SURFACE VEHICLE RECOMMENDED PRACTICE

J1939-15 | MAY2014

Issued 2003-11
Revised 2014-05

Superseding J1939-15 AUG2008

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

RATIONALE

Document is being revised to allow for additional stubs beyond the previous limit of 10 nodes. Scope is revised to exclude the use of flexible data rate messages as described in the CAN FD extension.

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.

The SAE J1939 communications network is intended for 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). Vehicles of interest include, but are not limited to, on-highway and off-highway trucks and their trailers, construction equipment, and agricultural equipment and implements.

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 describes a physical layer utilizing Unshielded Twisted Pair (UTP) cable with extended stub lengths for flexibility in ECU placement and network topology. Also, connectors are not specified.

CAN controllers are now available which support the newly introduced CAN Flexible Data Rate Frame format (known as “CAN FD”). These controllers, when used on SAE J1939-15 networks, must be restricted to use only the Classical Frame format compliant to ISO 11989-1 (2003).

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

General information regarding this series of recommended practices is found in SAE J1939.

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 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 J1939-13 Off-Board Diagnostic Connector

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 ISO Publications

Available from American National Standards Institute, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

ISO 11898 Road vehicles - Interchange of digital information - Controller Area Network (CAN) for high speed communication.

3. NETWORK PHYSICAL DESCRIPTION

The SAE J1939-15 physical layer has the same characteristics as the SAE J1939-11 physical layer except as described in this document. It is the responsibility of the vehicle manufacturer to determine when the SAE J1939-15 physical layer should be used versus the SAE J1939-11 physical layer. Appendix E, Table E1 contains a comparison of SAE J1939-15 characteristics versus SAE J1939-11.

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. The total number of ECUs will be limited by electrical loads on the bus line.

Stubs, being un-terminated, create signal reflections on the network. A total of up to 10 ECUs on a network segment is considered to present low risk of coincident reflections of sufficient magnitude to create bit errors and error frames. Up to 30 ECUs may be connected on a network segment if special care is taken to vary the spacing between stubs to avoid the effects of reflections. Consideration must also be given to EMC performance which may be affected by the total stub length.

The SAE J1939-15 network was designed as a reduced SAE J1939-11 network for connecting standard ECUs on a vehicle (e.g., Engine, ABS, Transmission). The SAE J1939-15 network allows the vehicle integrator to design a reduced network to meet design and cost goals with comparable performance to the SAE J1939-11 network.

3.2 Physical Media

This document defines a physical media of jacketed un-shielded twisted pair (UTP). These 2 wires have a characteristic impedance of 120 Ω and are 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.

3.3 Differential Voltage

Same as the SAE J1939-11 physical layer.

3.4 Bus Levels

Same as the SAE J1939-11 physical layer.

3.5 Bus Levels During Arbitration

Same as the SAE J1939-11 physical layer.

3.6 Common Mode Bus Voltage Range

Same as the SAE J1939-11 physical layer.

3.7 Bus Termination

The bus is electrically terminated at each end with a load resistor denoted by R_L. SAE J1939-11 requires that R_L be located external to ECUs. This Recommended Practice, J1939-15, defines Type I and Type II ECUs. Type I ECUs shall not contain the bus termination resistor R_L. Type II ECUs shall contain the bus termination resistor and if used shall be located only at one or both ends of an SAE J1939-15 network. Type II ECUs shall be clearly marked as specified in Section 5.2.5.

3.8 Internal Resistance

Same as the SAE J1939-11 physical layer.

3.9 Differential Internal Resistance

Same as the SAE J1939-11 physical layer.

3.10 Internal Capacitance

Same as the SAE J1939-11 physical layer.

3.11 Differential Internal Capacitance

Same as the SAE J1939-11 physical layer.

3.12 Bit Time

Same as the SAE J1939-11 physical layer.

3.13 Internal Delay Time

For those networks utilizing a diagnostic stub which may exceed 3 meters, ECU delay time is reduced to 0.7 µs.

3.14 CAN Bit Timing Requirements

The CAN bit timing requirements for the SAE J1939-15 are the same as the SAE J1939-11 physical layer, except Table 1 below should be used, which includes the Signal Rise / Fall Time parameter.

If a discrete circuit is used, the Signal Rise / Fall Time should be adjusted per Table 1, Note 2.

Some transceiver chips offer faster rise and fall times than are given in Table 1 without an increase in EMI. If emissions control or slope control is not integral to the transceiver, EMI performance must be equivalent.

The Signal Rise / Fall Time parameter has been included for clarity and to improve the Electromagnetic Compatibility (EMC) of the physical layer. The primary parameter for electromagnetic emission is the unbalance of the signals at CAN_H and CAN_L. To verify that the signals are balanced, the maximum voltage imbalance between CAN_H and CAN_L should not exceed 10 mV_{pp}. The differential voltage can be measured with ac-coupling and an oscilloscope: CAN_H minus CAN_L inverted.

TABLE 1 - AC PARAMETERS OF AN ECU DISCONNECTED FROM THE BUS LINE

Parameter	Symbol	Min	Nom	Max	Unit	Conditions
Bit time 1)	t_B	3.998	4.000	4.002	µs	250 Kbit/s
Internal Delay Time 2)	t_{ECU}	0.0		0.7	µs	
Internal Capacitance3)	C_{in}	0	50	100	pF	250 Kbit/s for CAN_H and CAN_L relative to Ground
Differential Internal Capacitance 3)	C_{diff}	0	25	50	pF	
Available Time 4)	t_{avail}	2.5			µs	40 m bus length
Signal Rise, Fall Time 5)	t_R, t_F	200		500	ns	measured from 10% to 90% of the signal

1) Including initial tolerance, temperature, aging, etc.

2) The value of t_{ECU} has to be guaranteed for a differential voltage of V_{diff} = 1.0V for a transition from recessive to dominant and of V_{diff} = 0.5V for a transition from dominant to recessive. With the bit timing from the example of note 1, a CAN-Interface delay of 500 ns is possible (controller not included) with a reserve of about 300 ns. This allows slower/longer slopes (R3 and R4 in Figures A.1 and A.2) and input filtering (R5, R6, C1, C2 in Figures A.1 and A.2). It is recommended to use this feature due to EMC. (See J1939-11 Appendix A for figures.) The minimal internal delay time may be zero. The maximum tolerable value is determined by the bit timing and the bus delay time.

3) In addition to the internal capacitance restrictions a bus connection should also have an inductance as low as possible. The minimum values of C_{in} and C_{diff} may be 0, the maximum tolerable values are determined by the bit timing and the network topology parameters L and d (see Table 3). Proper functionality is guaranteed if occurring cable resonant waves do not suppress the dominant differential voltage level below V_{diff} = 1V and do not increase the recessive differential voltage level above V_{diff} = 0.5V at each individual ECU (see J1939-11 Tables 3 and 4).

4) The available time results from the bit timing unit of the protocol IC. For a typical example, this time in most controller ICs corresponds to TSEG1. Due to mis-synchronization it is possible to lose the length of SJW. So the available time (t_{avail}) with one mis-synchronization is TSEG1-SJW ms. A tq time of 250 ns and SJW = 1 tq, TSEG1 = 13 tq, TSEG2 = 2tq results in t_{avail} = 3.00 µs.

5) A signal rise/fall time between 200-500 ns is required for the J1939-15 network if using adjustable circuits. Signal rise/fall times closer to 500 ns are preferred. Slower/longer signal rise/fall times improve the electromagnetic compatibility of the network by reducing radiated emissions and radiated susceptibility. The load on the ECU for the purpose of this parameter should be 60 ohms between CAN_H and CAN_L in parallel with 200 pf of capacitance (see Appendix A).

4. FUNCTIONAL DESCRIPTION

Same as the J1939-11 physical layer.

5. ELECTRICAL SPECIFICATION

5.1 Electrical Data

The parameter specifications in Tables 1 through 10 of SAE J1939-11 must be fulfilled throughout the operating temperature range of every ECU. These parameters allow up to a maximum of 10 ECUs to be connected to a given bus segment.

5.1.1 Electronic Control Unit

Same as the SAE J1939-11 physical layer.

5.1.1.1 Absolute Maximum Ratings

Same as the SAE J1939-11 physical layer.

5.1.1.2 DC Parameters

Same as the J1939-11 physical layer.

5.1.1.3 AC Parameters

Same as the J1939-11 physical layer.

5.1.2 Bus Voltages - Operational

The parameters specified in Table 5 and Table 6 of SAE J1939-11 apply when all ECUs are connected to a correctly terminated bus line. The maximum allowable ground offset between any ECUs on the bus is 2 Volts. The voltage extremes associated with this offset would occur in the dominant state (see Table 6 in SAE J1939-11).

5.1.3 Electrostatic Discharge (ESD)

Same as the SAE J1939-11 physical layer.

5.1.4 Example Physical Layer Circuits

The SAE J1939-15 ECU physical layer circuits are the same as the SAE J1939-11 ECU physical layer circuits.

If using a discrete transceiver circuit, or if an integrated circuit provides for adjusting the rise and fall time, the SAE J1939-15 ECU physical layer parameters are required to be adjusted so the signal rise/fall time is between 200-500ns to improve the SAE J1939-15 network Electromagnetic Compatibility. See Appendix A, Figure A1 for the preferred signal rise and signal fall waveforms.

The J1939-15 network (backbone and stubs) will not be connected to the CAN_SHLD terminal on the ECU physical layer circuit.

5.2 Physical Media Parameters

The following sections describe the characteristics of the cable, termination, and topology of the network. Table 2 contains the physical media parameter values for the SAE J1939-15 cable. Figure 1 shows the cable cross-section and the bend radius of the SAE J1939-15 cable.

Physical parameters not specified herein should meet requirements of SAE J1128 for type TXL, GXL, or SXL wire. These requirements include resistance to flame propagation, fluid compatibility, resistance to ozone, resistance to pinch, resistance to sandpaper abrasion, and resistance to hot water.

TABLE 2 - PHYSICAL MEDIA PARAMETERS FOR UN-SHIELDED TWISTED PAIR CABLE

Parameter	Symbol	Min	Nom	Max	Unit	Conditions
Impedance	Z	108	120	132	Ω	Three meter sample length measured at 1 Mhz between the two signal wires, using open/short method.
Specific Resistance	r_b	0	25	50	mΩ/m	1) measured at 20 °C
Specific Line Delay	t_p		5.0		ns/m	2)
Specific Capacitance	c_b	0	40	75	pF/m	
Cable size						3)
0.5 mm^2 Conductor (20 AWG)	a_c	0.508			mm^2	4) (see Figure 1)
Wire insulation dia.	d_{ci}	1.90		2.8	mm	
Cable diameter	d_c	5.08		7.6	mm	
0.8 mm^2 Conductor (18 AWG)	a_c	0.760			mm^2	4) (see Figure 1)
Wire insulation dia.	d_{ci}	2.03		3.05	mm	
Cable diameter	d_c	5.3		8.2	mm	
Temperature Range	°C	–40		+125	deg C	5)
Lay Length		28	33	38	mm	0.67 to 0.91 twist per 25.4mm
Cable Bend Radius	r	4x dia. of cable			mm	90 degree bend radius without cable performance or physical degradation. (see Figure 1)

1) 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 of the parameters of each ECU.

2) 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.

3) For environmental sealing applications, other cable and component insulation diameters may be available. Design engineers should ensure compatibility between cables, connectors and contacts.

4) Meet dimensional requirements of SAE J1128 for types TXL, GXL, or SXL.

5) 125 °C or per OEM specification.

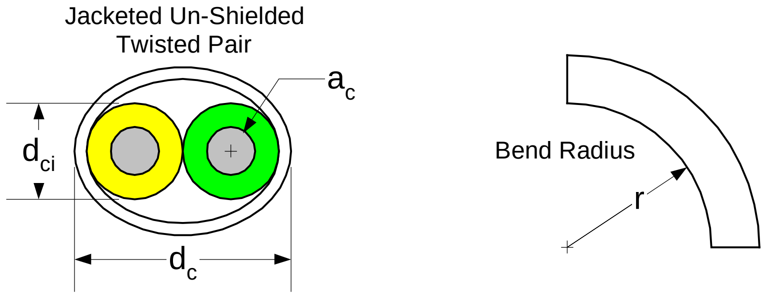

FIGURE 1 - CABLE CROSS-SECTION AND BEND RADIUS

5.2.1 Bus Line

The bus line consists of a CAN_H and CAN_L conductors. The CAN_H conductor wire should be yellow in color while the CAN_L conductor wire should be green.

5.2.2 Topology

Figures 2 through 4 show the different wiring topologies with different combinations of network terminations. The figures contain ECU 1, ECU 2, ECU n-1 and ECU n, which are Type I ECUs. ECU A and ECU B in Figures 3 and 4 are Type II ECUs. The dimensional requirements of the network are shown in Table 3.

The wiring topology of this network should be as close as possible to a linear structure in order to avoid cable reflections. In practice, it may be necessary to connect short cable stubs to a main backbone cable, as shown in the figures. To minimize standing waves, nodes should not be equally spaced on the network and cable stub lengths, dimension S, should not all be the same length.

The vehicle manufacturer shall control the SAE J1939-15 cable routing to prevent mutual inductance and / or capacitive coupling of unwanted signals onto the CAN_H and CAN_L wires. Coupled signals may interfere with communications and may degrade or damage the CAN transmission line transceivers over an extended period of time. The risk of coupling can be reduced by routing the J1939-15 cable away from high current, rapidly switched loads and the wires connected to these devices, including return paths of ECU ground or power. Examples of the devices and associated wiring to avoid include: starter motors, wiper relays, turn signal (flasher) relays, and lamp relays. Additionally, the routing of the network and stubs should avoid close proximity to emission sensitive components (e.g., radios, CBs, and other electronic components).

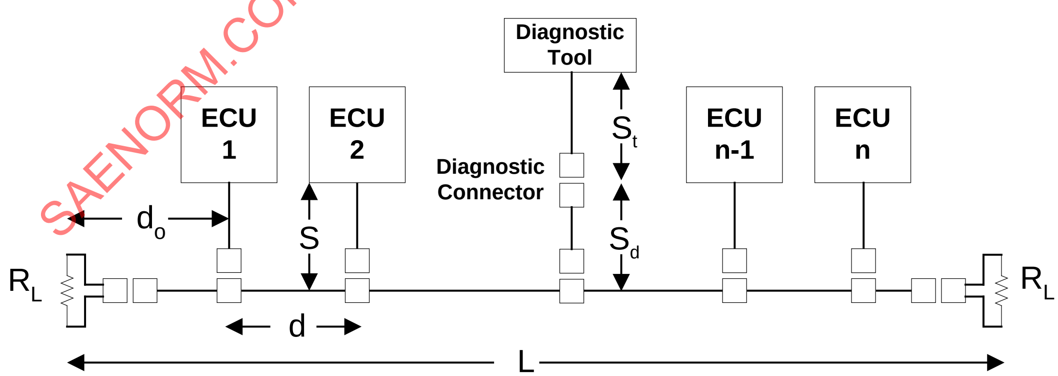

FIGURE 2 - WIRING NETWORK TOPOLOGY (TYPE I ECUS ONLY)

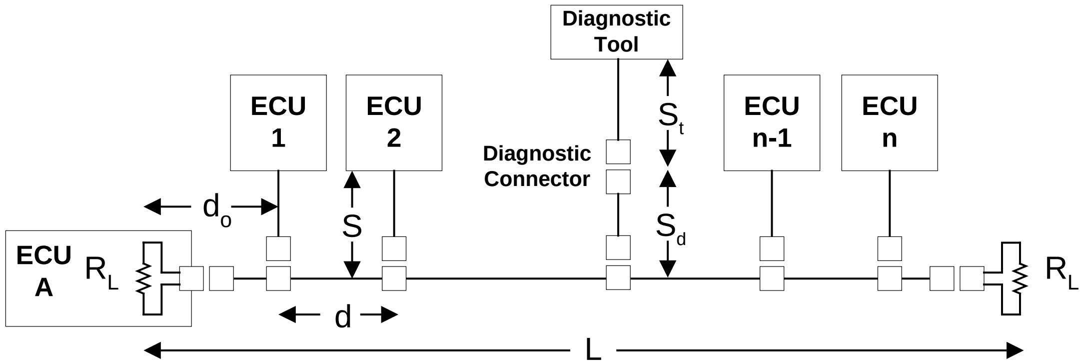

FIGURE 3 - WIRING NETWORK TOPOLOGY (ONE TYPE II ECU INSTALLED)

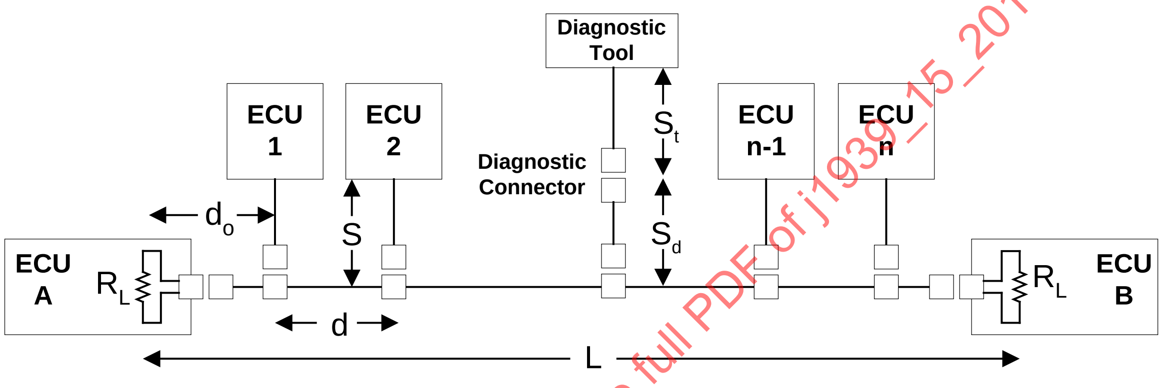

FIGURE 4 - WIRING NETWORK TOPOLOGY (TWO TYPE II ECUS INSTALLED)

TABLE 3 - NETWORK TOPOLOGY PARAMETERS

Parameter	Symbol	Min	Max	Unit	Conditions
Bus Length	L	0	40	m	The distance between the two Load Resistors (R_L), or between any two nodes (including the diagnostic scan tool), shall not exceed 40 meters.
Node Stub Length	S	0	3	m	
Diagnostic Stub Length	S_d	0	2.66	m	
Diagnostic Tool Cable Length	S_t	0	5	m	
Stub Distance	d	0.1	40	m	The distance between stubs on the backbone.
Stub Distance from R_L	d_0	0		m	R_L may be located within an ECU, but the ECU shall be marked as a Type II SAE J1939-15 ECU.

5.2.3 Terminating Resistor

Same as the SAE J1939-11 physical layer.

5.2.4 Shield Termination

Not Applicable to the SAE J1939-15 physical layer.

5.2.5 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 SAE J1939 ECU and does not require a marking. An ECU that contains an internal R_L shall be designated as a Type II SAE J1939 ECU. The Type II ECU shall have a unique marking on the outside housing to easily determine the internal R_L feature.

5.3 Connector Specifications

The type of connector is not specified for implementing the SAE J1939-15 network and a "standard" connector is not required. An ECU may be connected to the network with either a hard splice or connector. If a connector is used, the connector shall meet the Connector Electrical Performance Requirements in SAE J1939-11. If the three-pin connector described in the SAE J1939-11 document is installed on the SAE J1939-15 network, the drain wire CAN_SHLD terminal will not be used and a sealing plug will be installed.

It is the responsibility of the vehicle manufacturer to design the network with different keying structures to eliminate the possibility of connecting the network in a method that would be detrimental to proper communications. The connectors shall provide for the electrical connections of CAN_H and CAN_L conductor wires.

A SAE J1939-11 compliant ECU may require a three-pin connector described in the SAE J1939-11 document for connecting onto the SAE J1939-15 network. If the three-pin connector is required, the mating connector will not contain the drain wire CAN_SHLD terminal and a sealing plug will be installed. Figure 5 shows some examples of the SAE J1939-11 three-pin connector concept used in a SAE J1939-15 network.

See Figure 5 for the following connector usage descriptions:

The SAE J1939-11 connector used to connect the ECU to the 'backbone' of the network is called the 'Stub Connector' and is designated "A". The SAE J1939-11 connector used to connect the termination resistor to the ends of the backbone cable is called the 'Through Connector' and is designated "B". ECU 1 is installed onto the SAE J1939-15 'backbone' using a splice. ECU 2 is installed onto the SAE J1939-15 'backbone' using a two-pin connector concept. ECU 3 is installed onto the SAE J1939-15 'backbone' using a SAE J1939-11 three-pin connector concept including a terminating resistor.

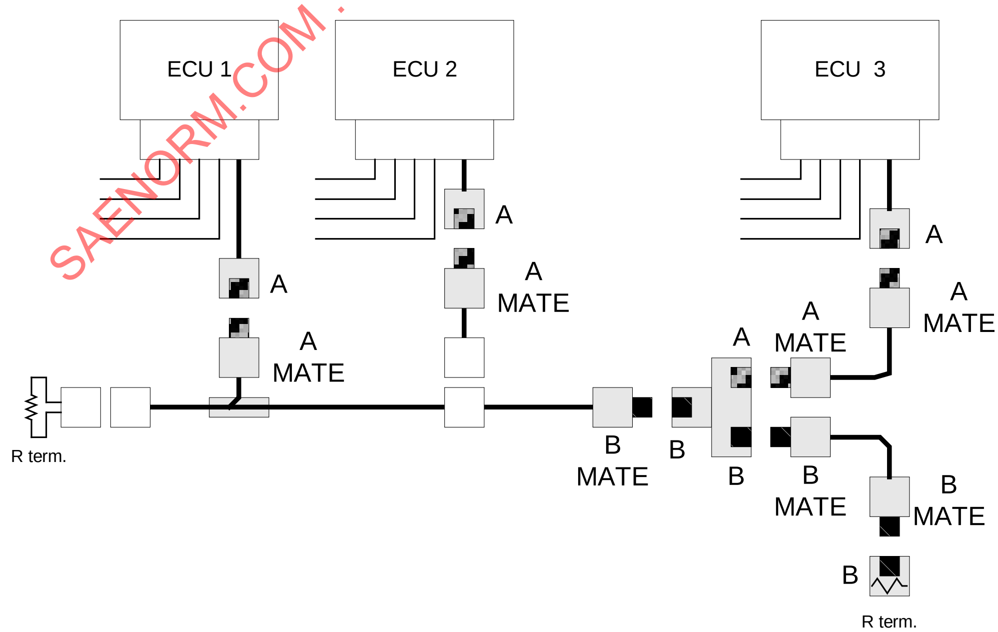

FIGURE 5 - AN EXAMPLE OF SAE J1939-11 CONNECTOR USAGE IN A SAE J1939-15 NETWORK

5.3.1 Connector Electrical Performance Requirements

Same as the SAE J1939-11 physical layer.

5.3.2 Connector Mechanical Requirements

When connectors are used in a cable network, the connectors should have locking, polarizing, stub connector versus backbone connector type keying, and retention devices that meet the requirements of the specific application. These connectors should also incorporate environmental protection appropriate for the application.

6. CONFORMANCE TESTS

Same as the SAE J1939-11 physical layer.

6.1 Recessive Output of the ECUs

Same as the SAE J1939-11 physical layer.

6.2 Internal Resistance of CAN_H and CAN_L

Same as the SAE J1939-11 physical layer.

6.3 Internal Differential Resistance

Same as the SAE J1939-11 physical layer.

6.4 Recessive Input Threshold of an ECU

Same as the SAE J1939-11 physical layer.

6.5 Dominant Output of an ECU

Same as the SAE J1939-11 physical layer.

6.6 Dominant Input Threshold of an ECU

Same as the SAE J1939-11 physical layer.

6.7 Internal Delay Time

Same as the SAE J1939-11 physical layer.

7. DISCUSSION OF BUS FAULTS

Same as the SAE J1939-11 physical layer.

7.1 Loss of Connection to Network

Same as the SAE J1939-11 physical layer.

7.2 Node Power or Ground Loss

Same as the SAE J1939-11 physical layer.

7.3 Unconnected Shield

Not Applicable to the SAE J1939-15 physical layer.

7.4 Open and Short Failures

Same as the SAE J1939-11 physical layer.

8. NOTES

8.1 Marginal Indicia

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 SAE TRUCK BUS CONTROL AND COMMUNICATIONS NETWORK COMMITTEE

APPENDIX A - EXAMPLE PHYSICAL LAYER CIRCUITS

See SAE J1939-11, Appendix A for an example circuit which meets the electrical specifications contained within this document. Figure A1 shows the preferred signal rise and fall times for a SAE J1939-15 network when transceivers supporting variable rise and fall times are used.

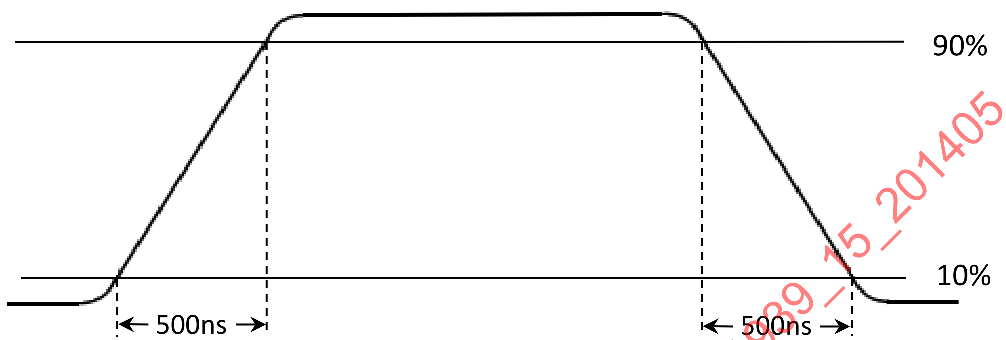

FIGURE A1 - EXAMPLE OF PREFERRED SIGNAL RISE/FALL WAVEFORMS

APPENDIX B - RECOMMENDED CABLE TERMINATION PROCEDURE

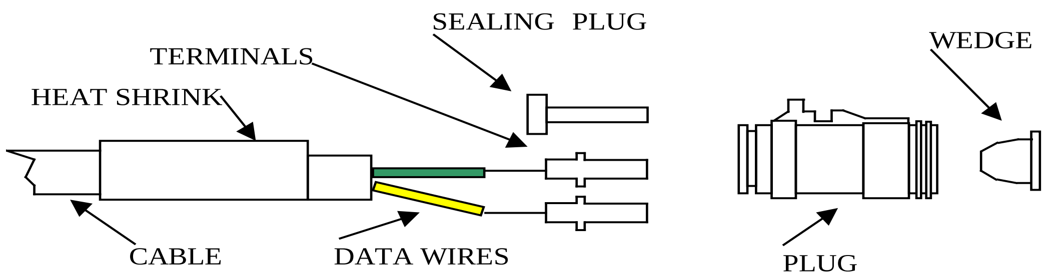

FIGURE B1 - CABLE TERMINATION 3 CAVITY CONNECTOR

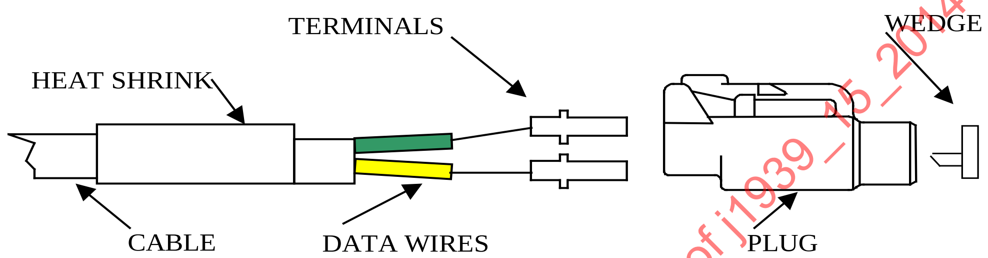

FIGURE B2 - CABLE TERMINATION OF A TYPICAL 2 CAVITY CONNECTOR

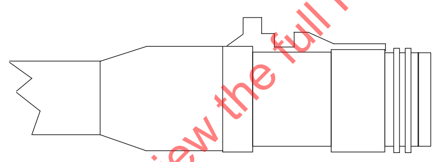

FIGURE B3 - TYPICAL FINISHED ASSEMBLY

1. Install sealing plug in un-used cavity of connector if it is a 3 pin (not required for 2 pin) type.

2. Remove cable outer jacket approximately 40-100 mm.

3. Strip insulation from wires 7 mm ± 0.8 mm.

4. Crimp a terminal on each wire per manufacturer's recommendation.

5. Slide adhesive-lined heat-shrinkable tubing onto the cable.

6. Install terminals into connector body per manufacturer's instructions. Isopropyl alcohol may be used to aid in assembly.

7. To maintain cable twisting, install the adhesive-lined heat-shrinkable tubing over the assembly and apply per manufacturer's recommendation. Cable twisting must begin at least 50 mm from the connector terminals. The maximum distance between the wires, over the untwisted length, is 3 mm.

8. If required, install wedge in front of connector body per manufacturer's instructions.