SAE INTERNATIONAL

SURFACE VEHICLE RECOMMENDED PRACTICE	J1939™-15	DEC2018
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(R) Physical Layer, 250 Kbps, Un-Shielded Twisted Pair (UTP)

RATIONALE

Document is revised to allow unjacketed cable for some installations, clarify minimum node and stub spacing, update ISO references and terminology, and correct table references to SAE J1939-11.

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.

TABLE OF CONTENTS

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 used on SAE J1939-15 networks must be restricted to use only Classical Frames as defined in ISO 11898- 1. A network which may have legacy controllers cannot tolerate FD Frames.

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 +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 J1939-13 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

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

ISO 16845-1:2016 Road vehicles - Controller area network (CAN) conformance test plan -- Part 1: Data link layer and physical signalling

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 ten 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 un-shielded twisted pair (UTP). In most cases, a jacket provides needed dimensional consistency as well as abrasion and other environmental protections for the signal wires within. For locations where additional physical protection is not needed and the cable/harness manufacturer provides other means or construction techniques that ensure dimensional and impedance consistency, the jacket may be omitted.

The two 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 a SAE J1939-15 network. Type II ECUs shall be clearly marked as specified in 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 m, 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.

Transceivers meeting the requirements of ISO 11898-1 are compatible with SAE J1939-15.

Table 1 - AC parameters of an ECU disconnected from the bus line

Parameter	Symbol	Min	Nom	Max	Unit	Conditions
Nominal bit time [1]	t_B	3.998	4.000	4.002	µs	250 Kbit/s
Data bit time [1]	t_D	3.998	4.000	4.002	µs	250 Kbit/s
Internal Delay Time [2]	t_{ECU}	0.0		0.7	µs	
Internal Capacitance[3]	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, and aging.

2) The value of t_{ECU} has to be guaranteed for a differential voltage of V_{diff} = 1.0 V for a transition from recessive to dominant and of V_{diff} = 0.5 V 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 and input filtering. It is recommended to use this feature due to EMC. 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} = 1 V and do not increase the recessive differential voltage level above V_{diff} = 0.5 V at each individual ECU (see SAE J1939-11 Tables 4 and 5).

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 to 500 ns is required for the SAE 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 Ω between CAN_H and CAN_L in parallel with 200 pf of capacitance (see Appendix A).

4. FUNCTIONAL DESCRIPTION

Same as the SAE J1939-11 physical layer.

5. ELECTRICAL SPECIFICATION

5.1 Electrical Data

The parameter specifications in Tables 2 through 11 of SAE J1939-11 must be fulfilled throughout the operating temperature range of every ECU.

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 SAE J1939-11 physical layer.

5.1.1.3 AC Parameters

Same as the SAE J1939-11 physical layer.

5.1.2 Bus Voltages - Operational

The parameters specified in Tables 6 and 7 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 V. The voltage extremes associated with this offset would occur in the dominant state (see Table 7 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 to 500 ns to improve the SAE J1939-15 network Electromagnetic Compatibility. See Appendix A, Figure A1 for the preferred signal rise and signal fall waveforms.

The SAE 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 [1]	r_b	0	25	50	mΩ/m	measured at 20 °C
Specific Line Delay [2]	t_p		5.0		ns/m	
Specific Capacitance	c_b	0	40	75	pF/m	
Cable size [3] [4]						
0.5 mm^2 Conductor (20 AWG)	a_c	0.508			mm^2	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	see Figure 1
Wire insulation dia	d_{ci}	2.03		3.05	mm	
Cable diameter	d_c	5.3		8.2	mm	
Temperature Range [5]	°C	–40		+125	°C	
Lay Length		28	33	38	mm	(0.67 to 0.91 twist per 25.4 mm)
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.

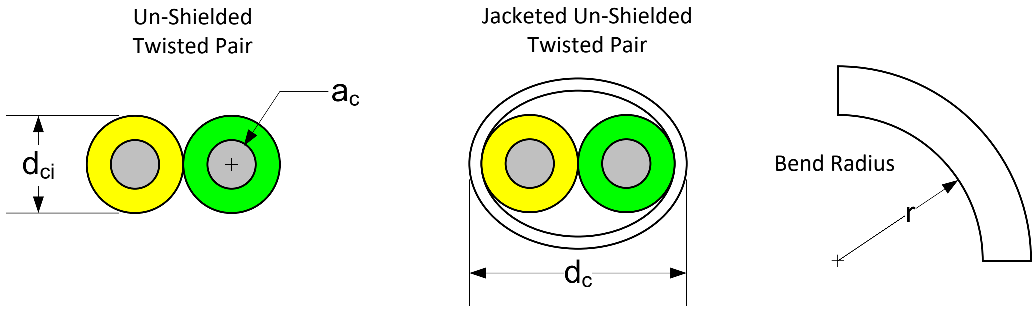

Figure 1 - Cable cross-section and bend radius

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. 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.)

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 SAE 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).

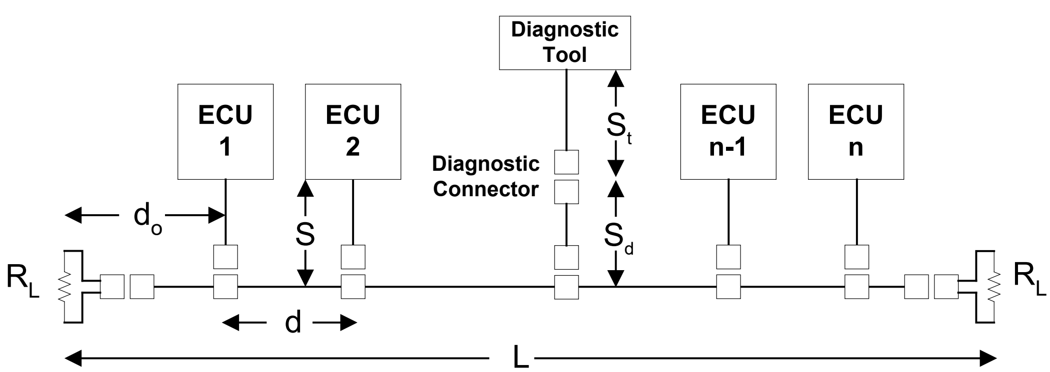

Figure 2 - Wiring network topology (Type I ECUs only)

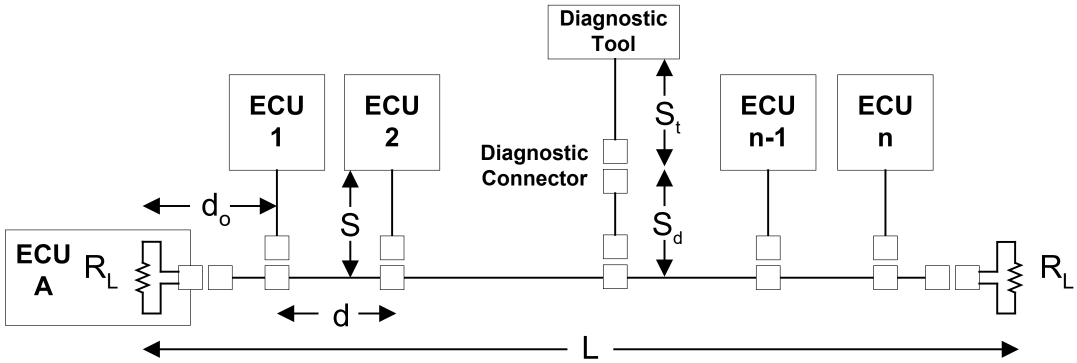

Figure 3 - Wiring network topology (one Type II ECU installed)

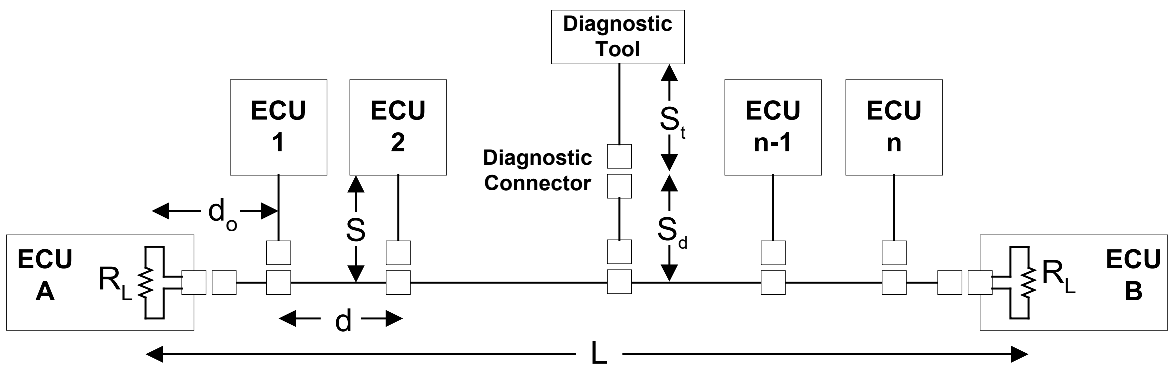

Figure 4 - Wiring network topology (two Type II ECUs installed)

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 m.
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.

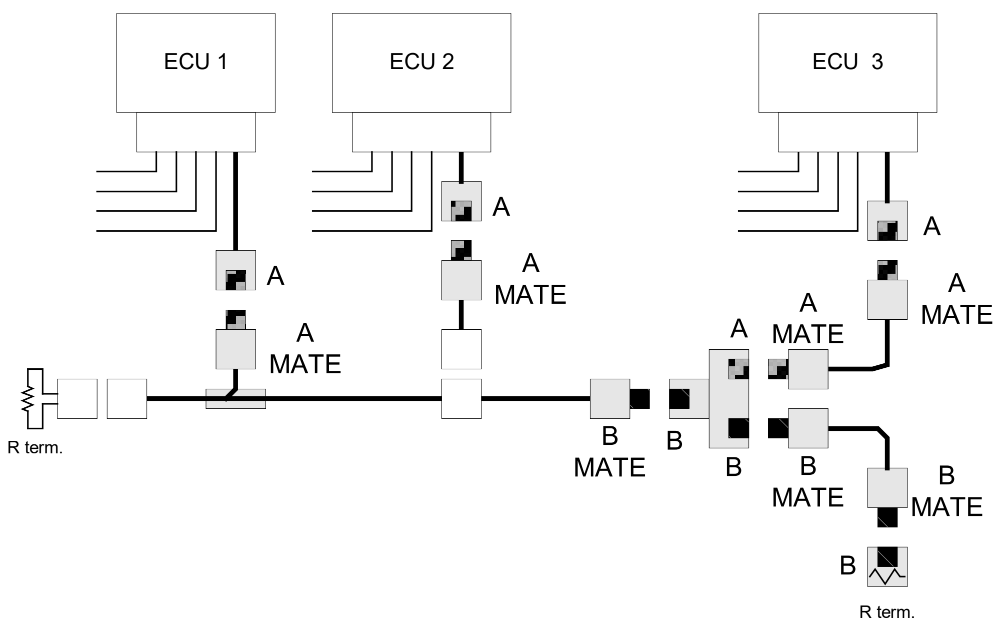

Figure 5 - An example of SAE J1939-11 connector usage in a SAE J1939-15 network

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 Revision Indicator

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

PREPARED BY THE SAE TRUCK BUS CONTROL AND COMMUNICATIONS NETWORK COMMITTEE OF THE TRUCK AND BUS ELECTRICAL ELECTRONIC STEERING COMMITTEE

APPENDIX A - EXAMPLE PHYSICAL LAYER CIRCUITS

Refer to 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.

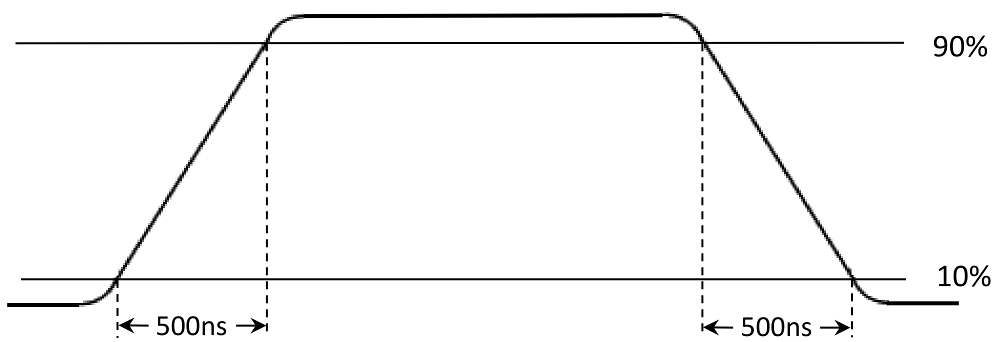

Figure A1 - Example of preferred signal rise/fall waveforms

APPENDIX B - RECOMMENDED CABLE TERMINATION PROCEDURE FOR JACKETED CABLE

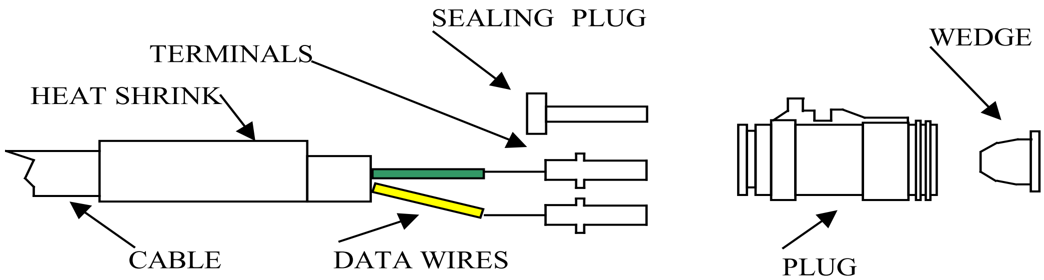

Figure B1 - Cable termination 3 cavity connector

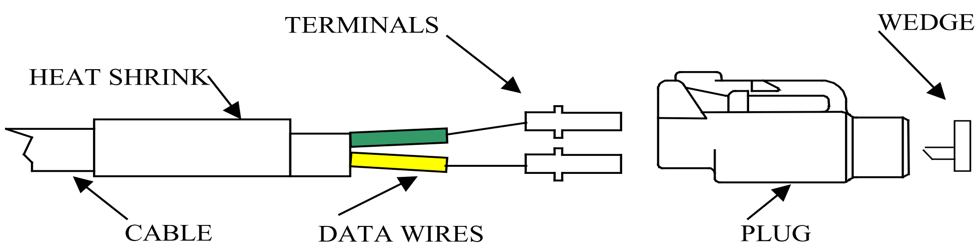

Figure B2 - Cable termination of a typical 2 cavity connector

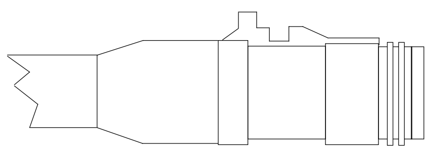

Figure B3 - Typical finished assembly

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 to 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. Maintain wire twist so that the untwisted length is no more than 50 mm from the wire seals in the finished connection. However, enough wire should be left untwisted to avoid deformation of the connector seals. 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.

APPENDIX C - RECOMMENDED CABLE SPLICE PROCEDURE FOR JACKETED CABLE

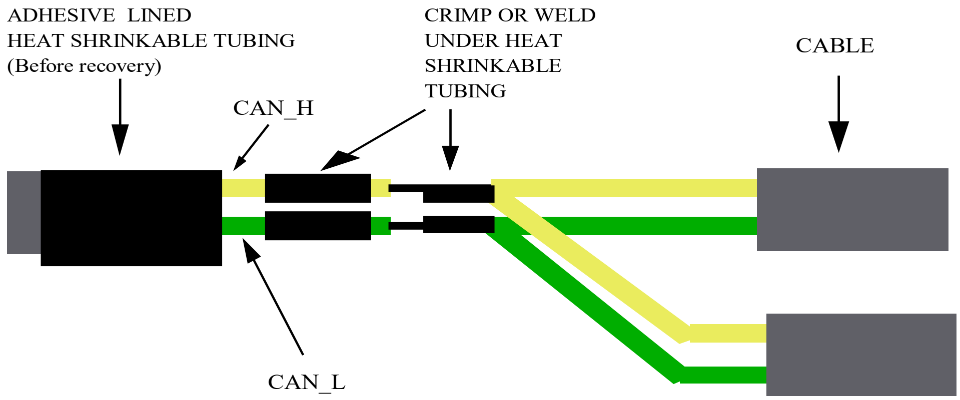

Figure C1 - Cable splice

1. Cut the end of the cable cleanly. Measure back approximately 40 to 100 mm and mark the cable jacket. Remove this section of cable jacket.

2. Remove 7 mm ± 0.8 mm of insulation on the data wire CAN-H.

3. Measure back approximately 21 mm on data wire CAN-L and cut it. Remove 7 mm ± 0.8 mm of insulation on this wire.

4. Repeat steps 1 through 3 for the other two cables that will be spliced, but Replace CAN-H with CAN-L in step 2, and Replace CAN-L with CAN-H in step 3. (The overall length of the assembly is minimized by offsetting the crimps or welds.)

5. Slide the two pieces of insulating heat-shrinkable tubing over the CAN-H and CAN-L data wires.

6. Slide the one piece of adhesive-lined heat-shrinkable tubing onto the cable.

7. Crimp, or weld, the three CAN-H data wires together, and the three CAN-L data wires together.

8. Solder the connections if desired.

9. Center the insulating heat-shrinkable tubing over the two crimped or welded data wires.

10. Center the adhesive-lined heat-shrinkable tubing over the assembly and apply per manufacturer's recommendation.

Figure C2 - Sealed cable splice-finished assembly

APPENDIX D - RECOMMENDED CABLE REPAIR PROCEDURE FOR JACKETED CABLE

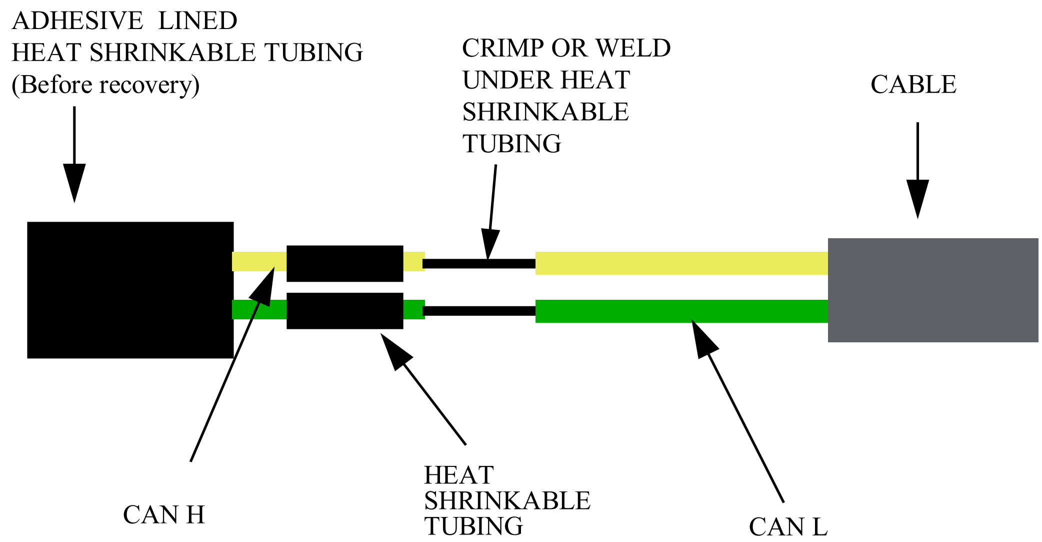

Figure D1 - Cable splice

A. Cut the end of the cables cleanly. Measure back approximately 40 to 100 mm and mark the cable jacket. Remove this section of cable jacket.

B. Strip the insulation of both data wires back 7 mm ± 0.8 mm.

C. Repeat this procedure for the other cable.

D. Install one end of a crimp on each of the data wires, on either cable. (The overall length of the assembly is minimized by offsetting the crimps or welds).

E. Slide the (two) pieces of insulating heat-shrinkable tubing over the crimps and onto the data wires.

F. Slide the (one) piece of adhesive-lined heat-shrinkable tubing onto the cable.

G. Insert the wires from the other cable into the appropriate crimp and install the crimp, maintaining polarity (CAN-H, CAN-L).

H. Center the insulating heat-shrinkable tubing over the two crimps and install the tubing per the manufacturer's recommendation.

I. Center the adhesive-lined heat-shrinkable tubing over the assembly and apply per manufacturer's recommendation.

Figure D2 - Cable splice-finished assembly

APPENDIX E - COMPARISON OF THE SAE J1939-15 VERSUS THE SAE J1939-11 PHYSICAL LAYER

Table E1 - Comparison SAE J1939-15 versus SAE J1939-11

Parameter	Network	Min	Max	Units	Conditions	Same as SAE J1939-11 or Different
Bus Length	SAE J1939-15 SAE J1939-11	0 0	40 40	m m	Backbone cable length between the two Load Resistors (R_L)	Same
Cable Stub Length	SAE J1939-15 SAE J1939-11	0 0	3 1	m m		Different
Node Distance	SAE J1939-15 SAE J1939-11	0.1 0.1	40 40	m m		Same
Minimum Distance from R_L	SAE J1939-15 SAE J1939-11	0 0		m m		Same
Number of Nodes	SAE J1939-15 SAE J1939-11		10 [1)] 30			Different
Physical Media	SAE J1939-15 SAE J1939-11				[Jacketed] Un-shielded Twisted Pair (UTP) Jacketed Shielded Twisted Pair (STP)	Different
Network Connections	SAE J1939-15 SAE J1939-11				Connector must meet requirements in 5.3, 5.3.1, and 5.3.2 Required 3-pin connector concept when used	Different
ECU Physical Layer Circuit	SAE J1939-15 SAE J1939-11					Same
ECU CAN_SHLD Terminal	SAE J1939-15 SAE J1939-11				Not connected to network Connected to network drain wire	Different
Signal Rise/Fall Time	SAE J1939-15 SAE J1939-11				200-500 ns Required (if adjustable) 200-500 ns Recommended	Different

[1)] See 3.1. Maximum number of nodes may be 30, same as SAE J1939-11.

APPENDIX F - SAE J1939-11 COMPLIANT TOOLS AND ECUS USED WITH THE SAE J1939-15 NETWORK

A mixed physical layer can occur when either a SAE J1939-11 compliant diagnostic tool or a SAE J1939-11 compliant ECU (with pigtail cable) is connected to the SAE J1939-15 network. The following figures show the recommended mixed physical layer configurations. Figure F1 shows a typical mixed physical layer configuration of a SAE J1939-11 compliant diagnostic tool connected to the SAE J1939-15 network. Figure F2 shows a typical mixed physical layer configuration of a SAE J1939-11 compliant ECU (using a SAE J1939-11 pigtail and 3-pin connector) connected to the SAE J1939-15 network. The SAE J1939-11 part of the connection will contain a CAN_SHLD terminal and drain wire, but the SAE J1939-15 mating part of the network will not contain a CAN_SHLD terminal or drain wire.

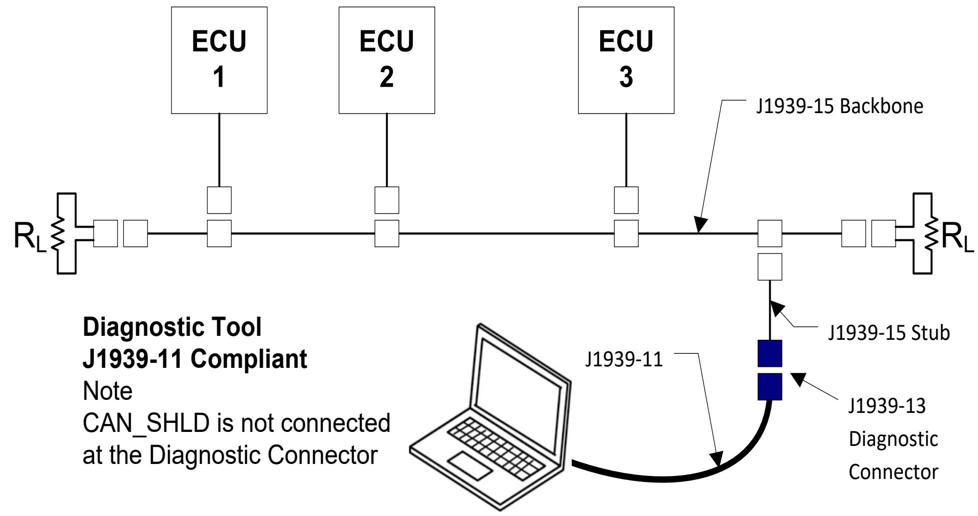

Figure F1 - SAE J1939-11 tool connected to the SAE J1939-15 network

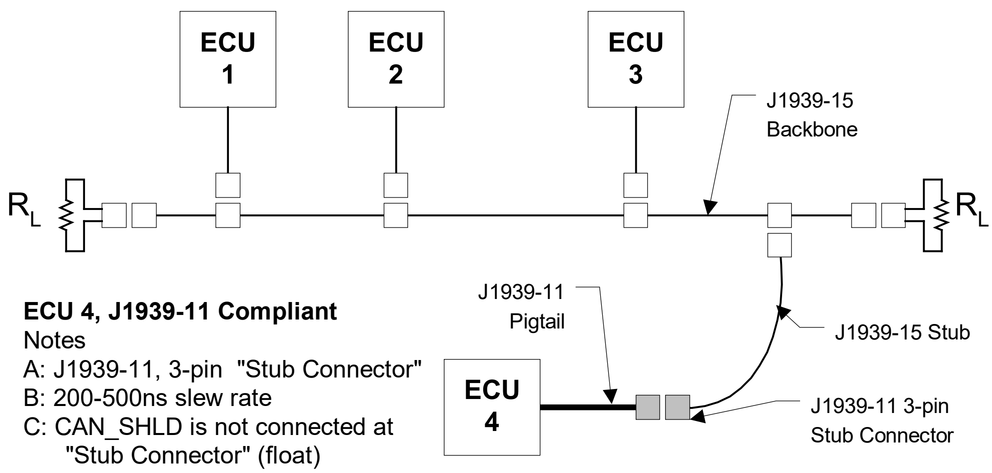

Figure F2 - ECU (using SAE J1939-11 pigtail and 3-pin connector) connected to the SAE J1939-15 network