0.508	n/a	n/a	mm ²	20 AWG
Wire Insulation Diameter	d_{ci}	2.23	n/a	3.05	mm	
Cable Diameter	d_c	6.0	n/a	8.5	mm	
0.8 mm ² Conductor Area	a_c	0.760	n/a	n/a	mm ²	18 AWG
Wire Insulation Diameter	d_{ci}	2.50	n/a	3.50	mm	
Cable Diameter	d_c	8.5	n/a	11.0	mm	
Shield Effectiveness		n/a	200	225	m Ω /m	
Lay Length	l	28	39	50	mm	0.51 to 0.91 twists per 25.4 mm
Temperature Range	C	-40	n/a	+125	°C	
Cable Bend Radius	r	4 times diameter of cable	n/a	n/a	mm	

4.1.2.1 Impedance

Impedance is to be determined using the method given in ISO 19642-2 for characteristic impedance in the frequency domain.

4.1.2.2 Specific Resistance

The differential voltage on the bus line seen by a receiving ECU depends on the line resistance between it and the transmitting ECU. Therefore, the total resistance of the signal wires is limited by the bus level parameters of each ECU. Resistance shall be measured at 20 °C using the method given in ISO 19642-2 for conductor resistance.

4.1.2.3 Specific Line Delay

The minimum delay time between two points of the bus line may be zero. The maximum value is determined by the bit time and the delay times of the transmitting and receiving circuitry. Use the method given in ISO 19642-2 for velocity of propagation.

4.1.2.4 Specific Capacitance

Measure capacitance using the method given in ISO 19642-2 for bus capacitance.

4.1.2.5 Cable Size

TXL, GXL, or SXL conductor wire may be used if cable assembly impedance is met. However, conductor insulation dimensions given in Table 1 may be larger than those specified in SAE J1128. Design engineers should ensure compatibility between cables, connectors, and contacts.

Cables shall meet performance requirements of SAE J1128 for types GXL or SXL (including drain wire where applicable).

4.1.2.6 Shield Effectiveness

Shield Effectiveness is measured at 1 MHz using the "Surface transfer impedance, effective" method per AS85485D.

4.1.2.7 Lay Length

Lay Length is the distance required to complete one 360-degree revolution of the helically laid signal conductors. Additionally, the maximum length of untwisted wire at a connector or splice shall be 50 mm.

4.1.2.8 Temperature Range

Temperature testing shall be per ISO 19642-2 long-term heat aging with 3000 hours at the maximum temperature given in Table 1 (or specified by the OEM) using a mandrel that is 4 times to 5 times the diameter of the cable.

4.1.2.9 Cable Bend Radius

Cables shall not have performance or physical degradation when bent 90 degrees at the given radius.

4.1.3 Environmental Requirements

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

4.1.4 Color

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