

SURFACE VEHICLE STANDARD

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Superseding J1850 MAY94

CLASS B DATA COMMUNICATIONS NETWORK INTERFACE

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- 1. Scope**—This SAE Standard establishes the requirements for a Class B Data Communication Network Interface applicable to all On- and Off-Road Land-Based Vehicles. It defines a minimum set of data communication requirements such that the resulting network is cost effective for simple applications and flexible enough to use in complex applications. Taken in total, the requirements contained in this document specify a data communications network that satisfies the needs of automotive manufacturers.

This specification describes two specific implementations of the network, based on media/Physical Layer differences. One Physical Layer is optimized for a data rate of 10.4 Kbps while the other Physical Layer is optimized for a data rate of 41.6 Kbps (see Appendix A for a checklist of application-specific features). The Physical Layer parameters are specified as they would be detected on the network media, not within any particular module or integrated circuit implementation.

Although devices may be constructed that can be configured to operate in either of the two primary implementations defined herein, it is expected that most manufacturers will focus specifically on either the 10.4 Kbps implementation or the 41.6 Kbps implementation depending on their specific application and corporate philosophy toward network usage. However, low-volume users of network-interface devices are expected to find it more effective to use a generic interface capable of handling either of the primary implementations specified in this document.

This SAE document is under the control and maintenance of the Vehicle Networks for Multiplexing and Data Communications (Multiplex) Committee. This committee will periodically review and update this document as needs dictate.

- 1.1 Objectives**—This document constitutes the requirements for a vehicle-data communications network. These requirements are related to the lowest two layers of the ISO Open System Interconnect (OSI) model (Ref. ISO 7498). These layers are the Data Link Layer and the Physical Layer. This network has been described using the ISO conventions in ISO/TC 22/SC 3/WG1 N429 E, dated October, 1990. Both documents are intended to describe the same network requirements but using different descriptive styles. If any technical differences are identified, the very latest revision of these documents should be used.

This document has been submitted as an American National Standard. As such, its format is somewhat different from the formal ISO description in that descriptions have been expanded, but are in no way less precise. A more textual format has been adopted herein to allow explanations to be included.

The vehicle application for this class of data communication (Class B) network is defined (Reference SAE J1213 APR88) to allow the sharing of vehicle parametric information. Also per the definition, this Class B network shall be capable of performing Class A functions.

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2. References

2.1 Applicable Documents—The following publications form a part of this specification to the extent specified herein. The latest issue of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J1113—Electromagnetic Susceptibility Measurements Procedures for Vehicle Components
 SAE J1211—A Recommended Environmental Procedure for Electronic Equipment Design
 SAE J1213/1—Glossary of Vehicle Networks for Multiplexing and Data Communications
 SAE J1547—Electromagnetic Susceptibility Measurement Procedures for Common Mode Injection
 SAE J1879—General Qualification and Production Acceptance Criteria for Integrated Circuits in Automotive Applications
 SAE J1962—Diagnostic Connector
 SAE J1979—E/E Diagnostic Test Modes
 SAE J2012—Diagnostic Codes/Messages
 SAE J2178—Class B Data Communication Network Messages
 SAE J2178/1—Class B Data Communication Network Messages: Detailed Header Formats and Physical Address Assignment
 SAE J2190—Enhanced E/E Diagnostic Test Modes

2.1.2 CISPR PUBLICATION—Available from Kristi Hansen, SAE, Troy Office, 3001 West Big Beaver Road, Suite 320, Troy, MI 48084-3174.

CISPR/D/WG2 (Secretariat) 19 Sept 1989 Radiated Emissions Antenna and Probe Test

2.1.3 ISO PUBLICATIONS—Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

ISO/TC22/SC3/WG1 N429E OCT90—Road vehicles—Serial data communication for automotive applications, low speed (125 Kbps and below)
 ISO 7498—Data processing systems—Open systems interconnection—Standard reference model
 ISO 7637/3—Road vehicles—Electrical disturbance by conduction and coupling—Part 3: Passenger cars and light commercial vehicles with nominal 12 V supply voltage and commercial vehicles with 24 V supply voltage—Electrical transient transmission by capacitive and inductive coupling via lines other than supply lines

2.2 Related Publication—The following publication is provided for information purposes only and is not a required part of this document.

2.2.1 SAE PUBLICATION—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J1930—Electrical/Electronic Systems Diagnostic Terms, Definitions, Abbreviations, & Acronyms

2.3 Definitions

2.3.1 ACTIVE STATE—The state of a bus wire which results when one or more nodes have “turned on” their physical layer circuitry. This is V_{oh} volts for Bus + (PWM and VPW) and V_{ol} volts for Bus - (PWM only). Refer to 7.3.2.2 (PWM DC Parameters) and 7.3.3.2 (VPW DC Parameters) for the values of V_{oh} and V_{ol} . The active state voltage level is determined by the source voltage of the physical layer drive circuitry.

2.3.2 ARBITRATION—The process of resolving which frame, or In-Frame Response data, continues to be transmitted when two or more nodes begin transmitting frames, or In-Frame Response data, simultaneously.

- 2.3.3 CLASS A DATA COMMUNICATIONS**—A system whereby vehicle wiring is reduced by the transmission and reception of multiple signals over the same signal bus between nodes that would have been accomplished by individual wires in a conventionally wired vehicle. The nodes used to accomplish multiplexed body wiring typically did not exist in the same or similar form in a conventionally wired vehicle.
- 2.3.4 CLASS B DATA COMMUNICATIONS**—A system whereby data (e.g., parametric data values) is transferred between nodes to eliminate redundant sensors and other system elements. The nodes in this form of a multiplex system typically already existed as stand-alone modules in a conventionally wired vehicle. A Class B network shall also be capable of performing Class A functions.
- 2.3.5 CLASS C DATA COMMUNICATIONS**—A system whereby high data rate signals typically associated with real-time control systems, such as engine controls and anti-lock brakes, are sent over the signal bus to facilitate distributed control and to further reduce vehicle wiring. A Class C network shall also be capable of performing Class A and Class B functions.
- 2.3.6 DOMINANT BIT**—A bit which wins arbitration when contending for the bus. For SAE J1850, a logic “0” is the dominant bit.
- 2.3.7 DUAL WIRE**—Two wires that are routed adjacently throughout the network and can be either a twisted or a parallel pair of wires.
- 2.3.8 FAULT TOLERANCE**—The ability of a system to survive a certain number of failures with allowance for possible downgraded performance while maintaining message transmission capability at the specified data rate.
- 2.3.9 FRAME**—One complete transmission of information, which may or may not include an “in-frame response.” For this network, each frame contains one and only one message. A frame is delineated by the Start of Frame (SOF) and End of Frame (EOF) symbols.
- 2.3.10 FUNCTIONAL ADDRESSING**—Labeling of messages based on their operation code or data content. See 5.1.2 for an example of the typical usage for functional addressing.
- 2.3.11 MESSAGE**—All of the data bytes contained in a frame. The message is what is left after the frame symbols have been removed from the frame. As such, the message is the sequence of bytes contained in the frame.
- 2.3.12 PASSIVE STATE**—The state of a bus wire which results when all nodes have “turned off” their physical layer circuitry. This is V_{ol} volts for Bus + (PWM and VPW) and V_{oh} volts for Bus - (PWM only). Refer to 7.3.2.2 (PWM DC Parameters) and 7.3.3.2 (VPW DC Parameters) for the values of V_{oh} and V_{ol} . The passive state voltage level is determined by the reference voltage of the bus wire termination resistor(s).
- 2.3.13 PHYSICAL ADDRESSING**—Labeling of messages for the physical location of their source and/or destination(s). See 5.1.1 for an example of the typical usage for physical addressing.
- 2.3.14 PULSE WIDTH MODULATION (PWM)**—A data bit format, where the width of a pulse of constant voltage or current determines the value (typically one or zero) of the data transmitted.
- 2.3.15 RECESSIVE BIT**—A bit which loses arbitration when contending for the bus with a dominant bit. For SAE J1850, a logic “1” is the recessive bit.
- 2.3.16 SLEEP-MODE**—Node behavior in a low power consumption standby state waiting to be switched on by a frame or other activity. This is distinct from an off-mode where the node is disconnected from the power supply.

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2.3.17 VARIABLE PULSE WIDTH (VPW) MODULATION—A method of using both the state of the bus and the width of the pulse to encode bit information. This encoding technique is used to reduce the number of bus transitions for a given bit rate. One embodiment would define a “ONE” (1) as a short active pulse or a long passive pulse while a “ZERO” (0) would be defined as a long active pulse or a short passive pulse. Since a frame is comprised of random 1's and 0's, general byte or frame times cannot be predicted in advance.

2.4 Abbreviations/Acronyms

BRK:	Break
CRC:	Cyclic Redundancy Check
E/E:	Electrical and Electronic
EMC:	Electromagnetic Compatibility
EMI:	Electromagnetic Interference
EOD:	End of Data
EOF:	End of Frame
IFR:	In-Frame Response (Byte/Bytes)
IFS:	Inter-Frame Separation
ISO:	International Standards Organization
Kbps:	Kilo bits per second
NA:	Not Applicable
NB:	Normalization Bit
OSI:	Open System Interconnect
SOF:	Start of Frame

3. Description of the Architecture

3.1 General—It is the intent of this network to interconnect different electronic modules on the vehicle using an “Open Architecture” approach. An open architecture network is one in which the addition or deletion of one or more modules (data nodes) has minimal hardware and/or software impact on the remaining modules.

In order to support an open architecture approach, the Class B network utilizes the concept of Carrier Sense Multiple Access (CSMA) with nondestructive contention resolution. Additionally this network supports the prioritization of frames such that, in the case of contention, the higher priority frames will always win arbitration and be completed.

3.2 Network Topology

3.2.1 DATA BUS TOPOLOGY—Data bus topology is the map of physical connections of the data bus nodes to the data bus. It includes all nodes and data buses involved in the data bus integration of the vehicle. A single-level bus topology, the simplest bus topology, is currently being used in several automotive applications. In a single-level bus topology, all nodes are interconnected via the same data bus. The redundancy requirements of a particular application may require a single-level topology to be implemented using multiple interconnecting cables operating in various modes (active or passive). However, the requirement to use multiple buses for redundancy purposes does not change the single-level bus topology definition if the following criteria are maintained:

- a. All nodes/devices transmit and receive from a single path.
- b. All nodes/devices receive all frames at the same time.
- c. Communication on each data bus is identical.

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3.2.2 DATA BUS CONTROL—Although various methods of data bus control can be used, this Class B network is intended for “masterless” bus control. The principal advantage of the masterless bus control concept is its ability to provide the basis for an open-architecture data communications system. Since a master does not exist, each node has an equal opportunity to initiate a data transmission once an idle bus has been detected. However, not all nodes and/or data are of equal importance, prioritization of frames is allowed and the highest priority frame will always be completed. This also implies that frame/data contention will not result in lost data. Two disadvantages of the masterless bus concept are that data latency cannot be guaranteed, except for the single highest system priority frame, and bus utilization extremes are difficult to evaluate.

3.3 References to the OSI Model—Although this document focuses on the data link layer and the physical layer, references are included for the application layer since this needs to be included for emission-related, diagnostic communication legislation requirements. The Class B network maps into the OSI model as described in the following paragraphs. This “mapping” is illustrated in Figure 1.

3.3.1 APPLICATION LAYER—At the top of the OSI reference model is the Application Layer. This layer establishes the relationship between the various application input and output devices, including what is expected of human operators. This layer documents the high level description of the function including control algorithms if appropriate. An example of an Application Layer functional description might be: “Pressing the head lamp button shall cause the low beam head lamp, marker and tail lamp filaments to be energized.” Legislated diagnostics is another area in which application layer requirements need to be specified.

3.3.2 DATA LINK LAYER—The primary function of the Data Link Layer is to convert bits and/or symbols to validated error free frames/data. Typical services provided are serialization (parallel to serial conversion) and clock recovery or bit synchronization. An important additional service provided by the Data Link Layer is error checking. When errors are detected, they may be corrected or higher layers may be notified.

3.3.3 PHYSICAL LAYER—The Physical Layer and its associated wiring form the interconnecting path for information transfer between Data Link Layers. Typical Physical Layer protocol elements include voltage/current levels, media impedance, and bit/symbol definition and timing.

3.4 Network Implementation—The network implementations based on this document have been reduced to commonize hardware, software, messages, and tools. The consolidation of messages has been documented in SAE J2178. The first byte or the first three bytes of these messages are called the “Header” byte(s). These header bytes fully define the associated requirements of this network interface, which previously had been optional. Figure 2 shows the general format for single byte header forms. Figure 3 shows the three byte header form. Figure 4 shows the specific bit assignments for priority, In-Frame Response, and Functional/Physical Address mapping in the three byte header format. For a complete description of the “KYZZ” bits shown in Figure 4 refer to SAE J2178/1.

4. Application Layer Details—The application of this communication network is the transfer of information from one node of the network to one or more other nodes. This transfer of information supports both operational and diagnostic needs. SAE has developed documents describing each of these types of applications, consistent with this document.

4.1 Normal Vehicle Operation (Down the Road) Messages—The messages sent during non-diagnostic operations are called normal vehicle operation messages. These normal vehicle operation messages are used for communication from a transmitter to one or more receivers across this network. The normal operation messages have been developed by the SAE for this communication network and are defined in SAE J2178. SAE defined messages and the “Reserved” messages of SAE J2178 shall remain specific to those definitions. In SAE J2178, there is also a set of “Reserved - Manufacturer” messages which, if used, will have meanings specific to a vehicle manufacturer but are likely to be different between manufacturers.

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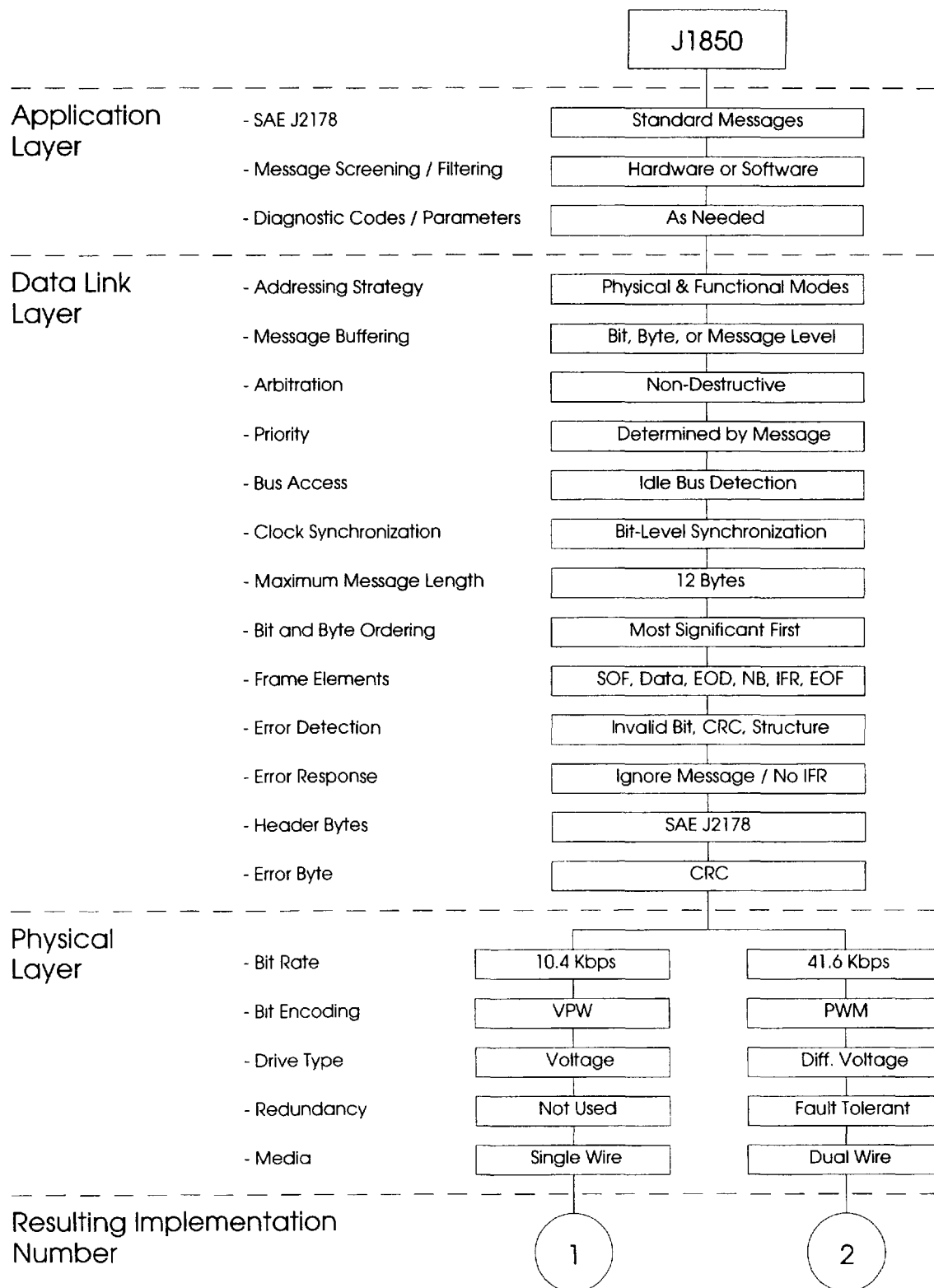


FIGURE 1—MAP OF SAE J1850 TO THE ISO OSI MODEL

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Single Byte Header:

Bit 7	6	5	4	3	2	1	0
Message ID (256)							

One Byte Form of Consolidated Header:

Bit 7	6	5	4	3	2	1	0
x	x	x	H=1	x	x	x	x
Message ID (128)							

FIGURE 2—SINGLE BYTE HEADER AND ONE BYTE FORM OF CONSOLIDATED HEADER

Three Byte Form of Consolidated Header:

Byte 1	Byte 2	Byte 3
See Figure 4 Below	Target Address	Source Address

FIGURE 3—THREE BYTE FORM OF CONSOLIDATED HEADER

Byte 1 of Three Byte Form of Consolidated Header:

Bit 7	6	5	4	3	2	1	0
P	P	P	0	K	Y	Z	Z
Priority (0 to 7)			H=0	Message Type (see below)			
Bit	Meaning			Value	Meaning		
K	In-Frame Response (IFR)			0	IFR Required		
				1	IFR Not Allowed		
Y	Addressing Mode			0	Functional Addressing		
				1	Physical Addressing		
ZZ	Specific Message Type			0 0	The meaning for these values are dependent on K & Y above. These meanings can be found in J2178/1.		
				0 1			
				1 0			
				1 1			

FIGURE 4—FIRST BYTE OF THREE BYTE FORM OF CONSOLIDATED HEADER

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4.2 Diagnostic Messages—It is expected that this network will be used for diagnostics of the devices utilizing the network. These diagnostic procedures may include legislated diagnostics, industry standard diagnostics, or manufacturer-specific diagnostic procedures.

Legislated diagnostics, and some level of voluntary industry standard diagnostics that reference this document, should only specify procedures and frames that conform to this document. SAE J1979 and SAE J2190 define the set of recognized test modes that are available and have been reserved for diagnostic purposes.

Manufacturer-specific test procedures utilizing this network may specify procedures that do not conform to the requirements of this recommended practice.

4.2.1 DIAGNOSTIC PARAMETRIC DATA—SAE J1979 and SAE J2190 define test modes and frame formats for use by off-vehicle test equipment to obtain diagnostic data from the vehicle. SAE J1979 and SAE J2190 messages conform to the requirements and limitations of this document.

4.2.2 DIAGNOSTIC MALFUNCTION CODES—SAE J2012 defines trouble codes to be assigned to various vehicle system malfunctions, and also assigns ranges of codes to be used for manufacturer-specific codes. SAE J1979 and SAE J2190 include messages to be used to retrieve these codes from the on-vehicle systems. When trouble codes are to be assigned to system malfunctions, the code structure of SAE J2012 should be used.

4.3 Frame Filtering—The network interface device may be capable of filtering frames on the network to select those appropriate to a given node. Because this Class B protocol may use more than one type of frame addressing (e.g., functional and physical; see 5.1), the criteria for these filtering operations may include multiple byte comparisons occurring over the first several frame bytes. Regardless of the exact technique used for frame filtering, the objective is to reduce the software and processing burden associated with network operations by limiting the number of received frames to just those necessary for any given node.

5. Data Link Layer Details—This section defines the requirements on the following Data Link Layer attributes:

- a. Addressing Strategy
- b. Network Access and Data Synchronization
- c. Frame Elements and Structure
- d. Error Detection
- e. Error Response

5.1 Addressing Strategy—Two types of addressing strategies are defined and can co-exist on this network. The two strategies serve different types of tasks and the flexibility to use both types on the same network provides a major benefit.

5.1.1 PHYSICAL ADDRESSING—Frames are exchanged only between two devices based on their “Physical” address within the network. Each node must be assigned a unique physical address within the network. This type of addressing strategy is used when the communications involve specific nodes and not the others that may be on the network. Diagnostic access would be one case where identification of a specific module is important.

5.1.2 FUNCTIONAL ADDRESSING—Frames can be transmitted between many devices based on the function of that frame on the network. Each node is assigned the set of functions that it cares about, either as transmitter or receiver, and can be located anywhere in the network. This type of addressing strategy is used when the physical location of the function is not important but could move around from one module to another. In the case of functional addressing, the function of the message is important and not the physical addresses of the nodes.

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5.2 Network Access and Data Synchronization—The network interface shall implement a multiple access arbitration-based protocol using nondestructive bit-by-bit arbitration to transparently resolve simultaneous access to the bus. Network access is allowed after detection of an idle bus. The definition of an idle bus is contained in 6.6.1.7.

Since a discrete clock wire is not used with this network, node synchronization can be derived from bit/symbol transitions on the bus.

5.2.1 FULL MESSAGE BUFFERING—One or more messages exist in their entirety in the interface device. This approach reduces software burden at the expense of hardware costs. Message filtering (or screening) is possible in such a device which reduces software burden even further.

5.2.2 BYTE BUFFERING—Each byte of a received message (or transmit message) is stored individually in the interface device. The controlling device is responsible for the timely servicing of the interface device to keep up with frame traffic.

5.3 Network Elements and Structure

The general format is:

idle, SOF, DATA_0, ..., DATA_N, CRC, EOD, NB, IFR_1, ..., IFR_N, EOF, IFS, idle:

The preceding acronyms are defined as follows:

idle: Idle Bus (occurs before SOF and after IFS)
 SOF: Start of Frame
 DATA: Data bytes (each 8 bits long)
 EOD: End of Data (only when IFR is used)
 CRC: CRC Error Detection Byte (may occur in IFR as well)
 NB: Normalization Bit (10.4 Kbps only)
 IFR: In-Frame Response Byte(s)
 EOF: End of Frame
 IFS: Inter-Frame Separation

NOTE—Break (BRK) can occur (be sent) on a network at any time.

5.3.1 FRAME ELEMENTS—The frame elements other than the symbols SOF, EOD, NB, EOF, IFS, and BRK will be byte oriented and must end on byte boundaries. Each byte will be 8 bits in length.

5.3.2 BIT ORDERING—The first bit of each byte transmitted on the network shall be the most significant bit (i.e., MSB first).

5.3.3 MAXIMUM FRAME LENGTH—The maximum number of continuous bit times that a single node is able to control the bus shall not exceed the value specified in 7.2.

5.3.4 FUNCTION OF SOF, EOD, EOF, IFS, NB, AND BRK—In addition to actual data bytes (i.e., data, CRC, IFR) frame delimiter symbols are defined to allow the data bus to function properly in a multitude of different applications. An overview of these symbols is provided here. Detailed timing requirements on each symbol can be found in 7.3.

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5.3.4.1 Start of Frame (SOF)—The SOF mark is used to uniquely identify the start of a frame. The SOF mark shall not be used in the calculation of the CRC error detection code.

5.3.4.2 End of Data (EOD)—End of Data (EOD) is used to signal the end of transmission by the originator of a frame. The in-frame response (IFR) section of the frame, if used, begins after the EOD time but before the EOF. If the IFR feature (see 5.3.7) is not used, then the bus would remain in the passive state thereby resulting in an End of Frame (EOF). If a frame includes an IFR, the originator of the frame will expect the recipient(s) of the frame to drive the network with one or more in-frame response bytes immediately following EOD.

5.3.4.3 End of Frame (EOF)—The completion of the EOF defines the end of a frame. After the last transmission byte (including in-frame response bytes where applicable), the bus will be left in a passive state. When EOF has expired, all receivers will consider the transmission complete.

5.3.4.4 Inter-Frame Separation (IFS)—Inter-Frame Separation is used to allow proper synchronization of various nodes during back-to-back frame transmissions. A transmitter must not initiate transmission on the bus before the completion of the IFS minimum period. However, receivers must synchronize to any other SOF occurring after the EOF minimum period in order to accommodate individual clock tolerances.

A transmitter that desires bus access must wait for either of two conditions before transmitting a SOF:

- a. IFS minimum has expired.
- b. EOF minimum has expired and another rising edge has been detected.

5.3.4.5 Normalization Bit (NB)—Only applicable to 10.4 Kbps implementation. For Variable Pulse Width Modulation, the first bit of In-Frame Response data is also passive and, therefore it is necessary to generate a Normalization Bit to follow the EOD symbol. This Normalization Bit shall define the start of the in-frame response. The Normalization Bit is defined in 6.6.2.5.

5.3.4.6 Break (BRK)—BRK is allowed to accommodate those situations in which bus communication is to be terminated and all nodes reset to a “ready-to-receive” state. If BRK is used, it must adhere to the requirements as specified in 6.6.

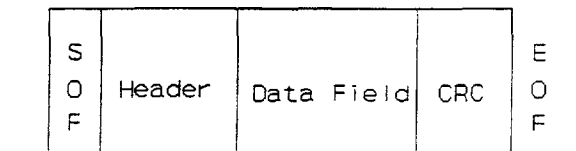
5.3.5 IDLE BUS (IDLE)—Idle bus is defined as any period of passive bus state occurring after IFS. During an idle bus, any node may transmit immediately. Contention may still occur when two or more nodes transmit nearly simultaneously; therefore, resynchronization to rising edges must continue to occur.

5.3.6 DATA BYTE(S)—A number of data bytes, each eight (8) bits in length, can be transmitted at the discretion of the system designer. However, the total message length (from SOF to EOF) shall not exceed the limit defined in 7.2.

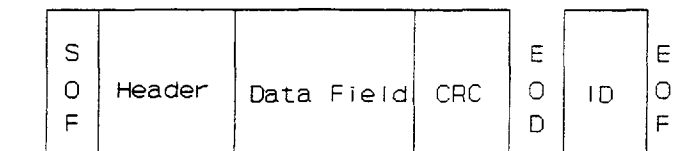
5.3.7 IN-FRAME RESPONSE (IFR)—For In-Frame Response, the response byte(s) are transmitted by the responders and begin after EOD. If the first bit of the in-frame response byte does not occur at this point and the bus remains passive for a period of time defined as EOF, then the originator and all receivers must consider the frame complete. In-frame response bytes may take one of the following forms (refer to Figure 5):

- a. None
- b. A single byte transmitted from a single recipient, typically a unique identifier (ID) or address.

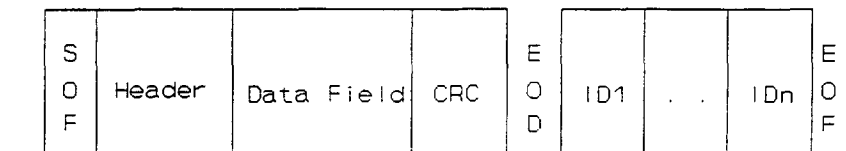
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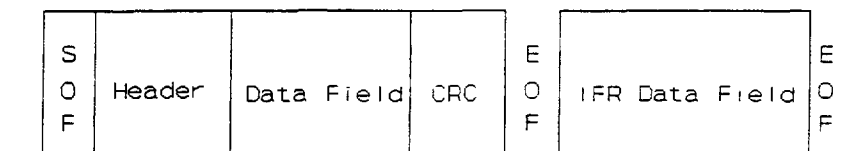
Type 0 - None



Type 1 - Single Byte From a Single Responder



Type 2 - Single Byte From Multiple Responders



Type 3 - Multiple Bytes From a Single Responder

FIGURE 5—TYPES OF IN-FRAME RESPONSE

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- c. Multiple bytes, a single byte transmitted from each recipient. The effect is to concatenate the individual response bytes into a response "stream." The response byte from each recipient must be unique, typically a physical address (ID n). Arbitration takes place during the response process so that each recipient, if arbitration is lost during its response byte, will retransmit the single byte until the recipient observes its unique byte in the response stream. Once a given recipient observes its own unique response byte, it discontinues the transmission process to allow any remaining responders to transmit their byte.
- d. One or more data bytes, all from a single recipient. A CRC byte may be appended to the data byte(s). The CRC byte is calculated as described in 5.4.1, except only the data in the response is used for the CRC calculation.

Refer to SAE J2178/1 for a detailed discussion of the different IFR types and for determination of which message types utilize which IFR types.

If in-frame response bytes are used, the overall frame/message length limit remains in effect. The sum total of data bytes, CRC bytes, and in-frame response bytes shall not exceed the frame length as specified in 7.2.

5.3.7.1 Normalization Bit—If the In-Frame Response is employed in the 10.4 Kbps implementation then a "Normalization Bit" is required. The Normalization Bit is described in 6.6.2.5.

5.4 Error Detection—The error descriptions in this document are loosely defined and classified. In general, the action taken after an error condition has been detected is manufacturer-specific unless it has been specified in this document.

5.4.1 CYCLIC REDUNDANCY CHECK (CRC)—The CRC is required with either of the header byte systems used. The method of calculating and checking the CRC byte is defined as follows. An invalid CRC byte may constitute a detected error.

- a. The CRC calculation and the CRC checker shift registers (or memory locations) will be located in the sender and receiver nodes, respectively, and shall be initially set to the "all ones" state during SOF. (The setting to "ones" prevents an "all zeros" CRC byte with an all zero-data stream.)
- b. All frame bits that occur after SOF and before the CRC field are used to form the Data Segment Polynomial which is designated as $D(X)$. For any given frame, this number can be interpreted as an "n-bit" binary constant, where n is equal to the frame length, counted in bits.
- c. The CRC division polynomial is $X^8 + X^4 + X^3 + X^2 + 1$. This polynomial is designated as $P(X)$.
- d. The Remainder Polynomial $R(X)$ is determined from the following Modulo 2 division equation:

$$\frac{X^8 * D(X) + X^n + X^{n+1} + \dots + X^{n+7}}{P(X)} = Q(X) + \frac{R(X)}{P(X)} \quad (\text{Eq.1})$$

NOTE— $Q(X)$ is the quotient resulting from the division process.

- e. The CRC byte is made equal to $\overline{R(X)}$, where $\overline{R(X)}$ is the ones complement of $R(X)$.

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- f. The Frame Polynomial $M(X)$ that is transmitted is shown in Equation 2:

$$M(X) = X^8 * D(X) + \overline{R(X)} \quad (\text{Eq.2})$$

- g. The receiver checking process shifts the entire received frame, including the transmitted CRC byte, through the CRC checker circuit. An error-free frame will always result in the unique constant polynomial of $X^7 + X^6 + X^2$ (C4 hex) in the checker shift register regardless of the frame content.
- h. Examples of frames with the appropriate CRC bytes are listed in Table 1.

TABLE 1—EXAMPLES OF FRAMES AND APPROPRIATE CRC BYTES

Data Bytes (hex)									CRC (hex)
00	00	00	00						59
F2	01	83							37
0F	AA	00	55						79
00	FF	55	11						B8
33	22	55	AA	BB	CC	DD	EE	FF	CB
92	6B	55							8C
FF	FF	FF	FF						74

- i. A status flag may be used to indicate the occurrence of a received CRC error.
- j. When In-Frame Response data is protected by a CRC field, the previous rules are used to define the CRC, except that the sender and receiver nodes are interchanged. The CRC calculation only includes the in-frame response bytes. (Note that the SOF, EOD, EOF, and NB are not used in the CRC calculation and serve as data delimiters.)

NOTE—Figure 6 illustrates a typical CRC generator and Figure 7 illustrates a typical CRC checker. With appropriate gating, the two circuits may be combined to use only a single-shift register for both CRC generation and CRC checking.

5.4.2 FRAME/MESSAGE LENGTH—A frame exceeding its defined length limit may constitute a detected error.

5.4.3 OUT-OF-RANGE—Data is corrupted in a vehicle network when transient interference is large enough to drive the receiver out of its dynamic range of operation. This out-of-range condition, where the receiver can no longer accurately decode the data, may be detected by an out-of-range detector. The following defines the operation of an out-of-range detector:

- a. Data is recovered by holding the receiver output in the state it was prior to the out-of-range condition for the duration of the interference.
- b. If the interfering transient is long enough to corrupt a desired bus symbol, accurate data recovery may not occur. This may constitute a detected error.